STANDARD CONSTRUCTION SPECIFICATIONS

PART 1 - ROADS

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Second Edition
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حكومة أبوظبي
GOVERNMENT OF ABU DHABI

SECOND EDITION

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Department of Municipalities and Transport
Abu Dhabi, United Arab Emirates

PART 1

ROADS

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CHAPTER 1 - GENERAL REQUIREMENTS

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Chapter 1: General Requirements

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1 GENERAL REQUIREMENTS

1.1 Introduction to the Standard Construction Specifications

1.1.1 Purpose and Scope

Scope of this document is to support and direct the construction of roads and road structures in the Abu Dhabi Emirate.

Specifications establish minimum acceptance requirements and provide uniform technical criteria for items of work to construct new facilities or rehabilitate existing transportation infrastructure. These Specifications are supplemented by the Standard Bill of Quantities, which includes the measurement and payment descriptions.

1.1.2 Application of This Document

This document defines standard construction specifications for roads and road structures that provide a Contractual basis for the Contractor's requirements for implementing road construction projects and requirements for construction managers to follow. These Specifications are a part of all Owner tender and Contract documents for roads and road structures projects construction.

These Specifications apply to all Owner road and road structures work projects, including new roads, rehabilitation of existing roads, and road structures. These Specifications apply to both urban and rural roads and accommodate variations in climate and terrain from one region in the Emirate to another.

This Specification document provides the scope of work description, material standards, and performance and quality acceptance criteria for the items of work involved in implementing the Owner's road construction Contracts. These Specifications are the basis for review and acceptance of all Contractor supplied materials and Contractor performed work.

Designers and project Engineers who have technically sound roadway design and implementation expertise can also use these Standard Specifications as guidance when describing items of work for the preparation of a roadway development or rehabilitation for inclusion in their resulting set of tender documents.

Primary users of these standard specifications include the following:

a. The Owner and other municipality agency Engineers who develop road designs and associated construction tender documents
b. Engineers and consultants who perform final road designs and develop tender documents for the Owner and other agencies in Abu Dhabi Emirate
c. The Owner, agencies, and the consultant Engineers who perform construction supervision of road works
d. The Contractors and consultants who tender for the Owner road construction projects and those construction Engineers who manage the site work
e. All Engineers, consultants, and Contractors working on road projects in Abu Dhabi Emirate

The Owner is responsible for making revisions and updates to these Standard Specifications for Road and Road Structure Works, and for overseeing its implementation. This Standard Specifications document supersedes all Standard Specifications previously used by the Owner for Contractual road work construction within the Emirate.

1.1.3 How to Use This Document

This document is a set of standard construction specifications that apply for all road work construction in Abu Dhabi Emirate. This document should be included as part of the Contract Documents for all roads and road structures construction projects.

This document contains specifications for most construction work items for typical highway, road and parking projects. For specific work that is unique to a particular project, these Standard Specifications should be supplemented with particulars of specific material and construction requirement specifications for such work as part of that Contract's "Particular Specifications."

1.1.4 Content and Format

These Standard Construction Specifications include three Parts as described in the following articles under this section. Every Part is divided into separate chapters, and each chapter contains different sections for the items of work appropriate to that chapter's category. Each section for an item of work includes the following subsections:

a. Description: General description of what this work item entails

b. Materials: Lists the various materials required for the item of work, with specific testing and performance specifications that are the basis for the acceptance of those materials

c. Construction requirements: Contains the detailed methodology that the Contractor shall use to install the item of work or the physical performance requirements for the completed work. This section also includes the performance testing and inspection criteria that are used as the basis of acceptance of the completed work.

These Standard Specifications do not include measurement and payment descriptions for items of work. Measurement and payment descriptions are included in the Contract's "bills of quantities" (BOQ), in which the reference between the two documents is the work item description.

1.1.4.1 Part 1 Roads

Part 1 of the Standard Construction Specifications includes those specifications required for construction of general road works that are typically included in road and highway projects. This part of the Specifications includes the following applicable chapters which are supported by the specifications in Part 2 :

a. Chapter 1 - General Requirements: Describes the responsibilities and duties of the Contractor for administrating and conducting the work as well as requirements for temporary works.

b. Chapter 2 - Earthworks: Includes work items for all roadway excavation and backfill.

c. Chapter 3 - Pavement: Contains the material and construction requirements for new construction and rehabilitation of pavements including asphaltic and Portland cement types.

d. Chapter 4 - Concrete Works: Provides for design and control of concrete mixes along with requirements for formwork, reinforcement, placing and curing for minor structure work that is typically associated with road construction.

e. Chapter 5 - Reinforcing Steel: Provides material and fabrication requirements for concrete reinforcement.

f. Chapter 6 - Masonry: Provides material and construction requirements for concrete block, brick and stone masonry.

g. Chapter 7 - Incidental Construction: Contains material and construction requirements for incidental road work items such as guardrails, kerbs, barriers, traffic control devices, finishes, etc.

h. Chapter 8 - Traffic Markings and Signs: Describes the materials and installation procedures needed for traffic markings and construction of various types of road and highway signs.

i. Chapter 9 - Traffic Control System: Contains work items related to permanent traffic controls.

j. Chapter 10 - Lighting and Electrical Distribution Works: Provides material and construction requirements for roadway lighting and electrical distribution works.

k. Chapter 11 - Utilities: Provides materials and installation descriptions for utility works and street furniture including protection requirements for all utilities that may be encountered.

l. Chapter 12 - Stormwater Drainage: Includes work items related to installation of roadway runoff collection and discharge as well as subsurface groundwater and facilities.

m. Chapter 13 - Landscaping and Irrigation: Provides materials and installation descriptions for project performed landscaping and irrigation works.

1.1.4.2 Part 2 Road Structures

Part 2 of the Standard Construction Specifications includes those specifications required for construction of major structures that are typically included in some road and highway projects. This part of the Specifications includes the following applicable chapters which are supported by the specifications in Part 1:

a. Chapter 16 - Introduction

b. Chapter 17 - Drilled Piles: Sets out requirements for Drilled Piles and their testing.

c. Chapter 18 - Driven Piles: Outlines requirements to be followed for Driven Piles Works.

d. Chapter 19 - Ground Anchors: Provides requirements to be followed for permanent ground anchors and their testing.

e. Chapter 20 - Earth Retaining Systems: Provides requirements for Earth Retaining systems.

f. Chapter 21 - Concrete Structures: Contains requirements for the construction of major concrete structures such as bridges, underpasses, tunnels, and culverts.

g. Chapter 22 - Prestressing Steel: Provides prestressing requirements for pre-tensioning or post-tensioning precast or cast-in-place concrete

h. Chapter 23 - Steel Structures: Includes standards for steel structures and non-destructive testing.

i. Chapter 24 - Painting: Provides requirements for surface treatment and painting of steel, aluminium, and concrete surfaces to control corrosion and deterioration in both aggressive & less aggressive environment.

j. Chapter 25 - Bearing Devices: Outlines requirements for furnishing and installing bridge bearings.

k. Chapter 26 - Bridge Deck Joint Systems: Contains standards for furnishing and installing bridge deck joint systems at locations where significant movements are expected or at fixed joints.

l. Chapter 27 - Railings: Provides materials and installation descriptions for concrete, steel, and aluminium railings and traffic barriers.

m. Chapter 28 - Waterproofing: Includes standards and requirements for installation of waterproofing systems on concrete surfaces.

n. Chapter 29 - Miscellaneous Items for Structures: Outlines standards and requirements for miscellaneous items that are not otherwise covered in these standard specifications.

o. Chapter 30 - Miscellaneous Metals: Outlines requirements for furnishing and installing miscellaneous metal items.

p. Chapter 31 - Metal Culverts: Contains requirements for the fabrication, erection, and inspection of metal culverts.

q. Chapter 32 - Precast Concrete Culverts: Contains requirements for the fabrication, erection, and inspection of buried precast concrete culverts.

r. Chapter 33 - Bridge Access Systems: Outlines requirements for different bridge access systems utilized for long-term inspection, operation, and maintenance.

s. Chapter 34 - Road Tunnels: Provides general requirements for different types of tunnel construction methods such as cut-and-cover tunnels, mined and bored tunnels in rock and soft ground, NATM tunnels, and immersed tunnels.

t. Chapter 35 - Bridge and Underpass Load Testing: Outlines requirements for static load testing as part of the acceptance process of new bridges and underpasses.

1.2 Abbreviations

Following abbreviations are used in these standard specifications:

cm: Centimetre

d: Day

dia: Diameter

ha: Hectare

h: Hour

kg: Kilogram

km: Kilometre

kN: kilo Newton

kW: Kilowatt

l: Litre

MDD: Maximum dry density

m: Metre

m^2: Square metre

m^3: Cubic metre

mg: Milligram

mm: Millimetre

mm^2: square millimetre

months: Months

MPa: Mega Pascal

nr: Number

sec: Second

set: Set

t: Ton

Reference to a technical society, institution, association or governmental authority is made in the specifications in accordance with the following abbreviations as well as those indicated on the Contract plans:

AA: Aluminium Association

AABC: Associated Air Balance Council

AAN: American Association of Nurserymen

AAMA: American Architectural Manufacturers Association

AASHTO: American Association of State Highway and Transportation Officials

ACI: American Concrete Institute

ADC: Air Diffuser Council

ADWEA: Abu Dhabi Water and Electricity Authority

AFI: Air Filter Institute

AGCA: Association General Contractors of America

AIA: American Institute of Architects

AIMA: Acoustical & Insulating Materials Association

AIEE: American Institute of Electrical Engineering

AISC: American Institute of Steel Construction

AISI: American Iron & Steel Institute

AITC: American Institute of Timber Construction

ALS: American Lumber Standards

AMCA: Air Moving & Conditioning Association

ANSI: American National Standards Institute

AOAC: Association of Official Agricultural Chemists

APA: American Plywood Association

ARI: Air Conditioning & Refrigeration Institute

AS: Australian Standards

ASAHC: American Society of Architectural Hardware Engineers

ASHRAE: American Society of Heating,

Refrigerating and Air-Conditioning Engineers

ASSE: American Society of Sanitary Engineering

ASTM: American Society for Testing & Materials, ASTM International

AWI: Architectural Woodwork Institute

AWPA: American Wood Preservers Association

AWPI: American Wood Preservers Institute

AWS: American Welding Society

AWWA: American Water Works Association

BHMA: Builders Hardware Manufacturers Association

BIA: Brick Institute of America

BRI: Building Research Institute

BS: British Standard

BSCP: British Standard Code of Practice

BS EN: European Standards

BSI: British Standards Institution

CDA: Copper Development Association

CEE: International Commission on Rules for Approval of Electrical Equipment (Europe)

CIRIA: Construction Industry Research and Information Association

CRSI: Concrete Reinforcing Steel Institute

CS: Commercial Standard, U.S. Department of Commerce

CSI: Construction Specifications Institute

CSP: Certified Safety Professional

CTI: Cooling Tower Institute

DIN: Deutsche Institute for Normung, Germany

EAD: Environmental Abu Dhabi

ETISALAT: Emirates Telecommunications Corporation

FGMA: Flat Glass Marketing Association

FPL: Forest Products Laboratory

FS: Federal Specification (U.S.)

FSIWA: Federation of Sewage & Industrial Waste Association

FTI: Facing Tile Institute

GA: Gypsum Association

GTA: Glass Tempering Association

HPMA: Hardwood Plywood Manufacturers Association

IEC: Int'l. Electrotechnical Commission

IEE: Institute of Elect. Engineers of London

IEEE: Institute of Elect. & Electronics Engineers

IES: Illuminating Engineering Society

ISA: Instrument Society of America

ISO: International Organization for Standardization, Switzerland

MIA: Marble Institute of America

MLMA: Metal Lath Manufacturers Association

MSSVFI: Manufacturers Standardization Society of the Valves and Fittings Industries

NAAMM: National Association of Architectural Metal Manufacturers

NACE: National Association Corrosion Engineers

NAFM: National Association of Fan Manufacturers

NAPF: National Association of Plastic Manufacturers

NBGQA: National Building Granite Quarries Association NBHA National Builders Hardware Association

NBS: National Bureau of Standards

NCMA: National Concrete Masonry Association

NEC: National Electrical Code (NPFA No.70)

NEMA: National Electrical Manufacturers Association

NEMI: National Elevator Mfg. Industry, Inc.

NFC: National Fire Code

NFPA: National Fire Protection Association

NFPA: National Forest Products Association

NHLA: National Hardwood Lumber Association

NHPMA: National Hardwood & Pine Manufactures Association

NPA: National Particleboard Association

NRMCA: National Ready Mixed Concrete Association

NSC: National Safety Council

NSF: National Sanitation Foundation

NTMA: National Terrazzo & Mosaic Association

NWC: National Water Council, UK

NWMA: National Woodwork Manufacturers Association

OSHA: Occupational Safety & Health Administration

PCA: Portland Cement Association

PCI: Prestressed Concrete Institute

PDI: Plumbing & Drainage Institute, USA

PEI: Porcelain Enamel Institute

PS: Product Standard, U.S. Dept. of Commerce

RIS: Redwood Inspection Service

RTI: Resilient Tile Institute

SCMA: Southern Cypress Manufacturers Association

SDI: Steel Door Institute

SIGMA: Sealed Insulating Glass Manufacturers Association.

SJI: Steel Joint Institute

SMACNA: Sheet Metal & Air Conditioning Contractors National Association

SMFMA: Sprayed Mineral Fibre Manufacturers Association, Inc.

SPIB: Southern Pine Inspection Bureau

SPR: Simplified Practice Recommendation, U.S. Dept. of Commerce

SSPC: Steel Structure Painting council

SWFPA: Structural Wood Fibre Products Association

TCA: Tile Council of America

TEMA: Tubular Exchange Manufacturing Association

TIMA: Thermal Insulation Manufacturers Association

TPI: Truss Plate Institute

UBC: Uniform Building Code

UL: Underwriters Laboratories, Inc.

UPC: Uniform Plumbing Code

UNCITRAL: United Nations Commission on International Trade

USACE: US Army Corps of Engineers

USBR: U.S. Bureau of Reclamation

USBS: U.S. Bureau of Standards

USCGS: U.S. Coast & Geodetic Survey

WCLB: West Coast Lumber Inspection Bureau

WRI: Wire Reinforcement Institute

WPA: Western Wood Products Association

1.3 Codes, Regulations and Referenced Specifications

The Contractor shall comply with all codes, regulations, specifications, and standards referred to throughout the Contract documents, as well as all codes, standards, and specifications of regulatory agencies specified herein.

1.3.1 Definitions

Terms used in this specification include the following:

1. Wherever the words "selected", "as directed," "as required," or words of like effect are used in these Standard Specifications, it is to be understood that the selection, direction, or requirements of the Engineer is intended. Similarly, the words "approved," "satisfactory," "equal," or words of like import shall mean "approved by," "satisfactory to," or "equal to" — as determined by the Engineer.
2. Wherever the words "necessary," "proper," or words of like import are used in these Standard Specifications — with respect to the extent, conduct, or character of work described — it is to be understood that they shall mean that the said work shall be carried out to the extent, conducted in a manner, or to be of such character that is necessary or proper in the opinion of the Engineer.
3. Where "as shown", "as indicated", "as detailed", or words of similar import are used, it shall be understood that reference to the Contract plans accompanying the specifications is made unless otherwise stated.
4. Where "as approved", "as reviewed", "as accepted", or words of similar import are used, it shall be understood that the approval, direction, requirement, permission, authorization, review, or acceptance of the Engineer is intended, unless otherwise stated.
5. As used in the Contract documents, "provide" shall be understood to mean, "provide complete in place", that is, "furnish and install".
6. Where “Employer”, “Department” or “Owner” is used in the Contract documents it shall be understood to mean Owner.
7. Where “Engineer” is used in the Contract documents, it shall be understood to mean the official representative or representative consultant of the Owner for administrating the Contract. “Engineer” also applies to the Engineer’s site staff including inspectors, surveyors, quantity surveyors, Engineers and laboratory personnel.

To avoid cumbersome and confusing repetition of expressions within these Standard Specifications, it is provided that whenever anything is done, or is to be done — if, as, or, when, or where “acceptable, accepted, approval, approved, authorized, condemned, considered necessary, contemplated, deemed necessary, designated, determined, directed, disapproved, established, given, indicated, insufficient, ordered, permitted, rejected, required, reserved, satisfactory, specified, sufficient, suitable, suspended, unacceptable, or unsatisfactory,” it shall be understood as if the expression were followed by the words “by the Engineer,” “to the Engineer,” or “of the Engineer.”

8. Where the term, “shall”, is used in a sentence in the Contract documents, implies an item that the Contractor is obligated to comply with as part of his Contractual requirements. Where the term, “will” is used in a sentence in the Contract documents, implies an item that the Owner or the Engineer is obligated to perform or comply with as part of their Contractual requirements. Where the term, “may” is used in a sentence in the Contract documents, implies an item that the Owner or Engineer reserves the right to obligate the Contractor to some item of work or requirement although they may elect to not exercise that obligation.
9. Wherever the following terms are used in these Standard Specifications, the intent and meaning will be interpreted as shown below.

When used in these standard specifications, the following terms have the meaning described.

Acceptance Plan

Acceptance plans are prescribed methods of sampling, measuring, and testing coupled with the criteria for the acceptability of a lot of material or construction.

Acceptable Quality Level (AQL)

AQLs measure the lot percent defective at/or below which the work is considered to be satisfactory.

Additive

Additives are substances or agents added in small amounts to a basic ingredient of a mixture prior to mixing.

Article

Articles refer to an immediate subheading of a section of these Standard Specifications that consists of sub-articles, items, sub-items, or paragraphs that set forth details and requirements essential or necessary to form the Standard Specifications. Specifications are divided into chapters; chapters into sections; sections into articles; articles into sub-articles, items, sub-items, and paragraphs.

Backfill

Backfill shall consist of the material used to replace, or the act of replacing, material removed during construction; it also may denote material placed or the act of placing material adjacent to structures.

Back Slope

In cuts, the back slope is the slope from the bottom of the ditch to the top of cut.

Bidder

Bidders consist of an individual, firm, or corporation that will submit a proposal to perform the proposed work.

Bridge

Bridges are aboveground structures, including supports, erected over a depression or over an obstruction — such as water, highways, or railways — or are elevated roadways that carry traffic or other moving loads. These structures have a length, measured along the centre of the roadway, that measures more than 6 m between the inside faces of end supports. A multiple-span box culvert is also considered a bridge when the length between the extreme ends of the openings exceeds 6 m.

Bridge Length

A bridge structure’s length is the overall length measured along the line of survey stationing back-to-back of back walls of abutments, if present; otherwise, end-to-end of the bridge floor; but in no case less than the total clear opening of the structure.

Bridge Roadway Width

Bridge roadway widths are measured at right angles to the longitudinal centreline of the bridge between the bottom of curbs.

Boulder

Boulders are rock fragments, usually rounded by weathering or abrasion, that will be retained on a 75 mm sieve.

Calendar Day

Calendar days are every day shown on the calendar, beginning and ending at midnight.

Calibrate

Calibration shall create the following outcomes:

- To determine settings of the plant that will provide correct proportions of the components of plant-mixed materials.
- To compare with a standard or check the graduations of a gauge or other measuring devices.

Camber

A camber consists of a slight arch designed or built into a structure to compensate for the natural deflection after loading.

Centreline

Centrelines are the defined and surveyed line shown on the Contract plans from which the roadway construction is controlled.

Certificate of Guarantee

A certificate of guarantee is a signed statement by a person having legal authority to bind a company or supplier to its product. Such certificates shall state that the material specifications and test results are in compliance with the specified requirements of AASHTO, ASTM, BS, or other designations.

Compaction

Compaction shall consist of the active or mechanical consolidation of a mass by rolling, tamping, or other similar means.

Construction Joint

Construction joints are joints made necessary by a prolonged interruption in the placing of concrete.

Consecutive Days

Two or more calendar days, one is following the other.

Contract

Contract refers to the entire and integrated agreement between the parties thereunder and supersedes all prior negotiations, representations, or agreements, either written or oral. The Contract documents develop the Contract between the Owner and the Contractor, setting forth the obligations of the parties thereunder, including, but not limited to, the performance of the work and the basis of payment.

Contractor

An individual, firm, or corporation that will contract with the Owner for performance of the work described in the Contract documents.

Contract Claim (Claim)

Claims are written demands submitted to the Owner in compliance with the Department of Transport Conditions of Contract and Schedule of Further Requirements seeking additional monetary compensation, time, or other adjustments to the Contract, the entitlement, or impact of which is disputed by the Owner.

Contract Documents

Contract documents include advertisement for proposal, the proposal, certification as to publication and notice of advertisement for proposal, appointment of agent by nonresident contractors, noncollusion affidavit, warranty concerning solicitation of the Contract by others, resolution of award of the Contract, executed form of the Contract, performance bond and payment bond, standard specifications, particular specifications, special provisions, plans, addenda, or other information mailed or otherwise transmitted to the prospective bidders prior to the receipt of bids, change and field orders, and supplemental agreements — all of which are to be treated as one instrument whether or not set forth at length in the form of the Contract.

Contract Plans

Contract plans show the location, character, dimensions, and details of the prescribed work — including layouts, profiles, cross sections, and other details or reproductions thereof.

Contract Time

Contract time defines the number of calendar days allowed for completion of the Contract work, including authorized time extensions.

Controlling Work Items

Controlling work items are the activities or work items on the critical path that have the least amount of total float. Controlling work items will also be referred to as a Critical Activity.

Country

When referring to country, it shall refer to the Districts of Abu Dhabi Emirate in which work herein specified is to be performed.

Culvert

Culverts shall consist of any structure not classified as a bridge or tunnel that provides an opening under the roadway.

Date

Day, month, and year reckoned according to the date corresponding to the Gregorian calendar.

Daily Work

Any work required by the Engineer to be performed and which is not otherwise covered or included in the project by the existing Contract documents, whether it be in the nature of additional work, altered work, deleted work, work due to differing site conditions, or otherwise. This term does not include a delay.

Deck

Decks are the surface layers of concrete and reinforcing steel on a bridge.

Delay

Delays are any unanticipated event, action, force, or factor that extends the Contractor’s time of performance of any controlling work item under the Contract. Delay is intended to cover all such events, actions, forces, or factors, whether styled delay, disruption, interference, impedance, hindrance, or otherwise, which are beyond the control of and not caused by the Contractor, or the Contractor’s subcontractors, material men, suppliers, or other agents. This term does not include extra work.

Density

Density measures the mass per unit volume of material, usually expressed in kilograms per cubic meter or grams per cubic centimetre.

Department

Department shall refer to the Abu Dhabi Department of Transport, the Owner.

Design Load

Design loads are the maximum anticipated loads that a structure must be support.

Detour

Detours are a temporary rerouting of traffic or the route traffic shall take during the temporary rerouting.

Directive

Directives are official, written communication with contractual status from the Engineer to the Contractor with respect to any or all phases of the Contract and work, including, but not limited to, progress, approvals, rejections, procedures, methods, and safety.

Dowel

Dowels are load transfer elements that usually consist of a plain, round steel bar.

Elevation

Elevation refers to the height above sea level or other datum.

Engineer-of-Record

An Engineer-of-Record is a professional engineer, or engineering firm, registered in the United Arab Emirates (UAE) that develops the criteria and concept for the project, performs the analysis, and is responsible for the preparation of the plans and specifications. This engineer or firm may be departmental in-house staff or a consultant retained by the Owner.

This position shall not be employed by the Contractor as its Engineer-of-Record.

Equipment

Equipment refers to the machinery and equipment, together with the necessary supplies for upkeep and maintenance thereof, and all other tools and apparatus necessary for the construction and acceptable completion of the work.

Existing

Existing refers to the physical status as of the date of the invitation for bids of any structure, base, surface, sub-grade, road, bridge, detour, or other unit affected by a particular project or designated highway.

Expansion Joint

Expansion joints provide for expansion of a rigid slab or wall, without damage to itself, adjacent slabs or walls, or structures.

Faulting

Faulting refers to the differential vertical displacement of rigid slabs at a joint or crack.

Grout

Grout, or mortar, is composed of sand, cement, water, and admixture, if required, of such consistency that it can easily be placed by pouring or pumping — if necessary.

Headwall

Headwalls are walls at the end of a culvert that prevent earth from spilling into the channel.

Inspector

Inspectors are authorized representatives of the Engineer assigned to make official inspections of the materials furnished and of the work performed by the Contractor.

Joint

Joints are a designed vertical plane of separation or weakness.

Laboratory

The official testing laboratory used or approved by the Owner or any other testing laboratory which may be designated by the Engineer.

Load Transfer Device

Load transfer devices are a mechanical means designed to carry loads across a joint.

Longitudinal Joint

Longitudinal joints are normally placed between traffic lanes to control longitudinal cracking.

Lot

Lots refer to a discrete quantity of material or work to which an acceptance procedure is applied.

Materials

Materials shall consist of any substances specified for use in the construction of the project and its appurtenances.

Minor Concrete

Minor concrete is nonstructural concrete as designated on the Contract plans or in the Standard Specifications.

Moisture Content

Moisture content shall be measured by the percentage, by weight, of water contained in soil or other material, usually based on the dry weight.

Original Ground

Original ground refers to the ground surface just prior to the initiation of the proposed work.

Owner

The Owner shall refer to the Abu Dhabi Department of Transport.

Plans

Plans shall refer to the approved plans, including reproductions thereof, showing the location, character, dimensions, and details of the work.

Program of Work

A work schedule prepared and submitted by the Contractor for the Engineer's approval prior to the commencement of the Work. Work programs shall show the equipment, the order of procedure, and the methods the Contractor proposes to use to carry out the Work.

Professional Engineer (PE)

PEs are engineers who hold PE certificate, or equivalent, or valid licenses permitting them to offer engineering services directly to the public, who are experienced in the work for which they are responsible, who take legal responsibility for their engineering designs, and who are bound by a code of ethics to protect the public health.

Quality Assurance (QA)

A group of planned regulatory procedures for taken measurements and samples, testing and evaluation for tests and measurements results, to provide satisfactory confidence to assure that the constructed works conforming to the specified requirements in the specifications, these regulations shall be applied by the Owner or specialized firms assigned by the Owner.

QA Procedures

These procedures shall refer to specific sampling, testing, measuring, and evaluation procedures for determining the degree of conformance to the quality and quantity requirements of the Standard Specifications.

Quality Control (QC)

A set of specific procedures for measurements, samplings, testing, and evaluation of tests and measurements results carried to determine the degree of compliance with quality requirements and standards indicated in the specifications and implemented by the Contractor.

Quality Index

Quality indexes refer to statistics computed when applying the variables acceptance procedures to estimate the level of quality actually achieved.

Random

Without bias or regularity.

Rejectable Quality Level (RQL)

RQLs refer to the level of lot percent defective at/or above which the work is considered to be unacceptable.

Reinforcement

Reinforcement shall refer to the steel embedded in concrete structures to resist tensile and compressive stresses and detrimental opening of cracks.

Right-of-Way (ROW)

ROW refers to the land that the Owner has title to, or right of use, for the road and its structures and appurtenances, and for material pits furnished by the Owner.

Riprap

Riprap refers to the protective covering of graded boulders, pieces of concrete or stone, with or without mortar, to prevent erosion.

Section

Sections are a numbered prime division of these Standard Specifications.

Shop Drawings

Shop drawings consist of the fabrication plans for any part of the work, including, but not limited to, precast concrete items, structural steel items, or other metal items, and connections thereof, which the Contractor is required to submit to the Engineer.

Sidewalk

Sidewalks are the portion of the roadway primarily constructed for the use of pedestrians.

Site

Sites refer to the land and other places provided by the Owner for the execution of the work.

Site Engineer

Site engineers are the on-site representatives of the Contractor duly authorized to receive and execute all instructions of the Engineer and to supervise and direct all of the Contractor's construction operations in all phases of the work.

Skew Angle

Skew angles shall complement the acute angle between two centrelines that cross; for a structure centreline, skew right means the right-side of the structure is ahead; skew left means the left-side of the structure is ahead.

Specialty Engineer

Specialty engineers shall undertakes the design and drawing preparation of components, systems, or installation methods and equipment for specific temporary portions of the project work or for special items of the permanent works not fully detailed in the Contract plans and required to be furnished by the Contractor, such as but not limited to pot bearing designs, nonstandard expansion joints, mechanically stabilized earth (MSE) wall designs and other specialty items. Specialty engineers may also provide designs and details for items of the permanent work declared by the Owner to be minor or nonstructural. Specialty engineers may be an employee or officer of the Contractor or a fabricator, an employee or officer of an entity providing components to a fabricator, or an independent consultant hired by the Contractor.

A specialty engineer is qualified if they have the following qualifications:

- Registration as a PE in United States or equivalent; and,
- Education and experience necessary to perform the submitted design as required by the Owner.

Specifications

Specifications shall consist of the directions, provisions, and requirements contained herein, together with all stipulations contained in the Contract documents, setting out or relating to the method and manner of performing the work, or to the quantities and qualities of materials and labour to be furnished under the Contract.

- Standard Specifications: Parts 1, 2, and 3 of the Standard Construction Specifications is a bound document book, applicable to all Department contracts containing adopted requirements, setting out or relating to the method or manner of performing work, or to the quantities and qualities of materials and labour.
- Particular Specifications: Particular specifications are approved project specific additions and revisions to the Standard Specifications, applicable to all Department contracts.
- Special Provisions: Special provisions are specific clauses adopted by the Owner that add to or revise the Standard Specifications or particular specifications, setting forth conditions varying from or additional to the Standard Specifications applicable to a specific project.

Subarticle

Subarticles are headed and numbered subdivisions of an article of a section of these Standard Specifications.

Subcontractor

Subcontractors are individuals, firms, or corporations to whom the Contractor sublets part of the work.

Substructure

Substructure consists of all or part of the structure below the bearings of simple and continuous spans, skewbacks of arches, and tops of footings of rigid frames — including back walls, wing walls, and wing protection railings.

Superintendent

A superintendent is the Contractor's authorized representative in responsible charge of the work.

Superstructure

Superstructure refers to the entire structure, except for the substructure.

Superelevation

Superelevation is the increasing of the cross slope on a curve to partially offset the centrifugal force generated when a vehicle rounds the curve.

Temporary Structure

Temporary structures are any structure required to maintain traffic during construction of the work, which will be dismantled — if required — when the work is completed.

Traffic Lane

Traffic lanes are the portion of a travelled way for movement of a single line of vehicles.

Tunnel

Tunnel is an underground or underwater vehicular or pedestrian passage.

Underpass

Underpass is a traffic or pedestrian passage that passes under another road.

Visual Inspection

Visual inspections shall be used by the Contractor to inspect for defects that can be seen.

Water-Cement (W/C) Ratio

This ratio measures the amount of water, exclusive of that absorbed by the aggregates, to the amount of cement in a concrete or mortar mixture; preferably stated as a decimal by mass.

Weephole

Weepholes are a hole through an abutment or retaining wall to relieve hydrostatic pressure from groundwater.

Work

Work shall refer to all labour, materials, and incidentals required to execute and complete the requirements of the Contract, including superintendence, use of equipment and tools, and all services and responsibilities prescribed or implied.

Working Day

A working day is any calendar day on which the Contractor works or is expected to work in accordance with the approved work progress schedule.

Working Drawings

Working drawings refer to the stress sheets, shop drawings, erection plans, falsework plans, framework plans, cofferdam plans, bending diagrams for reinforcing steel, or any other supplementary plans or similar data that the Contractor is required to submit to the Engineer for approval.

1.3.2 Reference Standards and Codes

1.3.2.1 General

Standards and codes referenced herein include the following:

a. All references to codes, regulations, specifications and standards referred to in the Contract documents shall, unless otherwise stated, mean the latest edition, amendment or revision of such reference standard in effect as of the date of submission of these tender documents by the tenderers to the Owner.

b. The Contractor shall obtain an original copy of the latest edition of all codes, local and administrative orders, regulations, standards and technical literature referred to in the contract documents including those referenced in inspection and test plans shall be given to the Engineer at no additional cost as directed by the Engineer.

c. Reference to a technical society, institution, association or governmental authority is made in the specifications in accordance with the following abbreviations:

    1. ADWEA: Abu Dhabi Water and Electrical Authority
    2. AASHTO: American Association of State Highway and Transportation Officials
    3. ACI: American Concrete Institute
    4. AF&PA: The American Forest & Paper Association
    5. AIA: American Institute of Architects
    6. AIMA: Acoustical & Insulating Materials Association
    7. AIEE: American Institute of Electrical Engineering
    8. AISC: American Institute of Steel Construction
    9. AISI: American Iron & Steel Institute

10. AMCA: Air Moving & Conditioning Association
11. AMRL: AASHTO Materials Reference Laboratory
12. ANSI: American National Standards Institute
13. ARI: Air Conditioning & Refrigeration Institute ASHRAE American Society of Heating, Refrigerating and Air Conditioning Engineers
14. ASBI: American Segmental Bridge Institute
15. ASCE: American Society of Civil Engineers
16. ASNT: American Society for Nondestructive Testing
17. ASTM: American Society for Testing & Materials (ASTM International)
18. AWS: American Welding Society
19. AWWA: American Water Works Association
20. BS: British Standard
21. BSCP: British Standard Code of Practice
22. BSI: British Standards Institution
23. CEE: International Commission on Rules for Approval of Electrical Equipment (Europe)
24. CEN: European Committee for Standardization (also EN)
25. CENELEC: European Committee for Electrotechnical Standardization
26. CIRIA: Construction Industry Research and Information Association
27. CRSI: Concrete Reinforcing Steel Institute
28. CSI: Construction Specifications Institute
29. DIN: Deutsche Institute for Normung
30. DMS: Departmental Material Specification
31. EN: European Standard (see CEN)
32. ETSI: European Telecommunications standards Institute
33. FHWA: Federal Highway Administration
34. FS: Federal Specification (US)
35. ICR: International Concrete Repair Institute
36. IEC: International. Electrotechnical Commission
37. IEE: Institute of Electrical Engineers of London
38. IEEE: Institute of Electrical & Electronics Engineering
39. IES: Illuminating Engineering Society
40. ISO: International Organization for Standardization
41. ITE: Institute of Transportation Engineers
42. IWRC: Independent Wire Rope Core
43. MSS: Manufacturer’s Standardization Society of the Valves and Fittings Industries
44. NACE: National Association of Corrosion Engineers
45. NATM: New Austrian Tunnelling Method
46. NBS: National Bureau of Standards
47. NCMA: National Concrete Masonry Association
48. NEC: National Electrical Code (NPFA No.70)
49. NEMA: National Electrical Manufacturers Association
50. NFC: National Fire Code
51. NFPA: National Fire Protection Association
52. NIST: National Institute of Standards and Technology
53. NRMCA: National Ready Mixed Concrete Association
54. NSBA: National Steel Bridge Alliance
55. NWC: National Water Council (UK)

56. OSHA: Occupational Safety & Health Administration (US)
57. PCA: Portland Cement Association
58. PCI: Precast/Prestressed Concrete Institute
59. SMACNA: Sheet Metal & Air Conditioning Contractors National Association
60. SSPC: The Society for Protective Coatings
61. UL: Underwriters Laboratories
62. UBC: Uniform Building Code
63. UPC: Uniform Plumbing Code
64. USACE: US Army Corps of Engineers
65. USC: United States Code
66. WRI: Wire Reinforcement Institute

Each of the above abbreviations, when followed by a number or letter designation, or combination of numbers and letters, designates a specification, test method, or other code or recommendation of the particular authority or organization shown.

1.3.2.2 Reference Standards and Codes Required in Chapter 1

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Guide Design Specifications for Bridge Temporary Works;
ADQCC (TR-516)	Road Structures Design Manual
ADQCC (TR-511)	Manual on Uniform Traffic Control Devices;
ADQCC (WA-725)	Irrigation Manual (Vol. 1, 2, 3, and 4)
ADQCC (WA-726)	Stormwater and subsoil drainage system (Vol. 1, 2, 3 and 4);
ADQCC (TR-511)	Manual on Uniform Traffic Control Devices
ADQCC (TR-531)	Work Zone Traffic Management Manual
CGPM	General Conference on Weights and Measures;
DOT-C-04	Abu Dhabi DOT - Construction Contract Administration Procedures;
DOT-C-05	Abu Dhabi DOT - Construction Supervision Manual;
DOT-M-05	Abu Dhabi DOT - Quality Assurance and Quality Control - Requirements for Road Projects;
DOT-M-07	Abu Dhabi DOT - Quality Assurance and Quality Control – Main Roads Division Quality Manual;
DOT-M-08	Abu Dhabi DOT - Environmental, Health and Safety Manual for Road Projects;
ITE	Equipment and Material Standards of the Institute of Transportation Engineers;
NFPA 241	Standard for Safeguarding Construction, Alteration, and Demolition Operations;
U.S. DOT FHWA	Department of Transportation Federal Highway Administration - Manual on Uniform Traffic Control Devices for Streets and Highways;

Table 1-1 and Table 1-2 presents American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials of this chapter. It also includes designations and titles.

Table 1-1: Designations and titles for ASTM standards that apply to this chapter

ASTM Designation	Title
ASTM E380 - 2010	*Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System).*
ASTM D4950 - 08	*Standard Classification and Specification of Automotive Service Greases.*
ASTM E810 - 03(2008)	*Standard Test Method for Coefficient of Retroreflective Sheeting Utilizing the Coplanar Geometry.*
ASTM D4956 - 11a	*Standard Specification for Retroreflective Sheeting for Traffic Control.*
ASTM D523 - 08	*Standard Test Method for Specular Gloss.*
ASTM G154 - 06	*Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.*
ASTM B209 - 10	*Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate.*

Table 1-2: Designations and titles for BS, and BS EN standards that apply to this chapter

BS Designation	BS EN Designation	Title
	BS EN 933-1:1997	*Tests for geometrical properties of aggregates. Determination of particle size distribution. sieving method.*
BS 812-105.2:1990		*Testing aggregates. Method for determination of particle shape. Elongation index of coarse aggregate.*

1.3.3 Equivalent Standards Acceptable

References to standards are made throughout these specifications to establish a standard of quality required and a procedure to be followed. Reference to one particular standard is not intended to prohibit the use of any other internationally recognized standard, which achieves the same level of quality, or requirement as those specifically mentioned in this specification.

1.3.4 Codes

All reference to codes, regulations, local and federal laws and regulations referred to in the Contract documents shall mean and are intended to be, the latest edition, amendment or revision of such reference in effect on the date of submission of the tender documents by the tendering party.

1.3.5 Governing Utility Departments and Agencies

List of governing bodies contained in Section 1.8.2 is not intended to be exhaustive. The Contractor shall carry out all works in strict accordance with current codes, regulations, local and administrative orders, specifications, and standards of all government bodies, even when these standard specifications does not list such agencies.

This Contract may include separate Contract Documents for constructing specific utility relocation or new installation work. These documents may include Contract plans, specifications and bills of quantities prepared by the responsibility utility agency and/or their consultant. The Contractor shall provide all necessary coordination with the utility agency and their consultant and meet all requirements of those separate Contract Documents, as directed or approved by the Engineer. Primary utility departments or agencies include:

a. Water and electrical services:
   1. Abu Dhabi Water and Electricity Authority (ADWEA), and subsidiaries:
      i. Abu Dhabi Water and Electricity Company (ADWEC)
      ii. Abu Dhabi transmission and Dispatch Company (TRANSCO)
      iii. Abu Dhabi Distribution Company (ADDC)
      iv. Al Ain distribution Company (AADC)
      v. Al Mirfa Power Company (AMPC)
b. Sewerage services:
   1. Abu Dhabi Sewerage Services Company (ADSSC) a subsidiary of ADWEA
c. Irrigation and drainage (includes underground pumping permits) services:
   1. Abu Dhabi City Municipality
d. District cooling services:
   1. Tabreed Abu Dhabi
e. Gas services and oil/gas pipelines:
   1. Abu Dhabi National Oil Company (ADNOC)
f. Telephone services:
   1. Etisalat
   2. Du

The Contractor, if approved by the relevant utility department, shall perform all work related to the installation of the proposed utility. If the Contractor is not approved by the relevant utility department to do such work, the Contractor will be required to employ a subcontractor who is approved by the relevant utility department and included on their current list of certified Contractors. A subcontractor so approved shall perform all work related to the complete installation of the system.

1.4 Unit Prices

A unit price is an amount proposed by bidders, stated on the tender form as a price per unit of measurement for materials or services to be added to or deducted from the Contract amount by Variation Order. It allows for the estimated quantities of work to be increased or decreased.

1.4.1 Procedures for Unit Prices

Contractors shall provide unit prices in compliance with the procedures as outlined in the Owner's Construction Contract Administration Procedures, the Construction Supervision Manual, the Procurement and Contracts Manual, and the following requirements:

1. Unit prices include all necessary labour materials, equipment cost for delivery, installation, insurance, overhead, profit, applicable taxes and all obligations, and liabilities of every kind arising under the Contract.
2. Measurement and payment: Refer to individual specification sections for work that requires establishment of unit prices. Methods of measurement and payment for unit prices are specified in the bills of quantities.
3. Owner reserves the right to reject the Contractor's measurement of work-in-place that involves use of established unit prices, and to have this work measured, at the Owner's expense, by an independent surveyor acceptable to the Contractor.

4. Refer to the tender documents, bills of quantities.

1.5 Metric Measurements

Owner construction projects use metric units of measurements in accordance with ASTM E380. Metric units used are the International System of Units (SI) developed and maintained by the General Conference on Weights and Measures (CGPM). Name International System of Units and the international abbreviation SI were adopted by the 11th CGPM in 1960. In some cases both metric SI units and English inch-pound (I-P) units are included in a section of the specifications; the measurements used in any particular case have been determined by the circumstances involved. Specifications requiring metric measurements may contain requirements for equipment (for example, printers and HVAC systems) described in I-P units; in which case equivalent metric substitution will be allowed. Specifications requiring metric measurements may include references to related non-metric industry and/or government standards in which case the requirements of the standard govern.

1.5.1 Use of Measurements

Measurements shall comply with the following requirements:

1. Measurements shall be in SI units unless otherwise authorized. The Contractor shall be responsible for all associated labour and materials when authorized to substitute one system of units for SI units and for the final assembly and performance of the specified work and/or products.
2. Hard metric: A hard metric measurement is indicated by an SI value with no expressed correlation to an I-P value (e.g., 38 mm). Products are considered to be hard metric when they are manufactured to metric dimensions or have an industry recognized metric designation.
3. Soft metric: A soft metric measurement is indicated by an I-P value which is a mathematical approximate of the SI value shown in parentheses (e.g., 1-1/2 inches (38.1 mm)). Metric measurements shall govern while the I-P value is provided for information.
4. Neutral: A neutral measurement is indicated by an identifier which has no expressed relation to either an SI or an I-P value (e.g., American Wire Gage (AWG) which indicates thickness but in itself is neither SI nor I-P).

1.5.2 Coordination of Measurements

Discrepancies, such as mismatches or product unavailability, arising from use of both metric and non-metric measurements and discrepancies between the measurements in the specifications and the measurements in the Contract plans shall be brought to the attention of the Engineer for resolution.

1.5.3 Relationship of Measurements to Submittals

Submittals for Engineer approval or for information only shall cover the SI products actually being furnished. The Contractor shall submit the required drawings and calculations in the same units used in the Contract documents describing the product or requirement unless otherwise instructed or approved. The Contractor shall use ASTM E380 as the basis for establishing metric measurements required to be used in submittals.

1.6 Work Restrictions

In addition to all responsibilities that are specifically described in the Contract documents, the Contractor shall have all responsibilities specified throughout these standard specifications. Wherever a Contract or Contractual documents stipulate that an item or work or special conditions require the approval of the Engineer, such approval by the Engineer shall not relieve the Contractor of his duties or responsibilities under the Contract.

1.6.1 r r Responsibility

The Contractor shall be deemed to have visited the site prior to submitting his Tender and to have made all necessary inspections and investigations and allowed in his Tender for the following:

1. Means of access and working space
2. Nature of the ground and sub-soils
3. Presence of existing foundations or other hidden obstructions
4. Level of the water table
5. Extent of rock
6. Support to neighbouring properties and structures
7. All other factors affecting the work

Any information made available to the Contractor, either in these documents or by any other source, will not relieve the Contractor of his responsibility to decide for himself the nature and extent of the work, nor will it guarantee that similar conditions will apply on other parts of the site.

The Contractor shall be deemed to have contacted the relevant authorities to establish the presence of any existing, live or redundant services, adjacent to or passing through the area of work and shall be deemed to have allowed in his Tender for their location, diversion, demolition or removal

Borehole logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at the borehole locations. Passage of time may result in a change of the subsurface conditions or water levels at the borehole locations. Owner does not guarantee any statements, opinions, or conclusions contained in the soil report.

The Contractor shall assume all responsibilities for:

1. Deductions and conclusions made by him regarding the nature of the soil to be dewatered and excavated
2. Difficulties involved
3. Maintaining the dewatering at required elevations
4. Carrying out his own investigation to satisfy himself of the validity of any subsoil information

1.6.2 Program of Works

The program of works shall be a project master program resource loaded submitted by the Contractor to the Engineer in accordance with the Department of Transport Conditions of Contract and Schedule of Further Requirements. The program of works shall also include Manpower Histogram, Cash flow, S-Curve and KPI’s. The program shall be prepared utilising the Precedence Diagram Method (PDM) of CPM scheduling technique, which shall contain the following:

1. Interim, milestone completion dates. Phasing and staging of the work as specified shall be prominently identified;
2. Mitigations of delay;
3. Procurement, fabrication, delivery installation and testing of major materials and equipment;
4. Submittals and Engineer/Owner’s review of material samples based on priority list as for work progress;
5. Submittals and Engineer/Owner’s review of shop drawings;
6. Interfacing, coordination and dependencies with preceding, concurrent and follow on Contractors;
7. Restrictions for manpower, material and/or equipment, if any;

8. Delivery of Owner furnished equipment, if any;
9. Work to be performed by other agencies which affect the schedule;
10. Maintenance of accesses to all the residential, recreational, business and institutional premises affected by the works;
11. Traffic detour planning and phasing;
12. Any restrains and restrictions imposed by service authorities or the Police;
13. Construction activities exceeding 14 days in duration shall be subdivided to an appropriate level, if required;
14. Schedule of activities shall be sufficiently described to include what is to be accomplished and which work areas. Activity duration shall be expressed in whole days (8hr/day) and the activity duration to be consistent with Production rate and Quantity as per proposed resources. Work that is to be performed by the subcontract shall be clearly defined;
15. The schedule diagram shall indicate a clearly defined critical path (not more than one), which shall be prominently distinguished;
16. The schedule should not contain more than 15% of the schedule activities on the critical path;
17. Program shall be resource loaded and schedule should show the proposed production rate and quantity of each activity;
18. A written narrative shall accompany the schedule submittal describing the Contractor’s approach and method of completion of the work. The narrative shall be adequate for the Engineer/Owner to understand the schedule and cross referenced to the requirement of Base line schedule check list. Also a schematic drawing showing the resources movement in the Project and the work methodology.
19. A calendar time scaled CPM network diagram schedule covering the complete Project shall be submitted. The schedule shall conform to the work-hours and constraints as outline in the Contract documents.
20. The Contractor shall maintain a project scheduler qualified in CPM scheduling techniques and familiar with the latest version of Primavera/MS Project-Project Planner Scheduling Software. The scheduler shall have the primary responsibility for monitoring status, updating progress and revising the program to reflect current contract status. The Contractor shall verify qualification of the scheduler by providing a description of construction project to which successful CPM network analysis has been applied. Submit a resume of a proposed scheduler for the approval of the Engineer/Owner.

1.6.3 Site Logistics Plan

The Contractor shall submit a Site Logistics Plan for review and approval of the Owner and Engineer.

1.6.4 Plant, Equipment and Labour

Contractor’s supply of plants, equipment, and labour shall comply with the following requirements:

1. The Contractor shall submit with his project schedule a detailed list of plant, equipment and labour which he undertakes to provide onsite to carry out the works. This list shall be as complete as possible and shall satisfy the Engineer as to its compatibility with the program of works. List shall include for each item of plant and equipment the type, manufacturer, model, identification number and year of manufacture. List shall include for labour the classifications and number for each classification.
2. The Contractor shall bring on the site of the works all of the items listed and such other equipment as may be required to expedite and complete the works and in no case thereafter shall the Contractor remove from the site any item of plant or equipment, or portions thereof, without the written consent of the Engineer.

3. All plant and equipment necessary for the construction of any type or section of the works must be on site and inspected and approved by the Engineer before the commencement of that particular type or section of the works. Any plant or equipment or portion thereof which becomes worn or defective shall be immediately repaired or replaced to the satisfaction of the Engineer.

1.6.5 Limits and Access to and Use of Site

Contractor’s responsibilities regarding any site access and use limitations:

1. Limits of the site shall be the limits of the areas defined on the Contract plans.
2. Access to the site is generally available as indicated on the Contract plans; the Contractor shall obtain such land as may be required and construct, maintain and remove such access roads as may be required for his construction operations and as directed by the Engineer. Such access or temporary roads constructed by the Contractor for his use shall not be constructed for use as public detours. No separate payment will be made by the Owner for such access or temporary roads.
3. Preparation, construction and maintenance of temporary roads within the site area shall be the Contractor's responsibility.
4. The Contractor shall take such measures as are necessary and as are directed by the Engineer to reduce and control any dust, sediment and pollution within the site as required in Section, 1.15.9.
5. The Contractor shall not disturb, damage or pull down any hedge, tree or building either within or outside the site areas without the written consent of the Engineer unless otherwise indicated on the Contract plans or specified in the Contract documents.
6. As may be prescribed in the Contract or directed by the Owner, the extent of portions of the site that the Contractor is to be given possession of and the order in which such portions shall be made available to him are subject to any requirements in the Contract and as to the order in which the works shall be executed. Owner will, with a written order to commence the works, give to the Contractor possession of so much of the site as may be required to enable the Contractor to commence and proceed with the construction of the works. The Contractor shall submit a written notice and request to the Owner to make available to the Contractor such further portions of the site as may be required to enable the Contractor to proceed with the construction of the works with due dispatch in accordance with the Work program.
7. The Contractor shall provide and maintain proper and safe passages across all open excavations at all necessary places on the site and wherever directed by the Engineer. In case of private or public lands, the Owner will provide a right-of-way along which the works are to be carried out and the Contractor shall confine the whole of the works' materials, plant and workmen to such right-of-way.
8. Relocation of utilities shall be extended beyond the limits of the site where required for completion of the works and as directed by the Engineer or as shown on the Contract plans.

1.6.6 Land for Contractor Use

Land provided for the Contractor use:

1. The Contractor shall be provided an area on which to situate his site offices and an additional area for laydown. It shall be the Contractor’s responsibility to obtain all necessary approvals and permits for use of property for his site purposes.
2. The Contractor shall be responsible for furnishing all utilities including but not limited to water, electricity, sewage disposal and telephone. The Contractor shall note that potable water, electricity and sewage disposal is not available from the public utility systems on island and that the Owner makes no guarantees of the availability of telephone service.

3. All costs associated with utilities shall be borne by the Contractor and deemed to have been included in the bid.
4. The Contractor shall be responsible for providing worker accommodations or camps.
5. The Contractor shall be responsible for all transportation to and from the work site each day of all workers. The Contractor shall consider that specific movement periods may be enforced and thus the Contractor shall manage traffic flow workers to appropriate periods. All cost for the worker's accommodation or camp and transportation shall be included in the price bid.

1.6.7 Excavated Materials and Debris

The Contractor shall recycle all excavated materials and debris and provide the Owner with Certificates as a part of Abu Dhabi Emirate's Environmental Sustainability Vision.

It is required for the Contractor to use suitable fill material excavated from within the Right-of-Way for purposes of filling load bearing areas such as, but not limited to, embankments, subgrade, trench backfill, other backfilling purposes, etc. prior to sourcing material from external borrow sites, subject to approval of the Engineer. The Engineer will consider excavation material unsuitable if it contains deposits of saturated or unsaturated soil mixtures or high salt content (to be reviewed and agreed with the Department) or organic matter unacceptable for filling material in load bearing areas. As directed by the Department, the Contractor is to dispose of any unsuitable excavated material as waste at locations directed by the Department. All suitable excavated material excavated at site, which cannot be accommodated within the Right-of-Way, shall be disposed of as surplus materials, subject to approval of and at locations directed by the Engineer and the Department.

All materials excavated on site with a potential for recycling such as, but not limited to, old concrete structures, pavers, boulders and rock, asphalt, construction and demolition waste, etc. shall be delivered to Tadweer's Al Dhafra Recycling Plant.

1.7 Field Engineering

This section specifies Contractor's administrative and procedural requirements for field Engineering services including, but not limited to, the following:

1. Land survey work
2. Civil-Engineering services
3. Damage surveys
4. Geotechnical monitoring

1.7.1 Submittals

The Contractor submittals shall meet the following requirements.

1. Certificates: Submit a certificate signed by the Contractor's supervisory person in charge of his surveying operations that certifies the location and elevation of improvements
2. Final property survey: submit a signed copy in electronic format, plus 5 paper copies of the final property survey
3. Project record documents: Submit a record of work performed and record survey data as required under the provisions of Section 1.24.

1.7.2 Quality Assurance

The Contractor shall meet the following quality assurance requirements.

1. Surveyor qualifications: Engage a land surveyor registered in the UAE and/or recognized as a qualified land surveyor having specific working experience in his profession in the UAE, to perform required land-surveying services.

2. Engineer qualifications: Engage an Engineer of the discipline required, registered in the UAE and/or recognized as a qualified Engineer having specific working experience in his profession in the UAE, to perform required Engineering services.

1.7.3 Examination

The Contractor shall meet the following requirements:

1. Engineer will identify existing control points and property line corner stakes.
2. Verify layout information shown on the Contract plans, in relation to the property survey and existing benchmarks, before proceeding to set-out the work. Locate and protect existing benchmarks and control points. Preserve permanent reference points during construction.
3. Do not change or relocate benchmarks or control points without prior written approval. Promptly report lost or destroyed reference points or requirements to relocate reference points because of necessary changes in grades or locations.
4. Promptly replace lost or destroyed project control points. Base replacements on the original survey control points.
5. Establish and maintain a minimum of 2 permanent benchmarks on the site, referenced to data established by survey control points.
6. Record benchmark locations, with horizontal and vertical data, on the site plan drawing and on the project record documents.
7. Existing utilities and equipment: Existence and location of underground and other utilities and construction indicated as existing are not guaranteed. Before beginning site work, investigate and verify the existence and location of underground utilities and other construction.
8. Provide written approval from the concerned authority.

1.7.4 Laying-out of the Works

The Contractor's work shall meet the following requirements:

1. Work from lines and levels established by the property survey. Establish benchmarks and markers to set lines and levels at each story of construction and elsewhere as needed to locate each element of the project. Calculate and measure required dimensions within indicated or recognized tolerances. Do not scale Contract plans to determine dimensions.
2. Advise entities engaged in construction activities of marked lines and levels provided for their use.
3. As construction proceeds, check every major element for line, level, and plumb.
4. Surveyor's log: Maintain a surveyor's log of control and other survey work. Make this log available for reference.
5. Record deviations from required lines and levels, and advise the Engineer when deviations that exceed indicated or recognized tolerances are detected. On project record drawings, record deviations that are accepted and not corrected.
6. On completion of foundation walls, major site improvements, and other work requiring field-Engineering services, prepare a certified survey showing dimensions, locations, angles, and elevations of construction and site work.
7. Site improvements: Locate and layout site improvements, including pavements, stakes for grading, fill and topsoil placement, utility slopes, and invert elevations.
8. Building lines and levels: Locate and layout batter boards or off-sets for structures, building foundations, column grids and locations, floor levels, and control lines and levels required for mechanical and electrical work.

9. Existing utilities: Furnish information necessary to adjust, move, or relocate existing structures, utility poles, lines, services, or other appurtenances located in or affected by construction. Coordinate with local authorities having jurisdiction.
10. Final property survey: Prepare a final property survey showing significant features (real property) for the project. Include on the survey a certification, signed by the surveyor, that principal metes, bounds, lines, and levels of the project are accurately positioned as shown on the survey.
11. The Contractor shall provide necessary coordination, survey equipment, personnel (surveyor, chainman, rodman, etc.) and transportation for the Engineer to check the accuracy of the Contractor's layout and quantity measurement surveys. The Contractor shall include this provision as part of his quality control plan as required in Section 1.13.
12. Recording: At project taking-over, have the final property survey recorded by or with local governing authorities as the official "property survey."

1.8 Project Utility Sources

This section covers standards and specifications of regulatory agencies which shall be used on this project including, but not limited to, those specified herein.

1.8.1 Building Codes

All reference to codes, regulations, local and administrative orders of the government bodies, and other regulatory authorities and specifications and standards referred in the Contract documents shall mean, and are intended to be, the latest edition, amendment or revision of such reference in effect as of the date of submission of the tender documents. Any items for which there are no relative codes, specifications or standards shall be of suitable quality or workmanship as determined by the Engineer. Details which qualify such items as being of acceptable quality shall be in accordance with Section 1.13.

1.8.2 Government Bodies

The Contractor shall carry out all works in strict accordance with current codes, regulations, local and administrative orders, specifications, and standards of all government bodies, including but not limited to the following:

a. Water and electrical services:
    1. Abu Dhabi Water and Electricity Authority (ADWEA), and subsidiaries:
        i. Abu Dhabi Water and Electricity Company (ADWEC)
        ii. Abu Dhabi Transmission and Dispatch Company (TRANSCO)
        iii. Abu Dhabi Distribution Company (ADDC)
        iv. Al Ain distribution Company (AADC)
        v. Al Mirfa Power Company (AMPC)
b. Sewerage services:
    1. Abu Dhabi Sewerage Services Company (ADSSC) a subsidiary of ADWEA
c. Irrigation and drainage (includes underground pumping permits) services:
    1. Abu Dhabi City Municipality
d. District cooling services:
    1. Tabreed Abu Dhabi
e. Gas services and oil/gas pipelines:

   1. Abu Dhabi National Oil Company (ADNOC)

f. Telephone services:
   1. Etisalat
   2. Du

g. Environmental Agency, Abu Dhabi (EAD)
h. UAE Armed Forces, GHQ
i. General Directorate of Civil Defence
j. Abu Dhabi Customs Administration (ADCA)
k. Abu Dhabi Urban Planning Council (UPC)
l. Municipality of Abu Dhabi City (ADM)
m. Al Ain City Municipality (AACM)
n. Western Region Municipality (WRM)
o. Department of Transport (DoT)
p. General Civil Aviation Authority (GCAA)
q. General directorate of Abu Dhabi Police (ADP)
r. Health Authority – Abu Dhabi (HAAD)
s. Ministry of Labour (MOL)
t. Ministry of Presidential Affairs (MOPA)
u. National Crisis and Emergency Management Authority
v. National Transport Authority (NTA)
w. Ruler's Representative Court of the Western Region (RRCWR)
x. The General Secretariat of the Executive Council (GSEC)
y. Western Region Development Council (WRDC)

1.9 Project Management and Coordination

This section outlines requirements for the Contractor's job-site operations and administration of the Contract. All work shall be performed under the observation of and in the presence of the Engineer.

1.9.1 Details of Contractor Supervisory Staff

The Contractor's supervisory and office staff shall be in accordance with the Annexure of the Tender Document and shall meet the following requirements.

1. Supervisory staff as detailed in the tender shall be available for the execution of the work under this Contract.
2. Each proposed Contractor key staff listed in the Contractor's tender is subject to approval by the Engineer.
3. Approval of the Contractor's site staff does not waive the right of the Engineer to withdraw that approval at any time thereafter as provided for by the Department of Transport Conditions of Contract and Schedule of Further Requirements.
4. It is pointed out that the provision of the supervisory staff submitted by the Contractor as detailed in his tender, does not relieve him in any way of his liability under the Contract to provide all the staff necessary for the satisfactory completion, commissioning and maintenance of the works and within the dates stated in the Contract.

5. The Contractor shall provide the names and details of the experience, qualifications and previous appointments for the supervisory staff including those of the Subcontractors who will be allocated to the project all as stipulated under the Department of Transport Conditions of Contract and Schedule of Further Requirements.
6. The Contractor's project manager shall be a degreed Engineer and have documented and recognized experience which shall include previous experience as a project manager and he/she shall be full-time assigned to the site. The Contractor's project manager shall have a minimum of 20-years proven experience as a project manager for construction projects similar in nature to the current contract plus be in continuous employment with The Contractor's organization for at least the last two years.
7. The Contractor's supervisory staff submittal shall include project nominated sponsors who are the senior officers or operational managers from the Contractor's headquarters or main office who are also shown as senior persons within the Contractors overall corporate organizational structure.
8. A full-time safety Engineer shall be assigned to the site to manage the Contractor's health and safety plan.
9. Submittal shall include the personal contact information, including telephone numbers and email addresses where the Contractor organization's sponsors, project manager, safety engineer and other senior site supervisory staff can be reached as applicable for both normal working coordination or in case of emergency by the Owner or the Owner's representatives.

1.9.2 Use of Site

The Contractor shall not use the site for any purpose other than carrying out the works.

1.9.3 Advertising

Do not display or permit advertisements to be displayed on the site without written approval of the Owner.

1.9.4 Working Hours

Normal working hours shall be 48 hours per week, Saturday through Thursday. The Contractor shall comply with Labour Laws and requirements of the Department of Transport Conditions of Contract and Schedule of Further Requirements.

1.9.5 Work Schedule Notifications

a. Any work done in the absence of the Engineer or his authorized inspector may be subject to rejection.
b. The Contractor shall notify the Engineer three working days in advance of any work to be done in order that inspection services may be provided.
c. Inspection by the Engineer during defects liability period is to be performed as follows:
    1. Engineer will give the Contractor due notice of his intention to carry out any inspections during the defects liability period.
    2. The Contractor shall arrange for a responsible representative to be present at the times and dates named by the Engineer.
    3. The Contractor's representative shall render all necessary assistance and take note of all matters and issues to which the Engineer directs his attention.

1.9.6 Adjoining Plant and Property

The Contractor shall meet the following requirements pertaining to adjoining construction plant and property.

1. Take all reasonable precautions to avoid interference with the operation of and to prevent damage to adjoining plant and property.
2. Obtain permission as necessary from the concerned authority and pay all necessary charges if required to use adjoining property.
3. Clear away and make good on completion or when directed.

1.9.7 Temporary Work

Provide and maintain during the execution of the works all shoring, strutting and other supports as may be necessary to preserve the stability of all plant and property that may be endangered or affected by the works. Temporary diversion of traffic shall be as per the requirements of Section 1.15.13.

1.9.8 Coordination

The Contractor shall provide coordination assurances for the following items:

1.9.8.1 General

a. Coordinate construction activities included under various sections of these specifications to assure efficient and orderly installation of each part of the works.
b. Coordinate construction operations included under different sections of the specifications that are dependent upon each other for proper installation, connection and operation.
c. Where installation of one part of the work is dependent on installation of other components, either before or after its own installation, schedules detailed design and construction activities in the sequence required to obtain the best results.
d. Where availability of space is limited, coordinate installation of different components to assure maximum accessibility for required maintenance, service and repair.
e. Make adequate provisions to accommodate items scheduled for later installation.
f. Where necessary, prepare memoranda for distribution to each party involved outlining special procedures required for coordination. Include such items as required notices, reports and attendance at meetings.
g. Prepare similar memoranda for the Engineer and separate Contractors, where coordination of their work is required.

1.9.8.2 Administrative Procedures

a. Contractors constructing other utilities and buildings may be working in the vicinity of the works during the course of this Contract.
b. Co-ordinate scheduling and timing of required administrative procedures with other construction activities to avoid conflicts and ensure orderly progress of the work. Such administrative activities include, but are not limited to, the following:
    1. Preparation of schedules
    2. Preparation of project correspondence
    3. Preparation of submittals
    4. Progress and coordination meetings
    5. Estimating and pricing Variation Orders
    6. Project closeout activities

1.9.8.3 Drawings

a. The Contractor shall be responsible for and shall pay the extra cost, if any, occasioned by any discrepancies, errors, or omissions in the drawings and other submittals furnished by him, whether or not approved by the Engineer.

b. Prepare and submit coordination drawings where close and careful coordination is required:

   1. Installation of products
   2. Materials fabricated off-site by separate entities
   3. Where limited space availability necessitates maximum utilization of space for efficient installation of different components.

c. Drawings shall indicate:

   1. Interrelationship of components detailed on separate shop drawings
   2. Required installation sequences
   3. Comply with requirements contained in Section 1.11.
   4. Take special care and precautions for specific coordination requirements for plant, equipment and other electromechanical installations, specified elsewhere or otherwise required.

1.9.8.4 Specifications

a. Arrangement of the specifications into divisions, sections and paragraphs shall not control or determine the division of work among subcontractors nor establish the extent of work to be performed by any particular trade.

b. The Contractor shall be responsible for the proper coordination of all Works including that required between different trades, Subcontractors, suppliers, utility authorities, government authorities, etc.

1.9.9 Work Plan

The Contractor shall submit his Construction work plan including his entire working procedure, forms, administration, submission of technical documents, correspondence, reporting, meeting, documentation, communication, etc, as otherwise may be specified or as required by the Engineer. The Contractor's work plans shall meet the following requirements:

1. The Contractor shall provide a work plan for each key activity, as requested by Engineer, to show construction methods. Relate the work plan to activities shown on the project schedule
2. The Contractor shall conduct a pre-work coordination meeting before the start of the work in each work zone or where a change in the construction operations is contemplated
3. The Contractor shall include in its baseline schedule and all progress schedules, allowances for normal inclement weather

1.9.10 Daily Report

Refer to Sections 1.13 and 1.13.10 , for daily reporting requirements.

1.9.11 Plant Record

Submit a daily record to the project Engineer in a format that the Engineer has approved, showing the type, model, number of hours worked, and capacity of all mechanical and power operated plant employed on the works. The Contractor shall incorporate this record in the daily report; refer to Section 1.131.9.10.

1.9.12 Defective Work

When any part of the works is known or suspected to be defective, the Contractor shall submit proposals as soon as possible to the Engineer for his approval for further testing, opening up, inspection, making good or removal and re-execution.

Whenever inspection or testing shows that any part of the works is not in accordance with the Contract, the Contractor shall take necessary measures, such as further testing, opening up, or experimental work, to establish the acceptability of the work. Such measures shall be at the Contractor's expense and shall not be grounds for extension of time.

1.9.13 Representatives for Emergencies

The Contractor shall file with the Engineer, the names, addresses, and telephone numbers of representatives who can be contacted at any time, in case of emergency. Representatives must be fully authorized and equipped to correct unsafe or excessively inconvenient conditions at short notice.

1.9.14 Maintaining Existing Facilities in Operation

The Contractor shall carry out the works in such manner to avoid disruption to existing utilities. In no case shall the Contractor interfere with the operation of existing facilities, pipelines, cables etc., without first obtaining the permission of the Engineer, the Owner and the relevant authority to which such facility pertains.

1.9.15 Working Hours and Engineers Supervision

No work shall be carried out during the night, on Fridays or on public holidays without the permission in writing of the Engineer, except when the work is unavoidable or absolutely necessary for the saving of life or property or for the safety of the works in which case the Contractor shall immediately advise the Engineer.

1.10 Construction Progress Documentation

Construction progress documentation shall meet the requirements outlined in this section.

1.10.1 Submittals

a. The Contractor shall submit the following: Preliminary progress schedule to the Engineer no later than 14 calendar days after notice of commencement for approval.

b. Detailed progress schedule, as follows:

   1. Submit initial detailed progress schedule within 28 calendar days after notice of commencement for approval by Engineer. The Contractor shall resubmit until such time as it has been approved by the Engineer.

   2. Submit an updated progress schedule utilizing the critical path method (CPM).

c. Submit the following with each progress schedule submission:

   1. The Contractor's certification that progress schedule submission is the actual schedule being utilized for execution of the work.

   2. CD with .XER file of the progress updated schedule prepared with the latest version of (P6) Enterprise Project Portfolio Manager or Professional Project Manager from Primavera Systems Incorporated or similar.

   3. Progress schedule: 5 legible copies

   4. Narrative progress report: 5 legible copies

   5. Progress quantity chart(s)

d. Before final payment, submit a final updated progress schedule.

1.10.2 Project Schedule

The Contractor shall use the critical path method (CPM) for preparing all project schedules, hereafter defined as the progress schedule.

1.10.3 Software

The Contractor shall use the following software applications to prepare the project schedule:

1. Professional Project Manager or Enterprise Project Portfolio Manager (P6) latest version, from Primavera Systems Incorporated or similar.
2. The Contractor shall provide to the Engineer one license of the latest version of the scheduling software. This license shall be added to the license serial number of the Owner.

1.10.4 Basis for Payment

The Contractor shall comply with the following requirements for basis of payment.

1.10.4.1 General

Schedule shall be the basis for measuring the Contractor progress. Failure of the Contractor to provide all information, as specified below, shall result in the disapproval of the entire progress schedule submission and may result in the inability of the Engineer to evaluate the Contractor progress for payment purposes.

1. Failure to submit acceptable progress schedule or progress schedule revisions If the Contractor fails within the time limits set forth in this article to submit an acceptable progress schedule, or fails to submit acceptable progress schedule revisions for modifications issued under the terms of this Contract, or fails to submit acceptable progress schedule revisions otherwise required, or to adequately status the progress schedule, or perform an acceptable mathematical analysis, to provide acceptable progress reports as required by this article, the Engineer may, in addition to other remedies provided under this article, withhold approval of all or any portion of the progress payments until an acceptable revision, status, mathematical analysis, or progress report is submitted and approved.

1.10.4.2 Non-Compliance

Failure of the Contractor to comply with the requirements of the Engineer under this article shall be grounds for a determination by the Engineer that the Contractor is not prosecuting the work with sufficient diligence to ensure completion within the time specified in the Contract. Upon making this determination, the Owner may terminate the Contractor's right to proceed with the work, or any separable part of it, in accordance with the default terms of this Contract.

1.10.4.3 Errors and unrealistic and/or unreasonable logic

In the event that any error, or unrealistic or unreasonable component, parameter, logical relationship or activity duration results is discovered in an approved network, or updating information, mathematical analysis, progress report, or pay estimate, the Engineer may require the Contractor to correct, revise and resubmit the network, or status information, or mathematical analysis, or progress report, or payment estimate for approval. Any payment amount made on the basis of such error, or unrealistic or unreasonable component, parameter or result may be adjusted by the Engineer in subsequent payment estimates.

1.10.5 Preliminary Critical Path Method

In addition to basic requirements outlined in the Department of Transport Conditions of Contract and Schedule of Further Requirements, the Contractor shall show, using the critical path method (CPM), a detailed schedule, beginning with notice to commence, for at least 90 days, and a balance summary for a project through final completion. Show at least the following activities:

1. Notice to commence
2. Permits
3. Design period, by phases of design
4. Submittals, with review time. The Contractor may use schedule of shop drawings and samples specified in Section 1.11.
5. Submittals of the Contractor quality control plan and health and safety plan
6. Early procurement activities for long lead equipment and materials
7. Mobilization
8. Engineer's review periods
9. Earthwork
10. Specified work sequences and construction constraints
11. Tender schedule
12. Contract milestone and completion dates
13. Major structural, mechanical, equipment, electrical, architectural, and instrumentation and control work
14. System start-up summary
15. Project close-out summary
16. Demobilization summary

Update preliminary progress schedule monthly; as part of progress payment process. Failure to do so may cause Engineer to withhold all or part of the monthly progress payment until the preliminary progress schedule is updated in a manner acceptable to Engineer. Format a detailed progress schedule in accordance with Section 1.10.7 and Section 1.10.5.

1.10.6 Detailed Progress Schedule

Detailed progress schedules shall comply with the following requirements:

1. In addition to requirements of the Department of Transport Conditions of Contract and Schedule of Further Requirements, submit detailed progress schedule beginning with notice to commence and continuing through final completion.
2. Show the duration and sequences of activities required for complete performance of the work reflecting means and methods chosen by the Contractor.
3. When accepted by Engineer, detailed progress schedule will replace preliminary progress schedule and become baseline schedule. Subsequent updated submittals will be considered as updated progress schedules.
4. Format a detailed progress schedule in accordance with Section 1.10.7 and Section 1.10.5.
5. Update monthly to reflect actual progress and occurrences to date, including weather delays using a date agreed with the Engineer.

1.10.7 Progress Schedule Bar Chart

The Contractor shall provide a progress schedule bar chart that meets the following requirements:

1.10.7.1 General

comprehensive bar chart schedule, generally as outlined in Associated General Contractors of America Publication No. 1107.1, "Construction Planning and Scheduling, latest edition. If a conflict occurs between the AGC publication and this specification, this specification shall govern.

1.10.7.2 Format

a. Unless otherwise approved, white paper, A3 sheet size
b. Title block: Show name of project and Owner, date submitted, revision or update number, and name of the Contractor
c. Identify horizontally, across the top of the schedule, the time frame by year, month, and day
d. Identify each activity with a unique number and a brief description of the work associated with that activity.
e. Legend: Describe standard and special symbols used.

1.10.7.3 Contents

Identify, in chronological order, those activities reasonably required to complete the Work, including as applicable, but not limited to:

a. Obtaining permits, submittals for early product procurement, and long lead time items
b. Mobilization and other preliminary activities
c. Initial site work
d. Specified work sequences, constraints, and milestones, including substantial completion date(s)
e. Subcontract work
f. Major equipment design, fabrication, factory testing, and delivery dates
g. Site work
h. Concrete work
i. Structural steel work
j. Architectural features work
k. Equipment work
l. Mechanical work
m. Electrical work
n. Instrumentation and controls work
o. Other important Work for each major facility
p. Equipment and system start-up and test activities
q. Project closeout and cleanup
r. Demobilization

1.10.8 Progress Schedule Using Critical Path Method

The Contractor shall apply the critical path method (CPM), in accordance with the following requirements, to prepare progress schedules:

1.10.8.1 General

Comprehensive computer-generated schedule using CPM, generally as outlined in Associated General Contractors of America Publication No. 1107.1, "Construction Planning and Scheduling", latest edition. If a conflict occurs between the AGC publication and this specification, this specification shall govern.

1.10.8.2 Contents

a. Begin schedule with notice-to-commencement date and conclude with the date of final completion of defects liability period and end of maintenance period.
b. Identify work calendar basis using days as a unit of measure and UAE calendar.

c. Show complete interdependence and sequence of construction and project related activities reasonably required to complete the work. Identify the work of separate sections (or areas) and stages and other logically grouped activities, and clearly identify critical path of activities. Reflect sequences of the work, restraints, delivery windows, review times, Contract times and project milestones set forth in the agreement. Include as applicable, at a minimum:

    1. Obtaining permits, submittals for early product procurement, and long lead time items
    2. Mobilization and other preliminary activities
    3. Initial site work
    4. Specified work sequences, constraints, and milestones, including substantial completion date(s)
    5. Subcontract work
    6. Major equipment design, fabrication, factory testing, and delivery dates
    7. Site work
    8. Concrete work
    9. Architectural features work
    10. Equipment work
    11. Mechanical work
    12. Electrical work
    13. Instrumentation and control work
    14. Other important work for each major facility
    15. Equipment and system start-up and test activities
    16. Project closeout and cleanup
    17. Demobilization

d. No activity duration, exclusive of those for submittals review and product fabrication/delivery, shall be less than 1 day or more than 21 days, unless otherwise approved.

e. Activity duration for submittal review shall not be less than review time specified unless clearly identified and prior written acceptance has been obtained from the Engineer.

1.10.8.3 Network Graphical Display

a. Plot or print on paper not greater than A0 or smaller than A1, unless otherwise approved.

b. Title block: Show name of the Project, Owner, Engineer, Contractor, date submitted, revision or update number, and the name of the scheduler. Updated schedules shall indicate data date.

c. Identify horizontally across top of schedule the time frame by year, month, and day.

d. Identify each activity with a unique number and a brief description of the work associated with that activity.

e. Indicate the critical path.

f. Show, at a minimum, the controlling relationships between activities.

g. Plot activities on a time-scaled basis, with the length of each activity proportional to the current estimate of the duration.

h. Plot activities on an early start basis unless otherwise requested by Engineer.

i. Provide a legend to describe standard and special symbols used.

1.10.8.4 Schedule Report

On A4 white paper, unless otherwise approved. List information for each activity in tabular format, including, at a minimum:

a. Activity identification number
b. Activity description
c. Original duration
d. Remaining duration
e. Early start date (actual start on updated progress schedules)
f. Early finish date (actual finish on updated progress schedules)
g. Late start date. (early start on updated progress schedules)
h. Late finish date. (early start on updated progress schedules)
i. Total float
j. Cost-loading:
    1. Note the estimated cost to perform each work activity as per the approved rates, including submittals and submittal reviews, in the network in a tabular listing.
    2. Sum of all activity costs shall equal the Contract price. An unbalanced or front-end-loaded schedule will not be acceptable.
    3. Accepted cost-loaded progress schedule shall constitute the schedule of values.

1.10.9 Progress Quantity Charts

Reflect activity and Contract dates of progress schedule and show the planned number of units of production for each of above listed activities and cumulative progress to date and show average rate and cumulative curves for initial projected progress, actual progress, and revised planned project progress.

Submit revised progress quantity charts for each production activity named with each progress schedule submission.

1.10.10 Progress of the Work

A progress schedule shall document work progress in accordance with the following requirements:

a. Updated progress schedule shall reflect:
    1. Progress of work to within 5 working days before submission
    2. Approved changes in work scope and activities modified since submission3. Delays in submittals or resubmittals, deliveries, or work
    3. Adjusted or modified sequences of work
    4. Other identifiable changes
    5. Revised projections of progress and completion
    6. Report of changed logic
b. Produce detailed and specific schedule reports during the project, upon request of Engineer, to further define critical portions of the work
c. If the Contractor fails to complete an activity by its latest scheduled completion date and this failure is anticipated to extend Contract dates (or milestones), the Contractor shall, within 7 days of such failure, submit a written statement as to how the Contractor intends to correct non-performance and return to acceptable current progress schedule. Actions by the Contractor to complete the work within Contract times (or milestones) will not be justification for adjustment to Contract price or Contract times.
d. The Engineer may order the Contractor to increase plant, equipment, labour force or working hours if the Contractor fails to:

1. Complete a milestone activity by its completion date
2. Satisfactorily execute work as necessary to prevent delay to overall completion of project, at no additional cost to Owner.

1.10.11 Narrative Progress Report

The Contractor shall provide a narrative progress report that meets the following requirements:

1.10.11.1 Format

a. Organize same as progress schedule
b. Identify, on a cover letter, reporting period, date submitted, and name of the Contractor

1.10.11.2 Contents

a. Number of days worked over the period, work force on hand, construction equipment on hand (including utility vehicles such as pickup trucks, maintenance vehicles, stake trucks)
b. General progress of work, including a listing of activities started and percentage of completion over the reporting period, mobilization/demobilization of subcontractors, and major milestones achieved
c. The Contractor's plan for management of site (e.g., lay down and staging areas, construction traffic), utilization of construction equipment, build-up of trade labour, and identification of potential Contract changes
d. Identification of new activities and sequences as a result of executed Contract changes
e. Documentation of weather conditions over the reporting period, and any resulting impacts to the work.
f. Description of actual or potential delays, including related causes, and the steps taken or anticipated to mitigate their impact
g. Changes to activity logic
h. Changes to the critical path
i. Identification of, and accompanying reason for, any activities added or deleted since the last report
j. Steps taken to recover the schedule from the Contractor-caused delays

1.10.12 Progress Schedule Acceptance

Progress schedule acceptance will comply with the following requirements:

1.10.12.1 Engineer's Acceptance

Engineer's acceptance will demonstrate agreement that:

a. Proposed progress schedule is accepted with respect to:
   1. Contract dates, including final completion and all intermediate milestones are within the specified times
   2. Specified work sequences and constraints are shown as specified
   3. Access restrictions are accurately reflected
   4. Start-up and testing times are as specified
   5. Submittal review times are as specified
   6. Start-up testing duration is as specified and timing is acceptable

b. In all other respects, Engineer's acceptance of the Contractor's schedule indicates that, in Engineer's judgment, schedule represents reasonable plan for constructing project in accordance with the Contract documents. Engineer's review will not make any change in Contract requirements. Lack of comment on any aspect of schedule that is not in accordance with the Contract documents will not thereby indicate acceptance of that change, unless the Contractor has explicitly called the non-conformance to Engineer's attention in submittal. Progress schedule remains the Contractor's responsibility and the Contractor retains responsibility for performing all activities, for activity durations, and for activity sequences required to construct project in accordance with the Contract documents.

1.10.12.2 Unacceptable Preliminary Progress Schedule

a. Make requested corrections; resubmit within 10 calendar days

b. Until acceptable to Engineer, the Contractor shall continue review and revision process, during which time the Contractor shall update schedule on a monthly basis to reflect actual progress and occurrences to date

1.10.12.3 Unacceptable Detailed Progress Schedule

a. Make requested corrections; resubmit within 10 days

b. Until acceptable to Engineer, the Contractor shall continue review and revision process

1.10.12.4 Narrative Report

All changes to activity logic, duration, sequences, including addition or deletion of activities subsequent to Engineer's acceptance of baseline progress schedule, shall be delineated in the narrative report current with proposed updated progress schedule.

1.10.13 Adjustment of Contract Dates

Evaluation and reconciliation of adjustments of Contract times shall be based on the updated progress schedule at the time of proposed adjustment or claimed delay and as follows:

1.10.13.1 Schedule contingency

a. Use of schedule contingency suppression techniques such as preferential sequencing and extended activity times is prohibited.

b. Pursuant to contingency sharing provisions of this specification, no time extensions will be granted, nor will delay damages be paid until a delay occurs which (1) consumes all available contingency time, and (2) extends work beyond the Contract completion date

1.10.13.2 Float

a. Use of float suppression techniques such as preferential sequencing or logic, special lead/lag logic restraints, and extended activity times are prohibited. Use of float time disclosed or implied by use of alternate float-suppression techniques shall be shared to proportionate benefit of the Owner and the Contractor.

b. Pursuant to above float-sharing requirement, no time extensions will be granted nor delay damages paid until a delay occurs which an impacts project's critical path. consumes available float or contingency time and extends work beyond Contract completion date

1.10.13.3 Claims based on Contract dates

a. Where Engineer has not yet rendered formal decision on the Contractor's Claim for adjustment of Contract times, and parties are unable to agree as to amount of adjustment to be reflected in progress schedule, the Contractor shall reflect an interim adjustment in the progress schedule as acceptable to Engineer.

b. It is understood and agreed that such interim acceptance will not be binding on either the Contractor or the Owner, and will be made only for the purpose of continuing to schedule work until such time as formal decision has been rendered as to an adjustment, if any, of the Contract times.

c. The Contractor shall revise progress schedule prepared thereafter in accordance with Engineer's formal decision.

1.10.14 Qualifications for Personnel Responsible for Schedules

The Contractor shall designate a team with an authorized representative who shall be responsible for the preparation of all required progress schedule reports. This person shall be dedicated full-time to preparing all required schedule reports. This person shall be a qualified project controls Engineer or a planning Engineer who has previously created and reviewed computerized schedules. Qualifications of this individual shall be submitted to the Engineer for review with the preliminary progress schedule submission.

1.11 Submittal Procedures

This section describes submittal procedures, standards, and requirements for the following items:

1. Product data
2. Shop drawings
3. Samples
4. Operation and maintenance manuals
5. Certificates and affidavits
6. Miscellaneous submissions
7. Contract plans
8. Mistakes in Information

1.11.1 Definitions

This section defines submittal procedure terms.

a. Product data and shop drawings:

   1. Includes drawings, diagrams, illustrations, brochures, schedules, bills of materials, and other data prepared specifically for the works
   2. Information may be prepared by the Contractor, his subcontractors, suppliers or distributors, equipment manufacturer, or fabricators
   3. Information must illustrate or describe manufacture, fabrication, construction, and installation of the works or a portion thereof

b. Manufacturer's representative:

   1. Person actively working at manufacturer's factory with minimum 5 years experience
   2. Familiar with actual problems of manufacturing, installing, and operating the product
   3. Sales representatives or agents are not acceptable

c. Working (shop) drawings:

   1. The Contractor prepared plans for temporary structures and facilities
   2. Elements of work which may affect the safety of persons or property shall be checked and certified by a qualified Engineer
   3. Calculations demonstrating adequacy of the Contractor's design shall be submitted with the working drawings

4. Follow submittal procedures for shop drawings

d. Samples:
   1. Physical examples illustrating materials, equipment, or workmanship
   2. Establish standards by which the work will be judged

e. Manuals:
   1. Manufacturer's written installation, start-up, operating, maintenance and repair instructions
   2. Include parts lists, pictures, sketches and diagrams specific to the equipment supplied to document the manufacturer's requirements.

1.11.2 Submittal Procedure

The Contractor shall comply with the following submittal procedures:

a. Only the Contractor shall make submissions to the Engineer. All data and correspondence prepared by subcontractors and suppliers shall be submitted through the Contractor.

b. All submittals shall be in English.

c. Make all corrections and changes to shop drawings and working drawings as required by the Engineer and resubmit until approved.

d. Review submittals returned by the Engineer.
   1. Determine if changes requested by the Engineer will result in extra cost or will affect progress.
   2. Notify Engineer in writing within 5 days of receiving submittal if the Contractor believes additional costs are incurred, or if progress will be impeded.
   3. Failure of the Contractor to notify the Engineer of the extra costs or of progress implications with the work waives the Contractor Claim for compensation.

e. The Contractor shall review and approve all shop drawings, working drawings, product data, samples and manuals required by the Contract documents before submission.
   1. Review and approval shall be for compliance with the Contract requirements.
   2. Approval indicates the Contractor has verified all materials, field measurements, field construction criteria and similar items.
   3. Approval also indicated the Contractor has co-ordinated information contained in submittal with work requirements of other trades and with the Contract documents.

f. The Contractor reviews and submission to the Engineer shall be such as to not delay the works.

g. The Contractor shall prepare submittals in such a manner that no more than one resubmittal is necessary to obtain the Engineer's approval. If more than one resubmittal is required, the Owner reserves the right to deduct the cost of the Engineer's time to review all additional resubmittals (after the first resubmittal) from moneys due to the Contractor.

h. The Contractor shall not deliver materials or equipment to the site and shall not incorporate it into the work until it has been approved or authorized in writing by the Engineer.

i. Submit shop drawings, working drawings, product data and samples in accordance with the approved submittal schedule. Allow sufficient time for the Engineer's review, approval, and transmittal back to the Contractor.

j. The Contractor shall detail items not completely described on the Contract plans in accordance with standard Engineering practice.

1. Adjust dimensions shown on the Contract plans to reflect actual dimensions of equipment provided.
2. Coordinate dimensions shown on the Contract plans as well as actual equipment dimensions with measurements of existing, adjacent, incorporated, and completed work to ensure all components fit into the space available.
3. Verify all dimensions before beginning any work depending on such data.

k. Identify each and every deviation from the Contract documents to the Engineer either on the shop drawing or in the letter of transmittal.

1. Explain reason for deviation
2. Compare requested deviation with Contract requirement
3. Explain why deviation is equal to or better than Contract requirement
4. The Contractor shall not be relieved of responsibility for executing work in complete conformance with Contract documents for submittals not identifying deviations, even though such submittals have been approved

l. Miscellaneous structural items such as catwalks, pipe supports, equipment supports, grating supports, etc. shall be detailed by the Contractor once associate equipment has been approved. Such details shall be certified by a registered and qualified field Engineer. Submittal shall include all applicable calculations.

m. Submit shop drawings, working drawings, product data and samples for related equipment items and integrated system components at the same time. Partial submissions may be returned to the Contractor without review.

n. The Contractor shall direct Engineer's attention either in writing or on the resubmitted documents to each and every revision other than those requested by the Engineer on previous submittals.

o. Do not perform any work until shop drawings have been submitted to and approved by the Engineer. Shop drawings are not to be prepared after work has started or is complete.

p. All submittals from the Contractor shall include a label or stamp which indicates that the submittal has been reviewed and approved by the Contractor for conformance to the Contract requirements. Labels or stamp shall generally conform to the following:

1. SUBMITTAL NO. ______________
2. PROJECT NO. _________________
3. CONTRACTOR: ____________________________________
4. REVIEWED AND APPROVED for conformance with the Contract documents BY: _______________________________ DATE: ______________ Signature of the Contractor
5. References:
   i. CONTRACT PLANS NOS.____
   ii. SPECIFICATION NOS. __________________________________
6. A 10 character submittal identification and numbering system shall be used.
   i. First character shall be either "D", "S", or "M" representing shop or working drawing (D), sample (S), and operation/maintenance manual (M).
   ii. Next five digits shall be the applicable specification section number.
   iii. Next three digits shall be the numbers 001 through 999 to sequentially number each separate package submitted under each specific specification section number.

iv. Last character shall be the letter "A" through "Z" indicating whether the submittal is the first submission (A) or a resubmission (B through Z).

v. An example of a submittal number is D-4.1.3-008-B which indicates:

a) D - Shop Drawing

b) 4.1.3 - Specification for concrete

c) 008 - Eighth separate submittal under this section.

d) B - Second submission (first resubmittal) of that particular information.

q. Engineer's review:

1. Engineer's review is for general conformance with the Contract requirements only; all work is still subject to the detailed requirements of the Contract documents.
2. Engineer's review is to help the Contractor by discovering errors and omissions.
3. Engineer's review does not relieve the Contractor of the obligation and responsibility to co-ordinate and plan the details of the works and fulfil the intent and purpose of the Contract.
4. Engineer's review shall not relieve the Contractor of the responsibility for accuracy, proper fit, or proper functioning and performance of the work.

r. Engineer reserves the right to require written confirmation from the Contractor that the comments placed on submittals stamped "Approved as Noted" will actually be implemented.

s. Engineer will make every reasonable effort to process and return each submittal within 14 calendar days after its receipt in the Engineer's office. If additional time is needed, the Engineer will advise the Contractor in writing before the 14 day period has elapsed.

1. Large or multiple submittals may require additional time.
2. The Contractor may prioritize submittals and Engineer will review and return them in the order of the highest priority.
3. If requested by the Contractor, individual drawings from large submittals with numerous drawings may be returned as they are reviewed rather than waiting for the entire review to be completed.
4. Need for resubmissions or delays in obtaining the Engineer's review or approval shall not entitle the Contractor to a time extension for Contract completion.

t. Categories used by the Engineer to evaluate submittals are defined below:

1. Approved:

i. No discrepancies have been identified

ii. Approved As Noted

iii. Submittal is acceptable subject to incorporation of the comments listed

2. Not approved (disapproved)

i. Submittal is unacceptable for the reasons cited

ii. Item Incorrect:

a) Submittal is being returned without review

b) Insufficient information has been provided or the submittal does not comply with the Contract requirements

3. Comments noted:

i. Submittal is not required by the Contract documents

ii. Engineer will include it in the project files for information only

4. Revise and resubmit:
   i. Submittal must be revised, corrected and resubmitted to the Engineer.
5. Approval not required: Submittal to the Engineer for the item concerned is not a requirement of the Contract.
6. Submit specified Item:
   i. Engineer's initial review indicates the item or detail submitted is not the specified item; therefore further review is aborted.

u. Incomplete submittals including those not correctly transmitted, incorrectly titled and identified, or not bearing the Contractor's review and approval stamp may be returned to the Contractor without review.

v. Minimum copies for Engineer's review:
1. One (1) reproducible copies plus three (3) photocopies or blue line prints for each shop drawing in A3, A1 or A0 size format as appropriate.
2. Three (3) copies of all product data and manuals.
3. Engineer will return one (1) reproducible and one photocopy or blue line print of each shop drawing and one (1) copies of product data or manuals to the Contractor.

w. Engineer may require additional copies of all submittals by notifying the Contractor in writing and such additional copies will be at no extra cost.

1.11.3 Product Data Submittals

The Contractor shall comply with the following requirements when submitting product data:

1. Shall be explicit with regard to details of the actual products being furnished
2. Provide sufficient information ~~to~~ for the Engineer's approval to determine that the products submitted conform to the specification requirements including, but not limited to, recent third party test reports.
3. Submittals with more than one style, size, capacity, etc. of a product on a page shall clearly indicate which product type is being submitted for approval. Failure to do this shall be cause for disapproval
4. Present information on A4 size paper whenever possible
5. Include the name of the product manufacturer on all catalogue data

1.11.4 Shop Drawing Submittals

The Contractor shall comply with the following requirements when submitting shop drawings:

a. Provide detailed drawings and written descriptions of both the assembly and all components

b. Drawings shall indicate proposed installation of work as well as materials and equipment being furnished

c. Information shown on shop drawings shall be complete and sufficient for Engineer to review for compliance with Contract requirements. Information shall include but not necessarily be limited to the following:
1. Layout dimensions and component sizes including bases, foundations, anchors, and similar items
2. Design criteria
3. Materials of construction
4. Component and assembly weights

5. Utility requirements (power, water, etc.)
6. Manufacturer’s rating or performance curves
7. Wiring diagrams and control schematics
8. Recommended spare parts
9. Special tools
10. Deviations from Contract requirements
11. Additional requirements contained in individual specification sections

d. Copies of the Contract plans are not acceptable for submission as component arrangement (layout) drawings. Use shop drawing title block and standard sheet format provided by the Engineer.

e. Manufacturer’s model numbers or catalogue numbers alone shall not be acceptable for describing equipment or components.

1.11.5 Sample Submittals

The Contractor shall comply with the following requirements when submitting samples.

a. Furnish samples as required by the individual specification section.

b. Unless otherwise specified, samples shall be labelled and properly identified with the following:

1. Date
2. Part(s) of the works for which offered
3. Specification section and applicable paragraph numbers
4. Supplier / manufacturer
5. Product identification (trade name)
6. Samples shall be accompanied by an approved transmittal form, specifications and other pertinent data required for Engineer to determine that the material conforms to the specification

c. Three sets of samples shall be submitted unless otherwise specified.

d. One set of approved samples and all disapproved samples will be returned to the Contractor.

e. If requested in writing by the Contractor, samples of value will be returned to the Contractor after completion of the work.

f. Approved samples returned to the Contractor may only be incorporated into the work upon written approval of the Engineer.

1.11.6 Operations and Maintenance Manual Submittals

The Contractor shall submit 6 copies of operation and maintenance (O&M) manuals that contain all items required in Section 1.26.

1.11.7 Certificates and Affidavits

The Contractor shall provide the original and seven copies of manufacturers’ certificates in accordance with the following and the requirements specified Section 1.11.1:

1. Certificate indicates test results, component manufacture, or installation complies with specified standards.
2. Affidavit is a sworn statement by an officer of the company manufacturing the product indicating that the information on the certificate is true and accurate. An affidavit shall accompany all certificates.

A statement from the Contractor, subcontractor, equipment supplier, or agent indicating the product meets the requirements of the Contract documents shall not be considered as a certificate. Such submittals will not be approved. Corresponding equipment, products, or components will not be accepted.

1.11.8 Miscellaneous Submissions

1.11.8.1 Manufacturers' Guarantees and Warranti

a. Submit originals, including organization registration stamps (unless otherwise specified)

b. Submit before final acceptance

1.11.8.2 Work Plans

a. Submit 3 copies, unless otherwise specified, at least 30 days before beginning work

1.11.8.3 Staging and Detour Plans

See Section 1.15.13 for details.

1.11.8.4 Submittal Schedule

a. Show the proposed date the Contractor will deliver each required submittal to the Engineer for review in format provided by the Engineer

b. Submit within 10 calendar days of receiving letter of intent

1.11.8.5 Health and safety plan (HSP)

a. Submit 3 copies of the Contractor's project specific HSP unless otherwise specified

b. Refer to Section 1.12.7 for specific requirements

c. No work shall commence on the site until the HSP is approved

1.11.8.6 Accident Reports

a. Submit 3 copies unless otherwise specified

b. Refer to Section 1.12.7 for specific requirements

1.11.8.7 Reports

a. Progress reports: Prepare and submit the progress reports described hereinafter in a form provided by the Engineer. Refer to Section 1.10.10 for specific requirements.

b. Work activities and procurement reports: Reports should be referenced where relevant to the approved Contractor's construction schedule. Refer to Section 1.6.1 and Section 1.18.3 for specific requirements. Submit three copies unless otherwise specified.

c. The Contractor's daily reports: Refer to Section 1.9.10 for specific requirements.

   1. Submit on a daily basis no later than 9.00 am the following day
   2. Describe labour force and its allocation
   3. Describe material and equipment utilized
   4. Describe work progress during the day
   5. Describe temperature and weather conditions
   6. Describe any occurrence which may affect the progress of the works
   7. The Contractor's authorized representative must sign

d. Procurement status reports:
   1. Submit on a weekly basis
   2. Include a list of materials and items procured
   3. Include list of items delivered to the site
   4. Provide references to all correspondence and transmittals between the Contractor and the Engineer regarding approval of such materials and items
e. Inspection and test reports: Submit 3 copies unless otherwise specified
f. Survey data: Refer to Section 1.7.4 for specific requirements
g. Closeout submittals: Refer to Section 1.24 for specific requirements
h. Record (as-built) documents: Detailed hereafter
i. Final statement: Submit 3 copies in accordance with the applicable clauses of the Department of Transport Conditions of Contract and Schedule of Further Requirements
j. Organization chart:
   1. Submit for Engineer's approval within 10 days of the commencement date
   2. Show the management, administrative, quality control, safety and construction supervision organization
   3. Include all personnel from Engineer through foreman level reporting to the onsite Engineer
      i. Describe personnel duties
      ii. Amplify details provided in the "schedule of data" submitted with the tender
      iii. Provide qualifications and experience of all personnel shown on the organization chart
   4. Update the organization chart whenever key personnel are reassigned
   5. Engineer may interview any of the Contractor's proposed staff before approval
   6. Engineer may direct the Contractor to remove personnel from the site who, in the Engineer's sole opinion:
      i. Exhibit inappropriate conduct
      ii. Who are incompetent, negligent in the performance of their duties
      iii. Who are otherwise considered undesirable
k. Letter of authority:
   1. Submit within 10 days of the commencement date and before beginning any construction activities
   2. Identify the Contractor's representative and detail the extent of his authority and responsibility
   3. All site work to be under direct supervision of the Contractor's representative
   4. The Contractor's representative shall be present at the job site whenever work is underway
   5. The Contractor's representative shall have full authority to represent the Contractor
   6. Communication given to or received from the Contractor's representative shall be as binding as that given to or received from the Contractor
l. Site layout for the Contractor's facilities:
   1. Submit within 10 days of the commencement date for approval by the Engineer
   2. Site plan should include but not necessarily be limited to the following:

i. Temporary facilities including accommodation
ii. Storage areas including permanent dumping of excavated material and all debris
iii. Fences, gates and security lighting
iv. Access for subcontractors, vendors, plant staff, visitors, etc.

m. Correspondence:

1. Provide one original and three photocopies of transmittals and letters including attachments and enclosures
2. Submit on A4 size whenever possible
3. Clearly indicate the following on each document
4. Project number
5. Title of project
6. The Contractor's name
7. Date
8. Correspondence reference number
9. Signed by the Contractor or his representative

1.11.9 Contract Plans

Contract plans forming part of the Contract are listed in the tender documents. The Contractor shall comply with the following:

1.11.9.1 Compliance with the Contract Plans

a. All work, during its progress, and upon completion shall conform to the lines, elevations and grades as shown on the Contract plans.

b. The Contractor shall complete the proposed work in every detail as specified.

c. The Contractor shall bring to the notice of the Engineer any detail or details that have been omitted from the Contract plans and specifications which are essential to the intended completeness of the works.

1.11.9.2 Additional Plans

The Engineer may issue additional plans to the Contractor as work progresses.

1.11.9.3 Record Drawings and Specifications

a. The Contractor shall maintain one record copy of all Contract plans, specifications, addenda, variations, approved submittals, correspondence, and transmittals at the site in good order and readily available to the Owner and the Engineer.

b. In addition to the requirements of the specifications, record drawings shall be clearly and correctly marked and the record specifications annotated by the Contractor to show:

1. All changes made during the construction process, the date the changes are made and those parts of the works affected by the changes
2. Works as executed complete with:
   i. Existing and finished levels
   ii. Universal transverse mercator (UTM) coordinates
   iii. Profiles of all pipelines

iv. Dimensions

v. Reinforcing details

vi. Details of supports left in place

vii. Locations of all services encountered

viii. Any other information requested by the Engineer

ix. For mechanical equipment the details shall include the whole plant as erected

3. Contract plans shall be supplemented as necessary by schedules and data sheets indicating:

   i. Quantity

   ii. Quality

   iii. Types of materials installed

4. Draft record drawings shall be submitted to the Engineer for his approval, and then finalized in accordance with any amendments required by him

5. The Engineer will furnish the Contractor 1 set of A3 hard copy and 1 set of softcopy on CD of original Contract plans. Soft copy shall be provided in PDF and Microstation-V8 format. Microstation-V8 file shall be converted to AutoCAD (.DWG) format and included.

   i. The Contractor shall correct where required to portray the works as actually constructed. The Contractor shall prepare and supply the Engineer the revised A1 hardcopy and CDs marked "As-Built" Record Drawings for his approval.

   ii. On completion of the works the record drawings shall be handed over to the Engineer together with the CDs. Submitted softcopies of the as-built drawings shall be in AutoCAD (.DWG) format. If required by the Owner or Engineer to be submitted in Microstation-V8 format, the Contractor shall be responsible to convert the as-built drawings accordingly. The Contractor shall be responsible for editing and updating of the AutoCAD files required to provide as-built drawings in AutoCAD (.DWG) format that fully reflect the Contract documents with the as-built information.

   iii. Record drawing submission shall include:

      a) Ten bound sets of "as-built" record drawings (5 in A3 and 5 in A1)

      b) Three sets of CDs

      c) Each drawing shall have the Contract details and drawing number detailed to the approval of the Engineer.

c. No final payment shall be made except for work that has been completed in accordance with the specification and has been duly presented on the "as-built" record drawings.

d. The Contractor shall not be entitled to any extra payment or extension of time for the preparation of the record drawings.

1.11.10 Mistakes in Information

The Contractor shall be responsible for and shall pay the extra cost, if any, occasioned by any discrepancies, errors, or omissions in drawings and other particulars supplied by him, whether they have been approved by the Engineer or not.

1.12 Regulatory Requirements

1.12.1 Description

Comply with all codes, standards, specifications of regulatory agencies having jurisdiction over this project including, but not limited to, those specified herein.

1.12.2 Codes

All reference to codes, regulations, local and administrative orders of the specifications and standards referred to in the Contract documents shall mean, and are intended to be, the latest edition, amendment or revision of such reference in effect as of the date of submission of these tender documents by the bidder.

There may be items for which there are no relative codes, specifications or standards:

1. Materials and workmanship of such items shall be of suitable quality as determined by the Engineer.
2. Details that qualify such items as being of the acceptable quality shall be submitted to the Engineer for approval in accordance with Section 1.11.

1.12.3 Government Bodies

The Contractor shall carry out all works in strict accordance with current codes, regulations, local and administrative orders, specifications and standards of all government bodies.

1.12.4 Permits, Licenses and No Objection Certificates

The Owner shall hold the Contractor responsible for compliance with the obligations imposed by the no objection certificate (NOC) to the extent that the Contractor's fulfilment of his obligations under the Contract may result in conditions requiring actions to comply with the NOC.

NOCs shall be obtained separately in respect of each section

Failure to complete the work including reinstatement of surfaces within the time specified in the NOC may cause the suspension of the issue of further NOC's for that particular section.

Unless otherwise explicitly provided for in these specifications, all permits, licenses and NOCs required for the proper execution of the works shall be obtained by the Contractor:

1. Before commencement of the execution of works on site
2. On satisfactory completion of each section

1.12.5 Notice of Intent

The Contractor shall comply with the following requirements.

a. The Contractor will encounter existing services during the course of the construction of the works. The Contractor must obtain his own information regarding:
    1. Nature of the ground and subsurface at the site
    2. Position of all underground pipelines and services affected by permanent and temporary works
b. Positions of services shown on the Contract plans have been based on information extracted from the records of the various service authorities and must be regarded as approximate only:
    1. The Engineer does not guarantee either the accuracy of the information or the location of such apparatus as shown on the Contract plans
    2. No warranty must be implied as to the position, depth, size or gradient thereof

c. Before opening up the ground for any purpose the Contractor must:
   1. Notify all concerned parties by issue of a formal “notice of intent”
   2. Obtain information by formal notice regarding the location of all underground services
   3. Complete responsibility for obtaining this information rests with the Contractor or party requiring to open up the ground
d. “Notices of Intent” are required to be circulated to all concerned parties. Contract plans and notices shall be sent in duplicate, one of which shall be retained by the addressee and the other returned to the sender duly marked to show all services within the proposed works.
e. "Notice of Intent" will be given 14 (fourteen) days in advance of the proposed works:
   1. In the event that the work is not started within 8 (eight) weeks of the date of the “Notice of Intent”, it will be deemed to have elapsed
   2. A further “Notice of Intent” will then be submitted
f. All locating work shall be carried out in advance of excavation work
   1. The Contractor shall obtain all information and assistance available from the service Authorities for locating the mains and services
   2. Engineer's approval shall be obtained for any trial excavations that may be necessary to confirm or establish the locations
   3. Absence of such information shall not relieve the Contractor of his liability for:
      i. Cost of any repair work necessitated by damage caused by him to such mains and services in the course of his work
      ii. Cost of all losses arising from their disruption
      iii. All costs for executing any bore holes and trial holes shall be deemed to be included in the Contractor's rates for the relevant item or items in the bills of quantities
g. No public or private facility shall be extinguished or interrupted without the written permission of the Engineer. Such permission will not be given until:
   1. Suitable permanent or temporary alternatives approved by the Engineer have been provided by the Contractor, or
   2. In the case of accommodation works, by the Owner of the facility or his agents.
h. The Contractor shall make arrangements with the service and public authorities concerned for the phasing into his program of works of all work that needs to be done by:
   1. Service and public authorities concerned or their Contractors
   2. The Contractor himself concurrently with the works
i. The Contractor shall take any and all measures reasonably required by any public or service authority for the support and full protection of all mains, pipes, cables and other apparatus during the progress of the works
   1. Construct and provide to the satisfaction of the authority concerned, all works necessary for the prevention of damage or interruption of services at no additional cost to the Owner
   2. If in the execution of the works, by reason of any subsidence caused by, or any act of neglect or default of the Contractor, any damage to any apparatus or any interruption of, or delay to the provision of any service is caused, the Contractor shall:
      i. Report it to the Engineer immediately
      ii. Bear and pay the cost reasonably incurred by the authority concerned in making good such damage

   iii. Make full compensation to the authority for any loss sustained by reason of such interruption or delay

j. The Contractor shall, at all times during the progress of the works, afford facilities to properly accredited agents of any public service authority for access to all or to any of their apparatus situated in or under the site, as may be necessary for:
   1. Inspection, reporting, maintaining, removing, renewing or altering such apparatus in connection with the construction of the works
   2. Any other purposes whatsoever

k. Absence of information shall not relieve the Contractor of his liability for the cost of:
   1. Any repair work necessitated by damage caused by him to such mains and services in the course of his work
   2. All losses arising from their disruption

l. Any temporary or permanent diversion of mains and services will only be permitted after agreement with the appropriate service authority and the Engineer:
   1. Permanent diversions will only be considered where:
      i. Main or service occupies the line and level of the pipe work or structure to be constructed by the Contractor
      ii. Position of the main or service completely prevents construction
   2. Only permanent diversions that the Engineer considers essential for the above reasons will be measured and paid for under the items in the bills of quantities
   3. Temporary diversion and restoration of mains or services shall be at the Contractor's expense

1.12.6 Protection of Existing Property and Utilities

The Contractor shall comply with the following requirements and specifications to protect existing property and utilities.

a. The Contractor shall conduct his operations in such a manner as to avoid injury or damage to:
   1. Adjacent property
   2. Improvements
   3. Facilities

b. The Contractor shall protect from injury or damage to adjacent property; improvements or facilities including but not limited to the following:
   1. Buildings
   2. Trees
   3. Landscaping and planting areas
   4. Ground cover
   5. Shrubbery
   6. Pole lines
   7. Fences
   8. Guard rails
   9. Guide posts
   10. Culvert and property markers
   11. Signs
   12. Structures

13. Conduits
14. Pipelines
15. Other improvements within or adjacent to the Contractor’s operations

c. The Contractor shall provide and install suitable safeguards to protect all objects under Clause b above from injury or damage. If injured or damaged by reason of the Contractor's operations, shall be replaced or restored:

   1. To a condition as good as when entered upon the work, or
   2. As required by the relevant authorities

d. The Contractor shall not disturb any property corners or survey markers without permission from the Engineer.

e. The Contractor shall be responsible for all damage to streets, utilities, roads, highways, ditches, embankments, bridges, culverts or other public or private property, which may be caused by transporting plant, equipment, materials, or men to or from the site of work:

   1. The Contractor shall make satisfactory and acceptable arrangements with the property owner and the Owner over the damaged property concerning its repair or replacement
   2. The Contractor shall bear the expense of replacing, restoring or resetting any of the aforementioned which may be damaged or disturbed by his operations including fines and charges levied by the respective service authority

f. All temporary and permanent safeguards will be at the Contractor’s expense.

g. The Contractor shall provide irrigation facilities and/or water to maintain existing vegetation and landscaping for areas where his work temporarily disrupts the existing irrigation system.

h. Any additional costs, due to difficulty of working or to any other reasons arising from the presence of the aforementioned shall be borne by the Contractor.

i. The Contractor is advised to note the current scale of fines and charges for repairs levied by the various services authorities in case of damage to services.

1.12.7 Health and Safety

The Contractor shall provide and maintain a safe, hazard-free and healthy workplace for his employees, for his Subcontractor employees, for the Owner, the Engineer, his representatives, visitors and the general public in accordance with the Owner’s Environmental, Health and Safety Manual.

The Contractor shall provide health and safety measures during all phases of the Contract and shall comply with all Laws, Ministerial Orders, Contractual regulations and department guidelines related to site and construction safety.

The Contractor shall at his expense:

a. Provide a safety officer who shall be responsible for preparing the Contractor’s safety plan, supervise other safety personnel, conducting safety awareness and training sessions, conduct required safety meetings, initiate and monitor safe working conditions on site, provide accident reporting and follow-up investigations and ensure that the Contractor's employees follow the safety procedures

b. Arrange for medical attention to be available when necessary

c. Provide dressing stations complete with all adequate first-aid equipment on the site

d. Display in suitable places the names of his employees who are available from time to time to render first aid services

e. Provide for the transport of serious cases to the nearest hospital

f. Arrange for personal protection equipment in accordance with the “Code of Construction Safety Practice” as published by the Dubai Municipality

g. Provide personal protection equipment as required for the Engineer’s site staff

h. Develop a health and safety plan and submit it to the Engineer for approval. This plan shall meet the following requirements:

1. Plan shall include detailed descriptions of the Contractor’s safety personnel, procedures, precautions, safety check lists, accident records and other safety documents that will be used throughout the project.
2. Plan shall involve all project employees and require their active participation in safety training that will promote recognition of unsafe acts, unsafe conditions and significant near miss incidents that require reporting and immediate corrective action to be taken.
3. Primary safety management tools:
   - i. 1-2 week look-ahead work planning
   - ii. Activity hazard analysis and job task analysis
   - iii. Site safety inspector reporting
   - iv. Safety induction, orientations, and training
   - v. Certifying competency of workers
   - vi. Risk review inspections
   - vii. Monthly safety statistics reporting
   - viii. Regular meetings on site
4. Plan shall include a planning schedule. During the project pre-mobilization planning and scheduling phase, the Contractor shall identify high risk hazardous activities for each work element, and include all safety requirements into the planning schedule, before works commence.
5. Plan shall include a risk assessment. The Contractor shall make provisions to ensure safe systems of work are in place. The Contractor shall carry out job task analysis (JTA) or activity hazard analysis (AHA) for high risk hazardous activities by:
   - i. Identifying high risk hazardous activities for each work element
   - ii. Making provisions for Engineering control measures and resources (time, manpower, equipment) to eliminate, isolate or protect site personnel from the identified hazard(s), before the work commences.
6. Plan shall outline orientation, inductions, and training.
   - i. Emphasis of the Contractor’s health and safety plan shall be the prevention of occupational injury and ill health by providing certified training. All modes of training, such as pictures, animations, oral, and written aides shall be considered to ensure the targeted employee understands the information being shared.
   - ii. The Contractor shall ensure that all their site personnel receive orientation and training in accordance with Ministerial Order 32 (1982), Article (3).
   - iii. The Contractor shall ensure during the preconstruction period, that all their project-based employees, including Sub-Contractors receive induction in the site specific hazards and safe work practices particular to the employees work activities and the approved project specific health and safety plan, this exercise shall be documented.
   - iv. All project health and safety employees must be made aware of their own responsibility to work in a safe manner.

7. The Contractor shall prepare, develop, and implement a project health and safety plan that is site specific.
8. Plan shall include, in detail, the following items:
    i. Responsible safety officer name and mobile phone number
    ii. Responsibility/accountability of key line personnel
    iii. Statement of the Contractor's safety and health policy and compliance requirement statement
    iv. Safety organization diagram
    v. Identification of competent/qualified persons
    vi. Scope of work evaluation
    vii. Induction and hazard recognition training program
    viii. Hazard/risk/exposure evaluation
    ix. Activity hazard analysis and control measures
    x. The Contractor's periodic safety inspections/audits
    xi. The Contractor's weekly safety planning look-ahead plan
    xii. List of specific safety equipment to be provided and a schedule for its delivery
    xiii. Hazard correction system
    xiv. Training and instruction policy
    xv. Project site orientation plan
    xvi. Accident/exposure investigation
    xvii. Emergency action plan
    xviii. Written hazard communication program
    xix. Site specific work zone traffic control plans for movement of the Contractor's vehicles
    xx. A scaffold management system
    xxi. Written trenching/shoring plan
    xxii. Written fall protection plan
    xxiii. Permit to work forms
    xxiv. List of qualifications of all safety staff.
    xxv. A list of all safety procedures to be utilized and a schedule for their submission
    xxvi. Isolated/protected shade area plan
    xxvii. Isolated/protected drinking water plan
    xxviii. Hearing conservation plan (if applicable)\
    xxix. Bus pick up/drop off points and station plan(s) for convenience of workers
    xxx. Safety statistics recording
    xxxi. Site safety awareness and incentives plans
    xxxii. Safety monitoring and performance plans
    xxxiii. Record keeping
    xxxiv. Incentives (recognition and rewards) program
    xxxv. Disciplinary action plan

xxxvi. Other programs as specified by regulatory authorities or Contract requirements

i. The Contractor’s health and safety plan shall be submitted for the Engineer’s review and approval within the earlier of 30 days of the commencement date, or at least 10 working days before starting any field work.

j. No work shall commence before the approval of the Contractor’s health and safety plan by the Engineer.

k. The Contractor shall be fully responsible for ensuring that the approved Contractor’s project safety plan is implemented and adhered to throughout the duration and extent of the project.

l. The Contractor’s project safety meetings will be held at least once a month at the jobsite.

1. Meetings shall be convened and conducted by the project HS manager or project HS Engineer.
2. All supervisors and foremen are expected to be in attendance.
3. Each Subcontractor will have a responsible safety representative present to follow through on information and resolutions discussed and adopted at these meetings.
4. Engineer's safety representative(s) may attend these meetings.

m. Agenda for the Contractor’s project safety meetings will generally include, but not be limited to the following:

1. Development of timely topics for discussion and dissemination of safety bulletins, signs and notices
2. A review of the safety inspections, audits, accidents and significant near misses
3. Identification of potential safety hazards in the coming month, discussion and implementation of steps to be taken to avoid the same
4. Appointment of safety representatives for subcontractors
5. Two-week look ahead risk mitigation planning
6. High risk activities
7. Activity hazard analysis
8. Hazard recognition training and tool box talks
9. Safety resources
10. Safety performance
11. Recognition and rewards
12. Lessons learned

n. In addition to the Contractor’s monthly safety meeting, the site foremen, supervisor or superintendant shall conduct a “tool box” safety meeting for each work crew, on a weekly basis, with a quick reminder meeting each morning before starting the work as safety awareness for the work to be conducted that week/day. Discussion shall include a description of specific work and site hazards and preventative measures. Meeting shall clarify work description for each individual on the crew as to their understanding on how to conduct their duties in a safe manner.

o. If an accident does occur, the Contractor shall investigate to determine the cause and take the required corrective action to prevent a recurrence.

1. The Contractor shall ensure all accidents are reported directly to both supervisors and the Engineer:
   i. The Contractor shall inform the Engineer verbally, immediately.

ii. If serious injury is apparent or suspected, the Contractor shall use the pre established emergency hospital services.

iii. Telephone number shall be prominently displayed at all site telephone locations.

iv. For small cuts, scratches, and other minor injuries, approved mobile first aid kits shall be available from the Contractor and for each Subcontractor.

2. All lost time injuries (ITIs), property damage accidents and material losses in which the property damage exceeds AED 1000/ shall be reported in writing to the Engineer within 48 hours of the accident.
3. The Contractor shall inform the Owner of accidents occurring during the daily working hours or as a result of the work using required reporting procedures and provide a copy to the Engineer in such cases.
4. In the event of an employee being sent to a doctor for medical check up and/or treatment, a release shall be obtained from the doctor stating the number of days off work required, as applicable, and confirmation whether:
5. Employee is not medically fit for duty
6. Employee is fit for light duty
7. Employee is fit for duty
8. Copy of doctor's release will accompany the accident report

p. First aid, medical facilities and medical items:

1. Both office and mobile first aid facilities in all Contractors site vehicles shall be provided at the project site, and where work activity is in progress.
2. A location map of the project indicating routing to emergency facilities shall be posted in the first aid station and on the project safety notice board, along with the list of designated emergency facilities; i.e., hospitals, doctors, ambulances and fire department, and their respective contact numbers.
3. Medical supply items for fist aid purposes shall be in accordance with the UAE regulations and Ministerial Orders.

q. Personal protective equipment (PPE), and monitoring equipment:

1. Minimum requirements for PPE shall be the wearing of hard hats, safety vest and safety footwear by all personnel, including subcontractors.
2. Supplemental requirements for PPE shall be developed and provided to cover specific items such as eye protection glasses, goggles, protective clothing, safety harness, ear protection, as per the hazard(s) associated with the work activity and environment.
3. All PPE shall conform to ANSI/BS/EN or equivalent standards and shall be approved by the Engineer.
4. Safety belts shall not be used as fall protection on site. Only positive personal fall protection systems reviewed and approved by the Engineer shall be used.
5. The Contractor shall be fully responsible for the design, construction and application of all safety equipment and systems used by themselves and their subcontractor(s).
6. The Contractor shall provide all their employees with the necessary PPE to carry out their assigned site activities in a safe manner as per the requirements of Ministerial Order 32 (1982), Article (1) or as directed by the Engineer.
7. The Contractor shall provide monitoring equipment to measure both ambient and personal noise levels.

8. The Contractor shall provide gas monitoring equipment to measure oxygen, flammable, toxic and other harmful gases that may exist inside a confined space.
9. All monitoring equipment shall meet ANSI/BS/EN or equivalent standards, be routinely calibrated and certified by an independent third party testing company having minimum ten (10) years experience, and approved by the Engineer.

r. Fire protection:

1. Suitable type and number of portable fire extinguishers shall be provided at the job site, in the offices, mess, welfare compound and site work areas, and installed in all vehicles of supervisor personnel for the complete duration of the project period.
2. In accordance with Civil Defence Authority, Abu Dhabi requirements, all heavy equipment, mobile and stationery plant, welding machines, compressors etc., shall have suitable fire extinguisher at close proximity or inside the cabin.

s. Fire prevention:

1. No burning of rubbish or debris shall be permitted.
2. All fuel storage tanks shall be properly grounded and vented, provided with suitable types of fire extinguishers, placed on posts, 3-4.5 meters from tanks.
   i. "Danger" or "No Smoking" warning ad prohibitive signs shall be prominently placed at these tanks in Arabic, English, Hindi and Urdu languages, as required.
   ii. Fuel storage tanks above ground shall be bonded to prevent the spread of liquids, in the event of fuel leakages in tanks the bund wall shall hold a capacity of 1.5 times the volume of the tank, and the floor area shall be protected to minimize the ingress of liquids into the ground.
   iii. Bund wall and floor design shall be submitted to the Engineer for approval.
3. Welding operations, if any, shall only be permitted in designated controlled areas, and shall be carried out in accordance with standards and recommended practices of the American Welding Society.
   i. Adequate fire extinguishing equipment shall be provided in the immediate vicinity of welding operations whenever combustible material is exposed.
   ii. Workmen shall be shielded from welding rays, sparks, slag, etc., by face shields, screens and filtered goggles.
   iii. A permit-to-work management control system shall be enacted during all welding hot work operations.
4. All compressed gas cylinders and acetylene cylinders shall comply with the requirements of the AGC Manual of Accident Prevention in Construction as to requirements for construction, use and storage
   i. All oxygen and acetylene cylinders, full or empty shall have safety valves, shall be kept separately in a shaded storage area, stored upright, tied off, capped, chained in place, and periodically inspected.
   ii. Welding works area shall be designated as a "No Smoking" zone and sign posted.
   iii. Flash back arrestors shall be used at all times.

t. Scaffolds, access and positive fall protection:

1. Scaffolds shall be provided for any work that cannot be accomplished safely from the ground.
2. Safe and defined access shall be provided to all work areas.

3. Ladders shall conform to applicable standards and inspected on a regular basis for defective or worn parts.
4. Design and management operating details for erection and use of scaffolds shall be evaluated by the Contractor and submitted to the Engineer for approval.
5. Engineer's approval however shall not remove any responsibility for scaffold design, construction and maintenance from the Contractor.
6. A scaffold management system shall be used to ensure that the scaffolds to be used are:
   i. Designed and approved by a certified competent person.
   ii. A method statement shall be provided for the Engineer’s review and approval for both the erection and disassembly of scaffolds.
   iii. Scaffolds shall be erected and disassembled by a certified scaffolder.
   iv. Scaffolds shall be inspected by a competent person, viz., a scaffolder or safety inspector before use.
   v. A scaffold tag system shall be used to record and inform end users that the structure is safe or unsafe to use during its service life.
7. Positive fall protection equipment shall be used whenever a worker of any trade works on an elevated platform 1.2 m or greater from the ground and other permanent or substantial footing(s).
8. All fall protective activities shall be in accordance with the approved Contractor’s fall protection safety plan, which shall include details of, but not be limited to the following:
   i. Horizontal and vertical positive fall protection devices
   ii. Operating procedures
   iii. Training
   iv. Certification of competency
   v. Defined key staff responsibilities

u. Work zones - working near live vehicle traffic:
1. Contactor shall ensure crash worthy barrier protection system(s) are provided to physically protect workers from errant vehicles entering a work zone, whilst working near or adjacent to live vehicle traffic.
2. Work zone and protection barrier system shall be in accordance with the Department’s requirements for establishment of traffic control work zone systems, and Traffic Police requirements.
3. The Contractor shall submit the work zone plans, crash worthy protection barrier system, and details to the Engineer for review and approval.
4. Use of plastic ballast “New Jersey” type barriers, and/or traffic cones shall not be permitted as adequate protection for workers from errant vehicles impacting a work zone.

v. Shaded areas and drinking water:
1. Shaded areas along with chilled potable drinking water supply shall be made readily available to all workers at site, wherever work activities are in operation, on an as-needed and continuous base.
2. These shaded areas and drinking water locations shall be isolated and physically protected from the work zone, in such a way to minimize the risk of workers becoming injured from the ongoing work activities, whilst taking their drink breaks, in particular from moving heavy equipment and machinery, e.g., PTR’s, haulage trucks, JCB’s and public vehicles.

3. No one shall be permitted to take temporary breaks or rest periods within any work activity area, e.g., adjacent to live vehicle traffic, on a scaffold, inside a trench or confined space.

w. Excavations:

1. Excavations shall comply with requirements for trenching and shoring, with special attention to the following:

   i. Sides of excavations over 1.5 m deep unless capable of free standing without collapsing, shall have sides sloped to a safe angle of repose, battered, or be shored.

   ii. The Contractor shall ensure excavations are designed and approved by a competent person(s) to ensure slopes are stable, and the geometric configuration is suitably safe throughout its service life, both in the short and/or long term conditions.

   iii. Details for excavation slope design with calculations shall be evaluated by the Contractor and submitted to the Engineer for approval, as required.

   iv. Engineer's approval however, shall not remove any responsibility for excavation design and construction from the Contractor.

   v. Excavated material must be stored at least 2 m from the sides of all excavations.

   vi. Guard rails or barricades must be provided around all excavations.

   vii. Access facilities must be provided minimum every 7.0 m within the protected areas.

   viii. All excavations shall be kept free of water.

   ix. All excavations must always be made in the dry, with the ground water table reduced, minimum 0.5 m below excavation level by dewatering technique(s), as required.

   x. Warning and prohibition signs; “Danger–Deep Excavation”, and “Do Not Enter - Deep Excavation” in English, Arabic, Hindi & Urdu languages must be provided next to excavations, as required.

   xi. Contingency back-up pump(s) shall be available for use whenever there is a possibility of groundwater seepages, mechanical failure of a existing pump(s), and/or inclement weather conditions that may otherwise adversely affect the stability of an excavation.

x. Hand tools and power tools:

1. All hand tools and portable power tools shall be in good condition and shall be used for the purpose intended.
2. All electric power tools shall be grounded, and inspected frequently for worn out parts and connections by a certified electrician, the results of this exercise shall be documented.
3. Circular saws shall be equipped with guards that automatically enclose the cutting edges.
4. Radial arm power saws shall be equipped with an automatic brake.
5. Explosive actuated tools and their use shall be discouraged, and must have prior written approval from the Engineer before delivery to the project site.

y. Temporary electrical work:

1. All temporary electrical work shall be protected by ground fault circuit Interrupters (GFCI) and shall be in accordance with the AGC Manual of Accident Prevention in Construction.
2. All connections and installation shall be in compliance with ADWEA regulations.
3. If portable generators are used to supply temporary power needs, the generators shall be grounded, inspected and documented on a regular basis for proper operation.
4. All temporary electrical work shall be inspected on a weekly basis and audited by a certified electrician and results documented.

z. Use of explosives will not be allowed without specific approval from the Engineer, department, and relevant authorities. All explosive use and handling shall be under the direct responsibility of an approved properly certified and experienced blasting Engineer, as otherwise required in Article 2.4.2.4 of Chapter 2, Earthworks, and Article 34.3.2.1 of Chapter 34, Road Tunnels, of these standard specifications.

aa. Use of radioactive equipment having radioactive source shall be discouraged, and must have prior written approval by the Engineer before delivery to the project site

bb. Machinery and mechanized equipment:

1. All machinery and mechanized equipment to be used or installed shall be inspected for compliance with safety requirements and reporting forms shall be completed and submitted, as required.
2. Supplemental requirements covering operating rules shall be established before start of work using mechanized equipment and machinery.
3. Machine guards shall be provided on all moving parts of machinery that are directly exposed to operators.

cc. Workers site safety orientation shall include at least the following:

1. Personal Protective Equipment (PPE):
   i. Minimum PPE to be worn whilst at site
   ii. Hard hats shall be worn at all times
   iii. Safety boots shall be worn at all times
   iv. Safety vests, Class II, meeting EN471:1994 shall be worn at all times
2. Suitable protective eye covering shall be worn whenever welding, hammering metal, stone, or concrete, grinding, or cutting metal units
3. Disposable hearing protection, sponge type (SNR=28), shall be available at all times.

dd. The Contractor's check list:

1. Provide safety officer, submit credentials to the Engineer for approval
2. Prepare safety program
3. Post safety requirements on safety bulletin board
4. Prepare and post Fire Prevention Program
5. Analyze job for potential hazards and hazardous procedures
6. Establish plans for location of welfare facilities, material storage, personal facilities and traffic flow
7. Arrange for sanitary facilities with authorities
8. Arrange for debris removal to the EAD approved landfill facility, as required
9. Establish procedure to obtain subcontractor safety plans
10. Establish reporting requirements
11. Arrange for doctor
12. Arrange for hospital
13. Arrange for ambulance service
14. Post phone numbers for police, fire, medical ambulance, emergency services at each of the onsite telephone locations
15. Establish adequate first aid kit and stretcher facilities

16. Post chart to signify weekly checks of first aid kits
17. Locate archaeological sites to be protected
18. Prepare and post at each on site telephone location "off hours emergency notification list"
19. Arrange for security guard services
20. Prepare a watchman's log
21. Obtain any required reporting forms and posters
22. Verify insurance on subcontractors starting work on site before final execution of subcontracts
23. Obtain safety equipment and approval appropriate to operations such as:
    i. Hard hat, safety vest, safety boots, eye and ear protection
    ii. Safety harness and lifelines with spring shackles and eyes
    iii. Goggles
    iv. Leather rigger gloves
    v. Atmospheric gas detectors
    vi. Positive ventilation equipment
    vii. Ambient and personal sound monitoring equipment
    viii. Portable hand lamps (EX rated
    ix. Positive pressure face masks with associated portable compressor and air hoses
24. Post sketch showing locations of fire alarm boxes, hydrants, first aid facilities names/photos of personnel.
25. Arrange for and post, safety posters, and warning signs.
26. Conduct weekly and daily toolbox safety talks.
27. Set up an accident control chart.
28. Conduct monthly safety meetings.
29. Ensure competency certificates are issues and validated.
30. Appoint a safety supervisor and obtain approval.
31. Set date for the first safety meeting.
32. Ensure that all licenses and approvals issued by the various authorities having jurisdiction, are valid.

ee. Barriers and enclosures:

1. All open excavations, and other hazardous areas, which in the opinion of the Engineer result from or due to the Contractor's operations, shall be enclosed by temporary fencing to ensure that the general public cannot gain access.
2. Temporary fencing shall meet the requirements of Section 7.7 of Chapter 7, Incidental Construction, of these standard specifications, or as approved by the Engineer.
3. Damaged sections of temporary fencing shall be repaired or replaced promptly to maintain at all times the standards of fencing and installation as initially approved.
4. Temporary fencing shall not be removed from any location without the prior approval of the Engineer.

5. Barriers shall have high visibility red and white markings and, where necessary, shall have steady state flashing lighting units.

ff. Working in confined spaces:

1. The Contractor shall provide formal hazard recognition training to the work force and document this and inform their work force of the following:
    i. Dangers of toxic, asphyxiatory, inflammable or explosive gaseous conditions such as inside pump stations, underground structures, manholes, storm drains, and sewers
    ii. Physical injury, caused by falling objects, or by falling themselves
    iii. Dangers of bacterial infection while working in stormwater and sewage contaminated environment. The Contractor shall impress upon his staff the importance of personal hygiene
    iv. The Contractor shall be responsible for ensuring adequate precautions are taken by his workforce to safeguard against any accidents by ensuring they are aware of the hazards, know how to work in a controlled environment using a permit-to-work system of operation, as necessary.
    v. All members of the workforce shall be vaccinated against tetanus, typhoid, para-typhoid, cholera, Hepatitis-A and Hepatitis-B and shall carry up-to-date medical records at site.
    vi. The Contractor shall provide a medical certificate of fitness for all members of the work force who are expected to work in confined spaces for example, storm drains, manhole, pump stations, irrigation chambers etc. Personnel working in confined spaces shall have no medical history of the following:
        a) Any heart defect
        b) Any history of fits or blackouts
        c) Deafness or loss of balance
        d) Claustrophobia
        e) Recurrent back ailments
        f) Shortage of breathe on light exertion
    vii. Each group of workers engaged on storm drains, manholes, pumping stations and ancillary structures shall be provided and be familiar with the operation of reputable gas testing equipment suitable to check hydrogen sulphide, carbon monoxide, combustible gases and oxygen
    viii. Personal protective equipment shall include, but not be limited to, the following:
        a) Hard hats
        b) Safety boots (with no ferrous studded soles)
        c) Safety harness (strong readily washable with no ferrous attachments for life line)
        d) Leather gloves
        e) Overalls, with antistatic fabric
    ix. In addition to the above items, each group shall have with them at each entry point to a confined space the following:
        a) A lifting harness
        b) Four 15 m lifelines with spring shackle on one end, eye at other
        c) Suitable ladder

d) Lifting frame complete with ropes and shackles for hand operation

e) Powerful hand lamp, 'EX' rated

f) Ventilation blowers together with portable generator and flexible trunking

g) Positive pressure respiratory facemasks with associated portable compressor and air hoses

h) Gas detectors

i) Communication facilities

j) Washing facilities with disinfectants and toiletries

x. The Contractor shall provide high visibility safety barriers with red/white markings, to be erected around all unattended open manholes and cover them over with suitable temporary steel sheets. Whenever the Contractor's work force leaves the site of the works all manhole covers shall be replaced and fixed into position.

xi. Before entering inside any enclosed space the atmosphere shall be tested. Based upon a risk assessment, a permit-to-work procedure shall be operated, as necessary.

xii. The Contractor shall provide, erect and maintain adequate scaffolding, ladders, etc., required for work and to facilitate the Engineer to inspect and test the works. Remove them as directed upon completion of all works.

xiii. Safety Officer shall ensure that at least one person in each work group shall be trained in rescue procedures, resuscitation techniques, basic first aid and the use of gas detection apparatus.

xiv. Should any one working in a manhole, sewer or chamber, complain of nausea or dizziness: Assume this to be an Immediate Danger to Life or Health (IDLH). Immediately evacuate all personnel from that location. Work should resume only when it is safe to do so, or with the use of breathing apparatus under site supervision of the safety officer.

gg. Changes to the approved Contractor's health and safety plan. The approved health and safety plan shall be updated to include any new or unrealized hazards as identified on site, or as required to comply with new or revised government regulations. All proposed revisions to the initially approved project health and safety plan shall be formally submitted for the Engineer's approval, and incorporated as an addendum.

1.12.8 Housekeeping

a. Throughout the progress of his work, the Contractor shall keep the site and all working areas:

1. In tidy and workman-like condition
2. Free from rubbish and waste materials

b. Any temporary works, constructional plant/equipment, materials or other things that for the time being are not required for use by the Contractor may with the consent of the Engineer:

1. Be removed from the site, but otherwise shall be dispersed about the site in an orderly fashion
2. Shall be properly and securely stored thereon

c. Applicable requirements in the Department of Transport Conditions of Contract and Schedule of Further Requirements

d. Work areas and access ways shall be kept free of trash, materials and all tripping hazards

e. Temporary electrical wiring shall be protected from damage by traffic, be in good condition and protected by ground fault circuit interrupters

f. All portable containers for gas and other inflammable liquids shall have self closing lids. No plastic containers are allowed

g. All accidents are to be reported directly to supervisors, and the Engineer

    1. If serious injury is apparent or suspected, utilize the pre established emergency hospital services

    2. Telephone number shall be prominently displayed at all site telephone locations

    3. For small cuts, scratches, etc. approved first aid kits are to be available from the Contractor, and each subcontractor

h. In the event of a fire: Emergency evacuation plans and procedures shall be prepared and posted on the safety notice board(s) and communicated

    1. In the event of a fire, the procedures to be followed if the fire cannot be immediately contained, shall include notifying the nearest Abu Dhabi Civil Defence Fire Brigade, whose telephone number shall be prominently displayed at all site telephone locations, and site safety notice boards.

    2. Attempt to put out a manageable fire with available fire extinguishers and water hoses until help arrives, shall be encouraged, however, the contactor shall ensure they do not endanger any personnel in fighting a fire if their personnel are not suitably trained or volunteer to do so.

i. Project specific hazards:

    1. The Contractor shall ensure the workers site orientation includes reference to site-specific hazards related to the workers field of operation, and that both known hazards and Engineering controls measures are communicated to them, including the contents from the Contractor’s approved health and safety plan.

    2. Workers site safety orientation shall be documented.

j. Heavy equipment suppliers must supply certification of testing and obtain clearance from the project Engineer before commencement of their work.

k. Security:

    1. Watchman shall be deployed at controlled entrance and exit location(s), as required.

    2. No site visiting during nights, week-ends or holidays shall be permitted without prior permission from the Engineer.

    3. Visitors to site shall be instructed to report to the reception, and the Contractor’s safety representative for site safety induction and authorization to enter site areas, as approved by the Engineer.

1.12.9 Final Conditions of Work

Before application is made for the Owner to accept the work, all items of work shall be complete, ready to operate and in a clean condition. All trash, debris, unused building material and temporary structures shall have been removed from the site of the work. Tools and construction machinery not needed for repair and adjustment consequent to operational tests shall not be on the site. Walkways, parking areas and roadways, streets and lanes pertaining to the works shall be completely cleaned.

1.13 Contractor Quality Control

This section includes requirements for establishing and maintaining a quality control (QC) program and Contractor quality control (CQC) staff to control quality for on-site and off-site work and construction operations to ensure compliance with Contract requirements. The Contractor shall comply with the requirements outlined in the Owner’s Quality Assurance and Quality Control - Requirements

1.13.1 Contractor Quality Control References

Several publications, listed below, form a part of this specification to the extent referenced. Publications are referred to in the text by the basic designation only.

1. ASTM A880 (1989) Criteria for Use in Evaluation of Testing Laboratories and Organizations for Examination and Inspection of Steel, Stainless Steel, and Related Alloys
2. ASTM C1077 (1992) Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
3. ASTM D3666 (1992; Rev. A) Minimum Requirements for Agencies Testing and Inspecting Bituminous Paving Materials
4. ASTM D3740 (1988) Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
5. ASTM E329 (1993) Evaluation of Testing and Inspection Agencies as Used in Construction
6. ASTM E543 (1992; Rev. C) Evaluating Agencies That Perform Non-destructive Testing

The Contractor shall apply appropriate specifications. A definable feature of work is a task that is separate and distinct from other tasks and requires separate control requirements. As a minimum, if approved by the Engineer, the Contractor shall consider each section of the specifications as a definable feature of work. However, at times, there may be more than one definable feature of work in each section of the specifications.

1.13.2 Submittals during Construction

Submit in accordance with Section 1.13.21.13, a project-specific Contractor quality control plan within 21 calendar days after the NTC.

1.13.3 Information for the Engineer

Deliver the following to the Engineer:

1. Combined Contractor production report/Contractor quality control report (one sheet): Original and one copy, by 10:00 AM the next working day after each day that work is performed
2. Testing plan and log: one copy, at the end of each month
3. Monthly summary report of field tests: Original and one copy attached to the Contractor quality control report at the end of each month
4. CQC meeting minutes: one copy, within two calendar days of the meetings
5. Rework items list: one copy, by the last working day of the month
6. CQC certifications: As required by Section 1.13.14

1.13.4 Contractor Quality Control Program Requirements

Establish and maintain the Contractor quality control (CQC) program as described in this section. CQC program shall include a CQC organization, a CQC plan, CQC meetings, three phases of control, submittal review and approval (those submittals designated for Engineer approval shall be reviewed and approved submittal to the Engineer), testing, and CQC certifications and documentation necessary to provide materials, equipment, workmanship, fabrication, construction and operations which comply with the requirements of this Contract. CQC program shall cover construction operations on-site and shall be keyed to the proposed construction sequence.

1.13.5 Contractor Quality Control Organization

CQC manager shall comply with the requirements outlined in this section.

1.13.5.1 Duties

Provide a CQC manager at the work site to manage and implement the CQC program. Duties and responsibility the CQC manager shall have on this Contract is only the managing and implementing the CQC program. CQC manager is required to conduct the CQC meetings, perform the three phases of control, perform submittal review and approval except for those submittals designated for Engineer approval, ensure testing is performed and prepare CQC certifications and documentation required in this Contract. CQC manager is responsible for managing and coordinating the work in conjunction with the services of any independent testing laboratory when required by the specifications. No work or testing may be performed unless the CQC manager is on the site. CQC Manager shall report directly to an officer of the Contractor's company and shall not be the same individual as, nor be subordinate to, the construction manager, superintendent or the project manager.

1.13.5.2 Qualifications

This position may have collateral duties; however, the CQC manager shall be present full-time at the site and spend a minimum of 70 % of his time performing CQC duties. CQC manager shall have a collateral, direct reporting relationship to the Engineer. CQC manager may also be a member of the Contractor's design team and an active participant in the design of any plant being constructed under this Contract. CQC manager shall be a graduate of a four year accredited college program in an Engineering or architecture discipline with a minimum of five years experience as a construction superintendent, inspector, project manager, or construction manager. He/she shall have at least five years experience as a CQC manager on similar size and type construction Contracts that included the major trades that are part of this Contract.

1.13.6 Contractor Quality Control Requirements

Provide for approval by the Engineer, a CQC plan that covers both on-site and off-site work and includes the following:

1. A chart showing the CQC organizational structure and its relationship to the production side of the organization.
2. Names and qualifications, in resume format, for each person in the CQC organization.
3. Duties, responsibilities and authorities of each person in the CQC organization.
4. A listing of sub-consultant organizations such as, architectural and consulting Engineering firms that will be employed by the Contractor and a description of the services these firms will provide, with respect to construction.
5. A letter signed by an officer of the Contractor's firm appointing the CQC manager and stating that he/she is responsible for managing and implementing the CQC program as described in this Contract. Include in this letter the CQC manager's authority to direct the removal and replacement of non-conforming work. This letter shall indicate the CQC manager’s collateral reporting responsibility to the Engineer.
6. Procedures for reviewing, approving and managing submittals: Provide the name(s) of the person(s) in the CQC organization authorized to review and certify submittals before approval.
7. Testing laboratory information required by Section 1.13.131.13.12.
8. A testing plan and log that includes the tests required, referenced by the specification section number and paragraph number requiring the test, the frequency, and the person responsible for each test.
9. Procedures to identify, record, track and complete rework items.
10. Documentation procedures, including proposed report formats.
11. A list of the definable features of work.

12. A personnel matrix showing, for each section of the specification, which will review and approve submittals, which will perform and document the three phases of control, and which will perform and document the testing.
13. Preliminary work authorized before approval: Construction work that is authorized to proceed before the approval of the CQC plan is only the mobilization of storage and modular office units, temporary utilities, and surveying
14. Approval: Approval of the CQC plan is required before the start of construction. Engineer reserves the right to require changes in the CQC plan and operations as necessary to ensure the specified quality of work. Engineer reserves the right to interview any member of the CQC organization at any time in order to verify his/her submitted qualifications
15. Notification of changes: Notify the Engineer, in writing, of any proposed change, including changes in the CQC organization personnel, a minimum of seven calendar days before a proposed change. Proposed changes must be approved by the Engineer

1.13.7 Contractor Quality Control Planning Meeting

Before developing and submitting a CQC plan, the Contractor shall meet with the Engineer to discuss the CQC plan requirements of this Contract. In this meeting, the Contractor and Engineer shall develop a mutual understanding of the CQC plan requirements. This meeting shall be conducted in conjunction with the pre-construction meeting.

1.13.8 Coordination

After approval of the CQC plan, but before the start of construction, meet with the Engineer to discuss the CQC program required by this Contract. Purpose of this meeting is to develop a mutual understanding of the CQC details, including forms to be used for documentation, administration for on-site and off-site work, and the coordination of the Contractor's management, production and CQC personnel with the Engineer. As a minimum, the Contractor's personnel required to attend shall include the project manager, construction manager, and CQC manager. Minutes of the meeting shall be prepared by the CQC manager and signed by both the Contractor and the Engineer.

1.13.9 Contractor Quality Control Meetings

After the start of construction, the CQC manager shall conduct bi-weekly CQC meetings at the work site with the Contractor’s project manager. CQC manager shall prepare the minutes of the meeting and provide a copy to the Engineer within two working days after the meeting. Engineer will attend these meetings. CQC manager shall notify the Engineer at least 48 hours in advance of each meeting. As a minimum, the following shall be accomplished at each meeting:

a. Review the minutes of the previous meeting
b. Review the schedule and the status of work:
    1. Work or testing accomplished since last meeting
    2. Rework items identified since last meeting
    3. Rework items completed since last meeting
c. Review the status of submittals:
    1. Submittals reviewed and approved since last meeting
    2. Submittals required in the near future
    3. Status of pending submittals
d. Review the status of request for information (RFI):
    1. RFI’s reviewed since last meeting
    2. RFI’s required in the near future

3. Status of pending RFIs

e. Review the work to be accomplished in the next two weeks and documentation required. Schedule the three phases of control and testing:
   1. Establish completion dates for rework items
   2. Preparatory phases required
   3. Initial phases required
   4. Follow-up phases required
   5. Testing required
   6. Status of off-site work or testing
   7. Documentation required

f. Resolve CQC and production problems

g. Address items that may require revising the CQC plan:
   1. Changes in CQC organization personnel
   2. Changes in procedure

h. Discussion of the Contractor’s “As-Built” documentation status.

1.13.10 Three phases of Contractor Quality Control

Perform the three phases of control to ensure that work complies with Contract requirements. Three phases of control shall adequately cover both on-site and off-site work and shall include the following for each definable features of work.

1.13.10.1 Preparatory Phase

Notify the Engineer at least two working days in advance of each preparatory phase. Conduct a preparatory phase meeting with the construction manager and the foreman responsible for that definable feature of work. Document the results of the preparatory phase actions in the daily Contractor quality control report. Perform the following before beginning work on each definable feature of work:

1. Review each paragraph of the applicable specification sections.
2. Review the Contract plans.
3. Verify that appropriate shop drawings and submittals for materials and equipment have been submitted and approved. Verify receipt of approved factory test results, when required.
4. Review the testing plan and ensure that provisions have been made to provide the required CQC testing.
5. Examine the work area to ensure that the required preliminary work has been completed.
6. Examine the required materials, equipment and sample work to ensure that they are on hand and conform to the approved shop drawings and submitted data.
7. Review the accident prevention plan and appropriate activity hazard analysis to ensure that applicable safety requirements are met, and that required material safety data sheets (MSDS) are submitted.
8. Discuss construction methods.

1.13.10.2 Initial Phase

Notify the Engineer at least two working days in advance of each initial phase. When construction crews are ready to start work on a definable feature of work, conduct the initial phase, the construction manager, and the foreman responsible for that definable feature of work. Observe the initial segment of the definable feature of work to ensure that the work complies with Contract requirements. Document the results of the initial phase in the daily Contractor quality control report. Repeat the initial phase for each new crew to work on-site, or when acceptable levels of specified quality are not being met. Perform the following for each definable feature of work:

1. Establish the quality of workmanship required
2. Resolve conflicts
3. Review the accident prevention plan and the appropriate activity hazard analysis to ensure that applicable safety requirements are met
4. Ensure that testing is performed by the approved laboratory

1.13.10.3 Follow-up Phase

Perform the following for on-going work daily or more frequently as necessary until the completion of each definable feature of work and document in the daily Contractor quality control report:

1. Ensure the work is in compliance with Contract requirements
2. Maintain the quality of workmanship required
3. Ensure that testing is performed by the approved laboratory
4. Ensure that rework items are being corrected

1.13.11 Contractor Quality Submittal Review and Approval

Procedures for submission, review and approval of submittals are specified in Section 1.11.

1.13.12 Contractor Quality Control Testing

Except as stated otherwise in the specification sections, perform sampling and testing required under this Contract. Requirements for the independent testing laboratory shall be governed by the American Association of State Highway and Transportation Officials (AASHTO) program and the American Association for Laboratory Accreditation (AALA) program. Furnish to the Engineer for review and approval accreditation documentation including, a copy of the certificate of accreditation, scope of accreditation and latest directory of the accrediting organization for accredited laboratories. Scope of the laboratory's accreditation shall include the test methods required by the Contract.

1.13.13 Inspection of Testing Laboratories

Proposed testing laboratory facilities and records are subject to inspection by the Engineer. Records subject to inspection include equipment inventory, equipment calibration dates and procedures, library of test procedures, audit and inspection reports by agencies conducting laboratory evaluations and certifications, testing and management personnel qualifications, test report forms, and the internal CQC procedures.

1. Capability check: Engineer retains the right to check laboratory equipment in the proposed laboratory and the laboratory technician's testing procedures, techniques, and other items pertinent to testing, for compliance with the standards set forth in this Contract.
2. Test results: Cite applicable Contract requirements, tests or analytical procedures used. Provide actual results and include a statement that the item tested or analyzed conforms or fails to conform to specified requirements. Conspicuously stamp the cover sheet for each report in large red letters "CONFORMS" or "DOES NOT CONFORM" to the specification requirements, whichever is applicable. Test results shall be signed by a testing laboratory representative authorized to sign certified test reports. Furnish the signed reports, certifications, and other documentation to the Engineer via the CQC manager. Furnish a summary report of field tests at the end of each month. Attach a copy of the summary report to the last daily Contractor quality control report of each month.

1.13.14 Contractor Quality Certifications

1. The Contractor quality control report certification: Each Contractor quality control report shall contain the following statement: "on behalf of the Contractor, I certify that this report is complete and correct and equipment and material used and work performed during this reporting period is in compliance with the Contract plans and specifications to the best of my knowledge, except as noted in this report."
2. Invoice certification: Furnish a certificate to the Engineer with each payment request, signed by the CQC manager, attesting that as-built drawings are current and attesting that the work for which payment is requested, including stored material is in compliance with Contract requirements.
3. Completion certification: Upon completion of work under this Contract, the CQC manager shall furnish a certificate to the Engineer attesting that "the work has been completed, inspected, tested and is in compliance with the Contract."

1.13.15 Contractor Quality Control Documentation

Maintain current and complete records of on-site and off-site CQC program operations and activities.

1.13.15.1 The Contractor Production Report

Reports are required for each day that work is performed and shall be attached to the Contractor quality control report prepared for the same day. Account for each calendar day throughout the life of the Contract. Reporting of work shall be identified by terminology consistent with the construction schedule. The Contractor production reports shall be prepared, signed and dated by the construction manager and shall contain the following information:

a. Date of report, report number, name of the Contractor, Contract number, title and location of Contract and superintendent present

b. Weather conditions in the morning and in the afternoon including maximum and minimum temperatures

c. A list of the Contractor and subcontractor personnel on the work site, their trades, Owner, work location, description of work performed and hours worked

d. A list of job safety actions taken and safety inspections conducted. Indicate that safety requirements have been met including the results on the following:

   1. Was a job safety meeting held? (If YES, attach a copy of the meeting minutes)
   2. Were there any lost time accidents? (If YES, attach a copy of the completed accident report)
   3. Was trenching/scaffold/high voltage electrical/high work done? (If YES, attach a statement or checklist showing inspection performed)
   4. Was hazardous material/waste released into the environment? (If YES, attach description of incident, corrective action taken, and proposed actions to be taken to avoid similar incidents)
   5. A list of equipment/material received each day that is incorporated into the job
   6. A list of construction and plant equipment on the work site including the number of hours used, idle and down for repair
   7. Include a "remarks" section in this report, which will contain pertinent information including directions received, problems encountered during construction, work progress and delays, conflicts or errors in the Contract plans or specifications, field changes, safety hazards encountered, instructions given and corrective actions taken, delays encountered and a record of visitors to the work site

1.13.15.2 The Contractor Quality Control Report

Reports are required for each day that work is performed and for every seven consecutive calendar days of no-work and on the last day of a no work period. Account for each calendar day throughout the life of the Contract. Reporting of work shall be identified by terminology consistent with the construction schedule. Reports shall be prepared, signed and dated by the CQC manager and shall contain the following information:

a. Identify the control phase and the definable feature of work
b. Results of the preparatory phase meetings held including the location of the definable feature of work and a list of personnel present at the meeting. Indicate in the report that for this definable feature of work, the Contract plans and specifications have been reviewed, submittals have been approved, materials comply with approved submittals, materials are stored properly, preliminary work was done correctly, the testing plan has been reviewed, and work methods and schedule have been discussed.
c. Results of the initial phase meetings held including the location of the definable feature of work and a list of personnel present at the meeting. Indicate in the report that for this definable feature of work the preliminary work was done correctly, samples have been prepared and approved, the workmanship is satisfactory, test results are acceptable, work is in compliance with the Contract, and the required testing has been performed and include a list of who performed the tests.
d. Results of the follow-up phase inspections held including the location of the definable feature of work. Indicate in the report for this definable feature of work that the work complies with the Contract as approved in the initial phase, and that required testing has been performed and include a list of who performed the tests.
e. Results of the three phases of control for off-site work, if applicable, including actions taken.
f. List the rework items identified, but not corrected by close of business.
g. List the rework items corrected from the rework items list along with the corrective action taken.
h. Include a "remarks" section in this report which will contain pertinent information including directions received, quality control problem areas, deviations from the CQC plan, construction deficiencies encountered, CQC meetings held, acknowledgement that as-built drawings have been updated, corrective direction given by the CQC organization and corrective action taken by the Contractor.
i. The Contractor quality control report certification.

1.13.15.3 Testing Plan and Log

As tests are performed, the CQC Manager shall record on the "testing plan and log" the date the test was conducted, the date the test results were forwarded to the Engineer, remarks and acknowledgement that the accredited or Engineer approved independent testing laboratory was used. Attach a copy of the updated "testing plan and log" to the last daily Contractor quality control report of each month.

1.13.15.4 Rework Items List

CQC manager shall maintain a list of work that does not comply with the Contract, identifying what items need to be reworked, the date the item was originally discovered, and the date the item was corrected. There is no requirement to report a rework item that is corrected the same day it is discovered. Attach a copy of the "Contractor rework items list" to the last daily Contractor quality control report of each month. The Contractor shall be responsible for including on this list items needing rework including those identified by the Engineer.

1.13.15.5 As-Built Drawings

CQC manager is required to review the as-built drawings required in the "Contract closeout" section, to ensure that as-built drawings are kept current on a daily basis and marked to show deviations, which have been made from the Contract plans. CQC manager assigned to an area of responsibility shall initial each deviation and each revision. Upon completion of work, the CQC manager shall furnish a certificate attesting to the accuracy of the as-built drawings before submission of a copy to the Engineer.

1.14 Utility Coordinator

This section specifies the duty and services of a Utility Coordinator for all the utility works to be carried out under this Contract.

The Contractor shall employ and pay for services of a person, technically qualified and administratively experienced in field co-ordination for the type of utility work required for this project, for the duration of the work.

1.14.1 Utility Coordinator Submittal for Review

Submit curriculum vitae of Utility Coordinator for review and approval by the Engineer. Submit duties and powers delegated to the coordinator Engineer. Submit co-ordination drawings and progress schedules before submitting shop drawings, product data, and samples.

1.14.2 Utility rd r R r d D

Utility coordinator shall comply with the following requirements:

a. Coordinate all utility activities with that of other sections in the specification.
b. Coordinate progress schedules, including dates for submittals and for delivery of products.
c. Conduct meetings among those parties concerned with the work, to establish and maintain co-ordination, progress schedules and to resolve any co-ordination matters. Transmit minutes of meetings and reports to all concerned parties.
d. Participate in progress meetings.
e. Report on progress of the work (to be adjusted under coordination requirements) and any required changes in the schedules.
f. Follow-up submittals and the procurement process.

1.14.3 Utility Coordination Documentation

Utility coordination documentation shall meet the following requirements.

a. Prepare coordination drawings in a manner to provide for the most efficient use of available space, the best sequence of installation and for identification of potential conflicts.
b. Prepare a master schedule to identify requirements (submittals, testing, commissioning, O&M manuals, etc.) designated under each section of the specifications for activities, which directly relate to the work, including temporary utilities.
c. Identify pipe and equipment connections, standards and pressure ratings.
d. Identify electrical power characteristics and control wiring required for each item of equipment.
e. Maintain documents for the duration of the work, recording changes due to site instructions, modifications or adjustments.
f. After the Engineer reviews and approves the original and/or revised documents, reproduce and distribute copies to all concerned parties.

1.14.4 Coordination of Submittals

The Contractor shall coordinate submittals in accordance with the following requirements:

a. Review shop drawings, product data, and samples for compliance with Contract documents and transmit these to the Engineer for approval.

b. Check field dimensions and clearances and relationship to available space and anchors.

c. Check compatibility with equipment and work of other sections, electrical characteristics and operational control requirements.

d. Check motor voltages related with starting mode and control characteristics.

e. Coordinate controls, interlocks, wiring of push button switches and relays.

f. Coordinate wiring and control diagrams.

g. Review the effect of any changes on work of other sections.

h. Verify information and coordinate the maintenance of record documents.

1.14.5 Coordination of Substitutions and Modifications

The Contractor shall review proposals and requests from subcontractors. Verify compliance with Contract documents and for compatibility with work and products of other sections. Substitutions shall conform to the requirements outlined in Section 1.18.4. Submit with recommendation for action.

1.14.6 Observation of Work

Observe work for compliance with Contract documents. Maintain a list of observed deficiencies and defects; promptly submit.

1.14.7 Documentation

Documentation shall include:

a. Observe and maintain a record of tests. Record:

   1. Specification section number, product, and name of subcontractor/supplier
   2. Name of testing agency and name of inspector
   3. Phone/ fax no. or e-mail address of testing agency
   4. Name of manufacturer's representative present
   5. Date, time and duration of tests
   6. Type of test and results
   7. Retesting required

b. Assemble background documentation for dispute and Claim settlement by Engineer and Owner.

c. Submit copies of documentation to Engineer upon request.

1.14.8 Mains Electricity and Liaison with ADEWA

Requirements of liaising with ADEWA include the following:

a. Be acquainted with Abu Dhabi Electricity and Water Authority (ADEWA) regulations and requirements.

b. Liaise with ADEWA to determine the power supply required and all other pertinent information as required and make all necessary arrangements for its connection.

c. Arrange through written request for ADEWA to undertake the testing and inspection necessary in order that the electricity supplies may be connected when required.

Any delay caused by omission to make the request in good time, will not be accepted.

1.14.9 Utility Service and Process Interruption

Utility service and process interruptions initiated by the Contractor during the course of the work shall be scheduled in advance and approved by the relevant authority and Engineer before being implemented.

Unforeseen circumstances may make it necessary to postpone scheduled utility service and process interruptions. Such actions by the relevant authority shall not be cause for extension of time for completion or Claims for additional compensation.

1.14.10 Equipment Start-up

Equipment start-up shall be done as follows:

a. Verify utilities, connections, and controls are complete and equipment is in operable condition as required by the specifications.

b. Observe start-up and adjustments, test run, record time and date of start-up, and results.

c. Observe equipment demonstrations for the Owner; record times and additional information required for operation and maintenance manuals.

1.14.11 Inspection and Acceptance of Equipment

Before inspection, verify that equipment is tested, operational, clean and ready for operation. Assist Engineer with review. Prepare list of items to be completed and corrected.

1.14.12 Scheduling

Schedule shall include the following:

1. Sequence of work
2. Materials and shop drawings submittal
3. Material procurement
4. Inspection and testing
5. Manufacturer services and training

1.15 Construction Facilities and Temporary Controls

This section outlines standards, specifications, and requirements for construction facilities and temporary controls.

1.15.1 Submittals

The Contractor shall submit for the Engineer's approval, the following items:

a. Copies of permits and approvals for construction as required by laws, regulations and governing agencies

b. Temporary utility submittals

c. Electric power supply and distribution plans

d. Water supply and distribution plans

e. Drainage plans

f. Dewatering well locations

g. Sanitary service plan
h. Temporary construction and site use plan containing:
    1. Access roads: Routes, cross-sections, and drainage facilities
    2. Parking area plans
    3. The Contractor’s field office, storage yard, and storage building plans, including gravel and/or paved surfaced area
    4. Fencing and protective barrier locations and details
    5. Engineer’s field office
    6. Staging area location plan
    7. Construction stages and corresponding traffic control and routing plans
    8. Plan for maintenance of existing plant operations (if applicable)
    9. Temporary lighting including offices and roads
i. Temporary control submittals:
    1. Plan for disposal of waste materials and intended haul routes as part of the CEMP prescribed in Sections 1.15.4 and 1.15.9.
    2. Environmental, sediment and pollution control plan.

1.15.2 Site Mobilization

Site mobilization shall include, but shall not be limited to, the following principal items:

1. Moving the Contractor’s and the Engineer’s field offices and equipment required for the first month of operations onto the project site
2. Installing temporary construction power, wiring, and lighting facilities
3. Providing onsite communication facilities, including telephones
4. Providing and erecting the Contractor’s work and storage yard
5. Posting required safety notices and establishing safety programs and procedures
6. Ensuring that the Contractor’s construction manager is at the site full time
7. Having the Contractor’s representative responsible for the site mobilization at site full time

Use area for the Contractor’s temporary facilities within worksite or as agreed by the Engineer. Submit site use plan for approval in accordance with the requirements in Section 1.15.1. All services and access shall be at the Contractor’s expense.

1.15.3 Protection of Work and Property

The Contractor shall follow the requirements in this section to protect work and property.

1.15.3.1 General

a. Comply with project safety rules while on Owner’s property.
b. Keep Engineer informed of any onsite accidents and related Claims.
c. Use of explosives: No blasting or use of explosives will be allowed unless specifically approved by the Engineer, Owner and relevant authorities.
d. Perform work within right-of-way and easements in a systematic manner that minimizes inconvenience to property owners and the public. Any excavations outside of the affection plan require an approved permit to dig from the Engineer.

e. Maintain in continuous service all existing oil and gas pipelines, underground power, telephone or communication cable, water mains, irrigation lines, sewers, poles and overhead power, and all other utilities encountered along line of the work, unless other arrangements satisfactory to the owner of said utilities have been made.

f. Where completion of the work requires temporary or permanent removal and/or relocation of existing utility, coordinate all activities with owner of said utility and perform all work to their satisfaction.

g. Protect, shore, brace, support, and maintain underground pipes, conduits, drains, and other underground utility construction uncovered or otherwise affected by construction operations.

h. Keep water control valves free from obstruction and available for use at all times.

i. In areas where the Contractor's operations are adjacent to or near a utility, such as gas, telephone, television, electric power, water, sewer, or irrigation system, and such operations may cause damage or inconvenience, suspend operations until arrangements necessary for protection have been made by the Contractor.

j. Notify property owners and utility offices that may be affected by construction operation at least 2 days in advance.

k. Before exposing a utility, obtain utility owner's permission. Should service of utility be interrupted due to the Contractor's operation, notify proper authority immediately. Cooperate with said authority in restoring service as promptly as possible and bear costs incurred.

l. Do not impair operation of existing sewer system. Prevent construction material, pavement, concrete, earth, volatile and corrosive wastes, and other debris from entering sewers, pump stations, or other sewer structures.

m. Maintain original site drainage wherever possible.

1.15.3.2 Site Security

a. Provide and maintain additional temporary security fences as necessary to protect the work and the Contractor furnished products not yet installed.

b. Barricades and lights:

   1. Provide as necessary to prevent unauthorized entry to construction areas inside and outside of fenced area, and as required to ensure public safety and the safety of the Contractor's employees, other Owner personnel, and others who may be affected by the work.

   2. Locate to enable access by facility operators and property owners.

c. Signs and equipment:

   1. Traffic control: Provide temporary traffic control devices as necessary to delineate traffic lanes to guide and separate traffic movements.

   2. High-level warning flag units: Provide two in advance of traffic approaching the work, each displaying three flags mounted at a height of 1 meter.

   3. Warning signs: Provide at obstructions, such as material piles and equipment.

   4. Illuminate barricades and obstructions with warning lights from sunset to sunrise.

1.15.3.3 Trees and Plantings

a. Protect from damage and preserve trees, shrubs, and other plants outside limits of the Work and within limits of the work, which are designated to remain undisturbed.

b. In event of damage to bark, trunks, limbs, or roots of plants that are not designated for removal, treat damage by corrective pruning, bark tracing, application of a heavy coating of tree paint, and other accepted horticultural and tree surgery practices.

c. Replace each plant that dies as a result of construction activities.

1.15.3.4 Dewatering

Construct, maintain, and operate cofferdams, channels, flume drains, sumps, pumps, or other temporary diversion and protection works. Furnish materials required, install, maintain, and operate necessary pumping and other equipment for the environmentally safe removal and disposal of water from the various parts of the work. Maintain foundations and parts of the work free from water. Before dewatering works proceed, the Contractor will submit drawings and calculations to the Engineer for approval and issue of permit to dewater from the Owner.

1.15.3.5 Archaeological Finds

a. General: Should finds of an archaeological or paleontological nature be made within the limits of the site, immediately notify Engineer and proceed in accordance with the general conditions. Continue the work in other areas without interruption.

b. Archaeological finds: Evidence of human occupation or use of an area within the Contract limits before the Year 1840. Evidence may consist of skeletons, stone, or other utensils, or evidence of habitations or structures.

c. Paleontological Finds: Evidence of prehistoric plant or animal life, such as skeletons, bones, fossils, or casts and other indications such as pictographs.

d. Engineer may order the work stopped in other areas if, in Engineer's opinion, the find is more extensive than may appear from uncovered material.

e. Protection of finds:

   1. Cover, fence, or otherwise protect finds until notice to resume the work is given.

   2. Cover finds with plastic film held in place by earth, rocks, or other weights placed outside the find. Should additional backfilling be necessary for safety or to prevent caving, place backfill material loosely over the plastic film.

   3. Sheet or shore as necessary to protect excavations underway. Place temporary fence to prevent unauthorized access.

   4. Dewater finds made below water table as necessary to protect construction work underway. Divert groundwater or surface runoff away from find by ditching or other acceptable means.

f. Removal of finds:

   1. All finds are property of Owner. Do not remove or disturb finds without Owner's written authorization.

   2. Should Owner elect to have a find removed, provide equipment, labour, and material to permit safe removal of find without damage. Provide transportation for delivery to individuals, institutions, or other places as Owner may find desirable, expedient, or required by law.

1.15.3.6 Endangered Species

a. Take precautions necessary and prudent to protect native endangered flora and fauna.

b. Notify Engineer of construction activities that might threaten endangered species or their habitats.

c. Engineer will mark areas known as habitats of endangered species before commencement of onsite activities.

d. Additional areas will be marked by Engineer as other habitats of endangered species become known during construction.

e. The Contractor shall provide temporary high visibility fencing around habitats to be protected

1.15.4 Engineer Field Offices

As stipulated in project Particular Specifications as per project requirements.

1.15.5 Agency Representatives Field Offices

As stipulated in project Particular Specifications as per project requirements.

1.15.6 Information Technology

As stipulated in project Particular Specifications as per project requirements.

1.15.7 Site Laboratory

Site laboratories shall comply with the requirements in this section.

1.15.7.1 Description

1. The Contractor shall provide a site laboratory for his and the Engineers quality control and testing.
2. Laboratory facilities shall be similar in construction and shall be maintained as specified for Engineer's site office facilities, in Section 1.15.4.
3. The Contractor shall provide a sufficient number of qualified personnel to perform sampling and testing duties as specified.
4. The Contractor shall provide suitable transportation as approved by the Engineer during the Contract period, for the exclusive use of the site laboratory, sufficient for both the Contractor's and the Engineer's laboratory personnel.
5. The Contractor shall provide the laboratory with equipment list A for projects having primarily road works with minor structures only. The Contractor shall provide the laboratory with equipment list B for projects having major structures, unless otherwise required in the particular specifications or directed by the Engineer.

1.15.7.2 Use of the Laboratory

Laboratory shall be for the use of the Contractor for his quality control program. However, Engineer shall have exclusive use of the laboratory at all times during the project for Engineer's acceptance and quality testing as otherwise required. The Contractor shall, provide a sufficient number of qualified personnel to perform sampling, testing and related duties under the direct supervision of the Engineer.

1.15.7.3 Location of the Laboratory

Location of the laboratory shall be adjacent to the Engineer's site office facilities unless otherwise approved by the Engineer. Laboratory shall be available and maintained until final acceptance of the project is provided.

1.15.7.4 Maintenance of the Laboratory

The Contractor shall at all times be responsible for maintaining the building, utilities and all testing equipment in an acceptable condition for use. All consumables shall be restocked by the Contractor in a timely manner.

1.15.7.5 Approval of the Laboratory

Before constructing the laboratory, the Contractor shall submit and obtain written approval from the Engineer of the shop drawings for the laboratory.

Before the start of work, the Engineer will inspect the laboratory to ensure the Contractor's compliance with these specifications. In the event the Contractor fails to comply with these specifications at any time during the Contract period, the Engineer may order any or all of the sampling and testing to be performed at any other laboratory designated by the Engineer with such fees and charges to be deducted from any amounts due to the Contractor.

1.15.7.6 Building Requirements

A site laboratory shall comply with the following building requirements.

a. Laboratory shall contain all necessary equipment in acceptable working order and adequate storage and working space for the following:

    1. Preparation of soil, aggregate, concrete and asphalt mix samples, etc.
    2. Storage of field sampling equipment, i.e. Sand cone density apparatus, stockpile sampling tools, concrete cube moulds, cement, bitumen and soil sampling equipment, etc.
    3. Soil and aggregate testing: Gradation, L.L., P.I., sand equivalent, proctor, aggregate flakiness and elongation, calibration of sand for density testing, speedy moisture, oven moisture, C.B.R., etc.
    4. Concrete testing: Making and curing concrete cubes, etc.
    5. Asphalt mix testing: Density of compacted samples, extraction gradation, bitumenometer for ash correction, marshall moulds, etc.

b. Site laboratory shall provide a minimum of 120 m^2 of office space with three separate individual offices of twelve square meters each enclosed with glass windows facing the remainder of the laboratory and furnished as otherwise specified in this specs, plus equipped with the following for use by the Engineer as required:

    1. Minimum 20 mbps broadband or wifi internet connection and router
    2. Latest spec Standard PC with monitor: Three (3)
    3. Laptop: One (1)
    4. A3 colour printer: One (1)
    5. Power supply surge protector: 1 per computer and peripheral device as required to protect all devices
    6. Local area network including all cables, switches, routers and accessories.
    7. Work centre: One (1)
    8. Digital camera: Two (2); Kodak or HP digital cameras with minimum 7 mp with minimum 3x optical zoom with minimum 1 GB memory card and all accessories (cables, software, batteries, chargers, etc.), or equal

c. Laboratory shall be provided with electricity; lighting; air conditioning and heating system; water; an inside storage tank for trichloroethylene; sinks; rigid flooring; desks; work benches; cupboards; curing tank; windows with blinds; doors and fans. A separate concrete curing room shall be provided which shall have a 15 m^2 floor space with necessary lighting, humidity and temperature controls, as directed by the Engineer.

    The office furniture, desks, chairs, work benches with metal work surfaces (aluminium or GI sheet), and cupboards for the site laboratories shall be as required by the Engineer and be new, and of the quality and quantity as approved by the Engineer.

Utility connections shall be as shown in the approved shop drawings. Additional enclosed area (racked) attached to the laboratory building shall be provided for reference sample storage.

Prior to constructing the laboratory, the Contractor shall obtain written approval from the Engineer of the Shop Drawing for the laboratory. After acceptance of the constructed laboratory and the equipment supplied, all upkeep, repairs and replacements will be the Contractor's responsibility.

1.15.7.7 Equipment List A

Laboratory shall contain, as a minimum, the equipment and supplies listed herein unless otherwise required by the particular specifications. All equipment shall be approved by the Engineer before being furnished, and it shall be maintained until the completion of the works. The equipment maintenance and servicing shall include independent calibration completed at least annually with the calibration certificates provided to the Engineer.

Item No.	Description	Quantity
1	Tongs	3
2	Speedy moisture tester large size	2
3	Heavy duty solution balance 3 kg x 0.0045 kg	2
4	Moisture tester reagent (1 carton)	24 cans
5	Cement pans tapered, 610 mm x 610 mm x 76 mm	12
6	Trowel triangular blade, 140 mm x 63.5 mm	6
7	Trowel rectangular blade, steel 114 mm x 254 mm	3
8	152 mm cube form with base plate	24
9	Sieve, brass 203.2 mm dia full height:	
	a. Sieve opening 50.8 mm	2
	b. Sieve opening 38.1 mm	2
	c. Sieve opening 25.4 mm	2
	d. Sieve opening 19.0 mm	2
	e. Sieve opening 12.7 mm	1
	f. Sieve opening 9.51 mm	1
	g. Sieve opening 6.35 mm	1
	h. Sieve opening 4.76 mm	1
	i. Sieve opening 2.38 mm	1
	j. Sieve opening 2.00 mm	2
	k. Sieve opening 1.68 mm	1
	l. Sieve opening 1.19 mm	1
	m. Sieve opening 0.595 mm	1
	n. Sieve opening 0.420 mm	2
	o. Sieve opening 0.297 mm	1
	p. Sieve opening 0.149 mm	1
	q. Sieve opening 0.074 mm	1
10	Brass pan for above	3
11	Brass cover with ring	3
12	Brass riddle sieve, 457 mm diameter:	
	a. Sieve opening 50.8 mm	1
	b. Sieve opening 38.1 mm	1
	c. Sieve opening 25.4 mm	1
	d. Sieve opening 19.0 mm	1
	e. Sieve opening 12.7 mm	1

	f. Sieve opening 9.51 mm	1
	g. Sieve opening 4.76 mm	1
13	Quartering canvas	2
14	Sieve shaker, (Inclino or equivalent)	1
15	Large capacity Gilson sample splitter with hopper	1
16	Sample bags, plastic lined	72
17	Aggregate scoop pans	2
18	Wet washing sieves, mesh opening 0.074 mm	4
19	Timing device 0-60 minutes	2
20	Fine sieve brush	6
21	Wire sieve brush	6
22	Tamping rod, 610 mm long 15.9 mm dia	2
23	Yield bucket, 0.00283 m^3	1
24	Yield bucket, 0.0283 m^3	1
25	Slump test set	2
26	Unit weight bucket, 0.01415 m^3	1
27	Mixing bowls stainless steel 222 mm x 102 mm	12
28	Pans, stainless steel, rectangular	12
29	Cement mould brush, brass	3
30	Combination compression tester (2,000 kN), With separate flexural frame attachment	1
31	Armoured concrete thermometers	5
32	Hot plate, 300 mm x 610 mm, 220 volts, 50 cycles	1
33	Single wall utility laboratory oven (425 litre)	1
34	Double wall gravity convection oven (720 litre)	1
35	Mettler precision balance, 12 kg. x 1.0 g. (Model P-10)	1
36	Platform beam scale cap. 320 kg.	1
37	Aggregates specific gravity set for fine aggregate, with jar and shaker	1
38	Density basket for coarse aggregate	1
39	Liquid limit device with counter	1
40	ASTM grooving tool	1
41	Spare cups for liquid limit device	2
42	Porcelain mixing dish	3
43	100 ml graduated cylinder	6
44	Wash bottles	4
45	500 ml graduated cylinder	3
46	Flexible spatula	6
47	Plastic limit plates	3
48	Soil mortar	2
49	Soil pestle	2
50	Modified compaction mould 152 mm dia	2
51	Modified compaction hammer	2
52	Sample ejector	1
53	Straight edge	4
54	Density pick	2
55	Chisel	4

56	Rubber mallet	2
57	Sampling spoons	6
58	Sand density cone with cylinder (1 set)	2
59	Field density plate	2
60	Calibrating container	1
61	Moisture tins, 3 oz. capacity (stainless steel or aluminium)	3 doz.
62	Moisture tins, 6 oz. capacity (stainless steel or aluminium)	3 doz.
63	Asbestos gloves	6 pairs
64	Stopwatch	2
65	Plastic lined canvas bags	100
66	Spatula, 152 mm long blade x 25.4 mm wide	6
67	Large scoop	2
68	Large pick	2
69	Shovel square edge	2
70	25.4 mm square tamping bar for 152 mm concrete cubes	2
71	CBR molds	6
72	Spacer disc. 150.81 mm dia. 61.366 mm high	1
73	Dial indicator	4
74	Swell plate	3
75	Tripod attachment	3
76	Surcharge weight, 2.268 kg annular disc	6
77	Surcharge weight, 2.268 kg slotted	6
78	Filter papers for CBR test moulds	3 boxes
79	Automatic multispeed CBR frame and drive (50 kN capacity) with full accessories and proving rings (50 kN, 28 kN, 4.7 kN)	1
80	Copies of all testing specifications (AASHTO, BS, ASTM, etc.) as required for quality testing by the various specification sections, or as required by the Engineer	1 set
81	Flakiness plate (BS EN 933-1)	2
82	Elongation gauge (BS 812)	1
83	Hot plate, 220 volts, 50 Hz.	1
84	Marshall compaction machine (automatic)	1
85	Marshall compaction moulds	6
86	Dial thermometers	6
87	Reflux extractor, glass, 4000 gm capacity	2
88	Filter papers for above	20 packs
89	Spare glass jars for above	3
90	Reflux extractor	3
91	Filter papers for above	20 packs
92	Spare glass jars for above	3
93	Bunsen burners	2
94	Continuous flow filterless centrifuge	1
95	Thermostatic water bath at least 150 mm deep with temperature control (60°C + 1/2°C) and fitted with shelf for supporting Marshall stability specimen	

	50mm from bottom of tank	1
96	Mechanical mixer with capacity of 3 litre and a mixing bowl surrounded by a heating element with a suitable control (isomantle heater)	1
97	Marshall Asphalt Stability Test set complete (220V 50Hz) 50 kN capacity (digital flow, stability readout)	1
98	Sample splitter, riffler, stainless steel	1
99	Wide mouth, clear glass bottles, 2 oz or 60 ml capacity screw-on-top	12 bottles
100	Double graduated cylinder, 50 ml	3
101	Aluminium beakers, 500 ml	6
102	Thermometers, 18-28 degrees C range	3
103	Pocket type thermometers, 0-250 degrees C range	3
104	Tape measure (3 m)	3
105	Tape measure (5 m)	2
106	Tape measure (30 m)	2
107	Funnels, 305 mm diameter	3
108	Funnels, 152 mm diameter	3
109	Funnels, 76.2 mm diameter	3
110	Tripod stands	3
111	Trichloroethylene, Benzene (replenished as needed)	400 litres
112	Measuring cups, Pyrex glass graduated in 14 cc divisions	2
113	Beakers, Pyrex glass, 500 ml cap.	6
114	Supply of distilled water	as needed
115	Supply of unleaded kerosene	as needed
116	5M straight edge and wedge device for measuring surface irregularity	2
117	Wheelbarrow	3
118	350 mm dia. x 450 mm deep plastic dustbin	6
119	Max/min thermometer	2
120	Tool kit (see below)	1
121	Wire gauze asbestos discs for use on hot plates	6
122	Digital surface coating thickness gauge (paint) Elcometer With probes for ferrous and non-ferrous substrates	1
123	Rubber tubing, 12.7 mm bore	6 m
124	Rubber tubing, 6 mm bore x 12.7 mm 0.D.	6 m
125	Other miscellaneous equipment in the quantities necessary to perform the required tests should also be supplied.	
126	Mercury Thermometers 0 - 250° C	3
127	Asphalt coring machine c/w 2 no. 10 cm coring tubes (Hilti, Controls or equivalent) and all related equipment	1 set
128	Sand equivalent test	1 Set
129	Sand absorption cone and tamping rod	1 Set
130	LA abrasion machine and accessories	1
131	Vernier calliper (digital)	1
132	Bitumen penetrometer	1

133	Ring and ball apparatus	1
134	Hydrometer set and high speed stirrer	1 set
135	Calculator Casio FX 880p (or equal)	2
136	ACV apparatus with accessories	1
137	Four wheel trolley and sack carts	1 set
138	VICAT apparatus and accessories	1 set
139	Tool kit comprising screwdrivers large and small, electrical screwdriver (circuit testing), pliers, 450 mm Stillson wrench, adjustable spanners; self grip wrench; hacksaw and blades; smooth and bastard files; electrical soldering iron, flux and solder; claw hammer; panel saw, and range of open ended and ring spanners (metric and ANSI inch sizes) in storage box	1 set
140	Centrifuge extraction machine 3000g capacity (3600 rpm)	
141	Filter papers for the above	200
142	Trichloro-ethylene (45gal drums)	2

Note: All consumable items shall be replenished as needs dictate.

As required by the Engineer, the Contractor shall provide the required computers from a reputed manufacturer with 19" LCD/LED monitors and LaserJet printer, all to the latest specifications for use by the Engineer to conduct all work related to the site laboratory.

1.15.7.8 Equipment List B

Laboratory shall contain, as a minimum, the equipment and supplies listed herein unless otherwise required by the particular specifications. All equipment shall be approved by the Engineer before being furnished, and it shall be maintained until the completion of the works. The equipment maintenance and servicing shall include independent calibration completed at least annually with the calibration certificates provided to the Engineer.

Description	**Quantity**
SOIL	
General	
Quartering canvas	2
Large capacity Gilson sample splitter with hopper	1
Heavy duty solution balance 12 kg capacity (digital)	1
Single wall utility laboratory oven (425 lt)	2
Pans, stainless steel, rectangular	12
Sieve shaker, (Inclino or equivalent)	1
Soil mortar	2
Soil pestle	2
Liquid limit and plastic limits	
Precision balance < 2 kg to 0.01gm accuracy (digital)	1
Liquid limit device with counter	1

ASTM grooving tool	1
Spare cups for liquid limit device	2
Porcelain mixing dish	3
500 ml. graduated cylinder	3
Flexible spatula	6
Plastic limit plates	3
Spatula, 152 mm long blade x 25.4 mm wide	6
Compaction and insitu density	
Speedy moisture tester large size	2
Sample bags, plastic lined	100
Modified compaction mould, 152 mm dia	2
Modified compaction hammer	2
Sample ejector	1
Straight edge	4
Density pick	2
Chisel	4
Rubber mallet	2
Sampling spoons	6
Sand density cone with cylinder (1 set)	2
Field density plate	2
Calibrating Container	1
Moisture tins, 3 oz. capacity (stainless steel or aluminium)	3 doz.
Moisture tins, 6 oz. capacity (stainless steel or aluminium)	3 doz.
Moisture tester reagent (1 carton)	24 cans
CBR test	
CBR moulds	3
Spacer disc. 150.81 mm dia. 61.366 mm high	1
Dial indicator	4
Swell plate	3
Tripod attachment	
Surcharge weight, 2.268 kg annular disc	3
Surcharge weight, 2.268 kg slotted	3
Filter papers for CBR test moulds	3 boxes
Automatic CBR frame and drive (50 kN capacity) with necessary accessories and proving rings	1
Sieve analysis (soils and aggregates)	
Sieve, brass 203.2 mm dia. full height:	
a. Sieve opening 50.8 mm	2
b. Sieve opening 38.1 mm	2
c. Sieve opening 25.4 mm	2
d. Sieve opening 19.0 mm	2
e. Sieve opening 12.7 mm	1
f. Sieve opening 9.51 mm	1
g. Sieve opening 6.35 mm	1
h. Sieve opening 4.76 mm	1
i. Sieve opening 2.38 mm	1

j. Sieve opening 2.00 mm	2
k. Sieve opening 1.68 mm	1
l. Sieve opening 1.19 mm	1
m. Sieve opening 0.595 mm	1
n. Sieve opening 0.420 mm	2
o. Sieve opening 0.297 mm	1
p. Sieve opening 0.149 mm	1
q. Sieve opening 0.074 mm	1
Brass pan for above	3
Brass cover with ring	3
AGGREGATES	
ACV apparatus with accessories	1
Aggregates specific gravity set for fine aggregate with jar and Shaker	1
Sand absorption cone and tamping rod	1 set
Sand equivalent test set	1
LA abrasion machine and accessories	1
Density basket for coarse aggregate	1
Aggregate scoop pans	2
Wet washing sieves 0.074 mm mesh opening	4
Timing device 0-60 minutes (digital)	2
Wire sieve brush	6
Tamping rod, 610 mm long 15.9 mm dia	2
Mixing bowls stainless steel 222 mm x 101.6 mm	12
Unit weight bucket, 14.2 litres	1
Platform beam scale cap. 320 kg.	1
CONCRETE	
Fresh concrete	
Yield bucket, 2.83 litres	1
Yield bucket, 28.32 litres	1
Slump test set	2
102 mm cube form with base plate	48
100 ml. graduated cylinder	6
25.4 mm square tamping bar for 102 mm concrete cubes	2
Wash bottles	4
Armoured concrete thermometers	5
Cement pans tapered, 610 mm x 610 mm x 76.2 mm	12
Cement mould brush, brass	3
Masonry saw with blades (set)	1
Vibrating hammer + frame with complete set of tamping heads.	1
Hardened concrete	
Combination compression tester (2,000 kN) with flexural frame (100 kN)	1
Mettler precision balance, 12 kg. x 1.0 g (Model P-10)	1
ASPHALT	
General	
Asbestos gloves	6 Pairs

Stopwatch	2
Trichloroethylene, Benzene	as required
Sample splitter, riffler, stainless steel	1
Beakers, Pyrex glass, 500 ml cap.	6
Aluminium beakers, 500 ml	6
Asphalt coring machine c/w 2 no 10 cm coring tubes (Hilti, Controls or equivalent) and all related equipment	1 set
Large scoop	2
Large pick	2
Shovel square edge	2
Vacuum pump, desiccator with dial indicator and perforated base plate, and accessories (set)	1
Pull-off tester 50 KN digital readout with 6 Nos. of 50 mm dollys (set)	1
Eleometer adhesion tester with 20 mm dollys (set)	1
Durometer hardness test (shore A & D) (set)	1
Moh's hardness tester (set)	1
Wet film comb	2

<u>General laboratory equipments and accessories</u>

Tongs	3
Calculator Casio FX 880p (or approved equal)	2
Copies of all testing specifications (AASHTO, BS, ASTM, etc.) as required for quality testing by the various specification sections, or as required by the Engineer	1 set
Tape measure (3 m)	3
Wheelbarrow	3
Tape measure (30 m)	2
350 mm dia. x 450 mm deep plastic dustbin	6
Double graduated cylinder, 50 ml	3
Tape measure (5 m)	2
Funnels, 305 mm diameter	3
Funnels, 152 mm diameter	3
Funnels, 76.2 mm diameter	3
Tripod stands	3
Four wheel trolley and sack carts	1 Set
Wide mouth, clear glass bottles, 2 oz or 60 ml capacity screw-on-top	12 bottles
Measuring cups, Pyrex glass graduated in 14.2 cc divisions	2
Supply of distilled water	as needed
Supply of unleaded kerosene	as needed
Max/min thermometer	2
Digital surface coating thickness gauge (paint) Elcometer For ferrous and non-ferrous substrates	1
Vernier Caliper (digital)	1
Trowel triangular blade, 140 mm x 64 mm	6
Trowel rectangular blade, steel 114 mm x 254 mm	3

Tool kit comprising screwdrivers large and small, electrical screwdriver (circuit testing), pliers, 450 mm
Stillson wrench, adjustable spanners; self grip wrench; hacksaw and blades; smooth and bastard files; electrical soldering iron, flux and solder; clawhammer; panel saw, and range of open ended and ring spanners (metric and ANSI inch sizes) in storage box 1 set

Note: All consumable items shall be replenished as needs dictate.

As required by the Engineer, the Contractor shall provide the required computers from a reputed manufacturer with 19" LCD/LED monitors and LaserJet printer, all to the latest specifications for use by the Engineer to conduct all work related to the site laboratory.

1.15.8 Project Signs

Provide and maintain project signs as shown on the Contract plans or described in the particular specifications. Submit design drawings and location plan for Engineer's approval before manufacture and erection. Project signs shall meet the additional requirements of Sub-article i of Article 1.15.13.1.

1.15.9 Temporary Controls

The Contractor shall prepare and submit for the Engineers approval an environmental sediment and pollution control plan as required in Section 1.15.1, Clause i. Plan shall consist of the following items:

a. Set of drawings showing the Contractor's proposed wind and rainfall erosion control measures that correspond to his Contract staging and detour plans. For each winter construction period between 15 October and 15 April, for each different proposed construction stage, the Contractor shall show on a set of drawings the locations of working zones and detours along with the temporary wind and rainfall erosion and sediment control measures to be installed. These items shall include the erosion and sedimentation controls as otherwise described in Section 1.17. Plans shall show specific protective fencing location for areas to be protected such as vegetated agriculture and landscaping to remain and environmentally sensitive, historic, public use, endangered species habitat and archaeology sites.
b. Details of proposed dewatering including sediment traps or filters at the discharge where required to protect discharge to existing storm drains or environmentally sensitive areas.
c. Details of dust and air pollution control measures proposed to be used as described in Clause j below and Section 1.17.
d. Details for hazardous existing materials procedure
e. Spill prevention plan, including the details of oil/water separators before stormwater discharge from maintenance yards and equipment repair staging areas, details of spill control for equipment refuelling (i.e. providing specific, spill controlled fuel storage and refuelling depots), details of spill containment for paint, thinners and other hazardous and petroleum chemicals storage facilities, and details of plan for emergency spill cleanup.
f. Details describing compliance with all EAD environmental requirements.
g. Plan shall be regularly updated and resubmitted for approval to match changes in the Contractors operations and staging.
h. Details for protecting inhabiting and endangered species
i. All environmental, spill control, erosion, sedimentation and pollution control measures shall meet the application and design requirements contained in Chapter 14 of the Abu Dhabi Road Drainage Manual AD-D-07.
j. Plan shall in general comply with the following requirements:

1. Air pollution control:
   i. Minimize air pollution from construction operations.
   ii. Burning of waste materials, rubbish, or other debris will be permitted only by direct approval of the Engineer.
   iii. Conduct operations of dumping rock and of carrying rock away in trucks to cause a minimum of dust. Give unpaved streets, roads, detours, or haul roads used in construction area a dust-preventive treatment or periodically water to prevent dust. Strictly adhere to applicable environmental regulations for dust prevention.
2. Water pollution control:
   i. Divert sanitary sewage and non-storm waste flow interfering with construction and requiring diversion to sanitary sewers. Do not cause or permit action to occur which would cause an overflow to existing waterway or storm drain.
   ii. Before commencing excavation and construction, obtain Engineer's agreement with detailed plans showing procedures intended to handle and dispose of sewage, groundwater, and storm water flow, including dewatering pump discharges.
   iii. Do not dispose of volatile wastes such as mineral spirits, oil, chemicals, or paint thinner in storm or sanitary drains. Disposal of wastes into streams or waterways is prohibited. Provide acceptable containers for collection and disposal of waste materials, debris, and rubbish and dispose of properly off-site. Provide plan and details for pollution prevention and spill controls for the Contractor's maintenance and storage yards and the equipment refuelling depot as part of the sediment and pollution prevention plan
3. Erosion, sediment, and flood control:
   i. Provide, maintain, and operate temporary facilities to control erosion and sediment releases, and to protect the work and existing facilities from flooding during construction period.
   ii. Design erosion and sediment controls to handle peak runoff per the requirements in Chapter 14 of the Abu Dhabi Road Drainage Manual, AD-D-07. Provide design and plans for site erosion, sediment and flood controls.

1.15.10 Storage Yards and Buildings

Storage yards and buildings shall meet the following requirements:

a. Temporary storage yards: Construct temporary storage yards for storage of products that are not subject to damage by weather conditions.
b. Temporary storage buildings:
   1. Provide environmental control systems that meet recommendations of manufacturers of equipment and materials stored.
   2. Arrange or partition to provide security of contents and ready access for inspection and inventory.
   3. Store combustible materials (paints, solvents, and fuels) in a well-ventilated and remote building meeting safety standards.

1.15.11 Access Roads

Access roads shall meet the following requirements:

1. Owner's Engineer is responsible for designating access roads outside of the project limits and right-of-way. The Contractor is responsible for access within the project limits of the affection

plan. Alignments and design of new routes must be approved by the Engineer. Access roads to site are subject to change and will be advised by the Owner and Engineer.

2. Maintain drainage ways. Install and maintain culverts to allow water to flow beneath access roads. Provide corrosion-resistant culvert pipe of adequate strength to resist construction loads.
3. Provide for temporary protection of any utilities that the access roads may be crossing per requirements of Chapter 11, Utilities.
4. Provide gravel, crushed rock, or other stabilization material to permit access by all motor vehicles at all times.
5. Maintain road grade and crown to eliminate potholes, rutting, and other irregularities that restrict access.
6. Upon completion of construction, restore ground surface disturbed by access road construction to original grade. Replace damaged or broken existing facilities to remain with new materials to match existing.

1.15.12 Parking Areas

Parking areas shall meet the following requirements:

1. Control vehicular parking to preclude interference with public traffic or parking, access by emergency vehicles, the Contractor's operations, or construction operations.
2. Provide parking facilities for Engineer's personnel working on the project for approximate 12 vehicles. No employee or equipment parking will be permitted on Owner's existing paved areas except as specifically designated for the Contractor's use.
3. Provide shade for parking area of the Engineer's office as per Section 1.15.4.

1.15.13 Traffic Control, Detour Schemes and Pedestrian Safety

Traffic control, detour schemes and pedestrian safety work during construction shall meet the following requirements:

a. Conduct the work to interfere as little as possible with public travel, whether vehicular or pedestrian.
b. Whenever it is necessary to cross, close, or obstruct roads, driveways, and walks, whether public or private, provide and maintain suitable and safe bridges, detours, or other temporary expedients for accommodation of public and private travel.
c. Maintenance of traffic is not required if the Contractor obtains written permission from Owner and tenant of private property, or from authority having jurisdiction over public property involved, to obstruct traffic at designated point.
d. In making street crossings, do not block more than one-half the street at a time. Whenever possible, widen shoulder on opposite side to facilitate traffic flow. Provide temporary surfacing on shoulders as necessary.
e. Maintain top of backfilled trenches before they are paved, to allow normal vehicular traffic to pass over. Provide temporary access driveways where required. Cleanup operations shall follow immediately behind backfilling.
f. Notify Engineer, fire department, and police department before closing any streets or portions thereof. Notify said departments when streets are again passable for emergency vehicles. Do not block off emergency vehicle access to consecutive arterial crossings or dead-end streets, in excess of 100 linear metres, without written permission from fire department. Conduct operations with the least interference to fire equipment access, and at no time prevent such access. Furnish the Contractor's night emergency telephone numbers to police department.

g. Detour plans: The Contractor shall prepare and submit for Engineers approval traffic control and detour plans that correspond to his proposed work and staging plans, meeting the following general requirements:

1. Preparation of detour plans:
   i. Detours shown on the tender documents are schematic and only reflect a general concept for implementing the construction of the works
   ii. It is the Contractor's responsibility to prepare the detailed plans (detour shop drawings), including alignments and profiles, in accordance with the requirements of the standard specifications. The Contractor shall meet the additional requirements for detour shop drawings as required in Sub-article q of Article 1.15.13.1.
   iii. This shall include the removal of greenery and relocation and/or protection of utilities that conflict with the detour scheme
   iv. The Contractor shall submit detailed shop drawings of the detour plans for the review and approval of the Engineer, the Owner and the traffic police, before commencing each stage of construction
   v. Traffic detours shall be designed in accordance with the applicable requirements of the Abu Dhabi Manual of Uniform Traffic Control Devices (AD-D-11), and as approved by the Engineer.
   vi. Temporary traffic control devices shall meet the requirements of Article 1.15.13.1.
   vii. The Contractor shall be required, when directed by the Engineer, to provide warning lights and reflective painted markings on continuous temporary barriers in areas where detour pavement is poorly illuminated
   viii. Updating of the detour shop drawings is the responsibility of the Contractor and shall be done in accordance with Paragraph 1 of Sub-article r of Article 1.15.13.1.
2. Construction of detours:
   i. The Contractor shall construct the detours in accordance with the approved shop drawings and specifications
   ii. The Contractor shall be responsible for coordinating the relocation and removal of all greenery which obstructs the construction of the detour route
   iii. Similarly, it shall be the Contractor's sole responsibility to obtain the necessary clearances and approvals for detours which conflict with existing or proposed utility installations
3. Sub-stage detours for utility installation:
   i. The Contractor shall consider the use of additional sub-stage detours to facilitate any utility installations in service reservation crossings that pass under existing roads or detour routes.
   ii. All utility installations shall be fully reviewed with the Engineer before commencing each detour phase
4. Local access: Vehicular and pedestrian access to facilities within the area affected by the construction works shall be maintained at all times
5. Maintenance of detour works:
   i. The Contractor shall maintain all temporary works in a safe and usable condition throughout the period they are in use.
   ii. Maintenance shall include, but not be limited to:
      a) Removing dirt and debris from temporary and permanent roadways in use relative to the project

b) Cleaning of signs, lights and reflectors

c) Replacement or repair as directed by the Engineer of any damaged traffic control devices

d) Realigning displaced barriers, barricades and other temporary traffic control devices

e) Removing/rectifying any unsafe or confusing conditions that would endanger the public

6. Construction period:

   i. The Contractor shall complete each stage of the works in the shortest period possible, and not more than shown in his work plan schedule

   ii. Construction to be completed for each stage shall be shown on the Contractor's approved staging plans

1.15.13.1 Temporary Traffic Control Devices (Detour Safety Items)

For temporary traffic control devices, the Contractor shall consider these specifications, the particular specifications, and the Contract plans in conjunction with AASHTO LRFD standards and the Manual on Uniform Traffic Control Devices (MUTCD). Hierarchy shall be particular specifications over these specifications and the Contract plans, over the MUTCD, over the AASHTO requirements. This section is subdivided as follows:

- Channelizing Devices, Sub-article a of this article
- Portable Changeable Message *Sign*Sign, Sub-article b of this article
- Advance Warning Arrow Board, Sub-article c of this article
- Temporary Barriers, Sub-article d of this article
- Temporary Crash Cushions Systems (Attenuators), Sub-article e of this article
- Portable Steel Barrier Gate, Sub-article f of this article
- Directional Safety Beacon System, Sub-article g of this article
- Temporary Signage, Sub-article h of this article
- Construction Identification Signage, Sub-article i of this article
- Temporary Light Standards, Sub-article j of this article
- Temporary Signals for Traffic and Pedestrians, Sub-article k of this article
- Flaggers, Sub-article l of this article
- Temporary Utility Protection and Removal at Detour Roads, Sub-article m of this article
- Accommodation of Existing Conditions, Sub-article o of this article
- Rumble Strips, Sub-article p of this article
- Temporary pedestrian access and safety items, Sub-article q of this article
- Detour plans (detour shop drawings), Sub-article r of this article

The Contractor shall be responsible for furnishing, installing, moving, maintaining, and removing all temporary traffic control devices with all accessories and hardware as necessary for each stage of construction. Upon removal, temporary traffic control devices shall become the property of the Contractor. Removal shall occur at the end of the project or at the request of the Engineer.

Upon completion of the works, the Contractor shall remove all detour pavements, temporary sidewalks, temporary works, and all temporary construction and shall restore the site to its original condition or to the condition indicated on the Contract plans.

The Contractor shall provide all labour and materials, and construct and maintain to the satisfaction of the Engineer temporary ramps for use during construction and for use of traffic in cases where it is necessary to direct traffic from an existing road onto a new road or vice versa.

Temporary staging shall be provided by the Contractor to enable any construction operations to be performed in the required sequence. Staging shall be properly designed and constructed for the loads which it will be required to support, and complete details for the arrangements proposed shall be submitted to the Engineer for approval. Such approval, however, will not relieve the Contractor of his responsibility for the adequacy of the staging. All temporary staging and temporary works shall be removed and disposed of by the Contractor and as approved by the Engineer.

As specifically provided under the various items, and in general, the Contractor shall maintain all temporary works in a safe and usable condition throughout the period they are in use. This shall include, but not be limited to, the following:

- Removing dirt and debris from temporary and permanent roadways
- Cleaning of signs, lights, and reflectors
- Realigning displaced barriers, barricades and other temporary traffic control devices
- Removing or rectifying any unsafe or confusing conditions that would endanger the public or the workers.

The Contractor shall comply with the installation requirements of the MUTCD, including providing detectable edging for pedestrians.

a. Channelizing Devices

The Contractor shall be responsible for furnishing, installing, maintaining, and removing all temporary channelization devices, and their appurtenances, needed to maintain safe and smooth traffic operations while protecting the works and the workers. These include the following:

1. Cones;
2. Delineators, including tubular markers;
3. Drums; and,
4. Barricades and barriers, including temporary attenuators.

Locations of the channelization devices shall be as shown on the Contract plans and as directed by the Engineer. Removal shall be on completion of the works or when directed by the Engineer. Maintenance shall include, but not by way of limitation, the following:

1. Reflective sheeting
2. Lighting
3. Flashing warning lights
4. Replacement
5. Work required for maintaining devices in their required condition and position

Temporary traffic barriers, construction barricades and drums shall have yellow lamps in the steady and/or flashing mode in accordance with the requirements of the Institute of Transportation Engineers (ITE) standard for flashing and steady burn warning lights, which is included in the ITE Equipment and Materials Standard, for night illumination at the sides bordering the line of traffic for the sake of giving warning. Lights shall be placed in such a way that highlights the barricades or drums without the use of vehicle lights.

Drums may be substituted for temporary barriers/barricades when directed or approved by the Engineer.

Traffic cones shall have the following features:

1. Omni directional red/white reflective sheeting, foil Type 1
2. Height shall be 750 mm
3. Weight shall be approximately 5 kg
4. Portable and easily stackable onto each other

5. Constructed of polyethylene, lightweight, recyclable with UV stabiliser
6. Designed to remain upright and sturdy when exposed to both direct sunlight and inclement weather conditions
7. Capable of receiving an inserted traffic cone lamp

Traffic cone lamps shall be for insertion into the traffic cone having either 500 mm or 750 mm height. Traffic cone lamps shall be stab lamp-LED type 62/S from M/s. Nissan or an equivalent, as approved by the Engineer, and shall have the following salient features:

1. Diameter shall be 200 mm
2. Direction of light shall be one sided only
3. Light colour shall be amber
4. Effective intensity shall be 190 cd

All traffic cone lamps shall be fitted with either monocell alkaline battery 1.5 V having minimum operating time of 300 hours or nickel cadmium rechargeable cell having a minimum operating time of 100 hours. All the above equipment shall be as supplied by M/s. Nissan or an equivalent source.

Flexible delineators shall be high visibility posts, Type 5, Safehit ® Post as supplied by M/s. Quixote Corp., or an equivalent, as approved by the Engineer.

Salient features of the high visibility flexible delineator post shall be 90 mm diameter, Orange colour post with 50 mm by 75 mm high intensity reflective strip, orange colour sheeting complying with ASTM type III.

Drums shall be at least 900 mm in height and shall meet the requirements for drums in Chapter 6 of the MUTCD. Lights meeting the above requirements for traffic cone lamps shall be affixed to the drums for use during hours of darkness or as shown on the Contract plans or directed by the Engineer.

Barricades shall be Type I, Type II, or Type III as defined in Chapter 6 of the MUTCD. Lights meeting the above requirements for traffic cone lamps shall be affixed to the barricades for use during hours of darkness or as shown on the Contract plans or directed by the Engineer.

Temporary barriers shall comply with the requirements of Sub-article d of Article 1.15.13.1. Temporary traffic attenuators shall meet the requirements of Sub-article e of Article 1.15.13.1.

Vertical panels complying with the requirements of Chapter 6 of the MUTCD shall also be acceptable.

b. Portable Changeable Message Sign

Portable changeable message signs (PCMS) shall meet the requirements established in Chapter 6 of the MUTCD. PCMS shall automatically adjust their brightness under varying light conditions to maintain legibility. They shall be equipped with a control system that allows the message to be reviewed before being displayed on the message sign and maintains memory when power is unavailable.

PCMS shall be equipped with a power source and battery back-up to provide continuous operation.

PCMS shall be mounted on a trailer or a truck such that the bottom of the message sign panel shall be at least 2.1m above the surface of the roadway.

Operation of the PCMS shall be per Chapter 6 of the MUTCD.

The PCMS shall employ one of the following technologies:

1. Fibre-optic/shutter
2. Light emitting diode
3. Light emitting diode/shutter
4. Flip disk

Regardless of the technology, the PCMS shall meet the following general requirements:

1. Be light emitting and must not rely solely on reflected light. The emitted light shall be generated using fibre optic or LED technology
2. Have a display consisting of individually controlled pixels no larger than 65 mm by 65 mm. If the display is composed of individual character modules, the space between modules must be minimized so alphanumeric characters of any size specified below can be displayed at any location within the matrix
3. When activated, the pixels shall display a yellow or orange image. When not activated, the pixels shall display a flat black image that matches the background of the sign face
4. Be capable of displaying alphanumeric characters that are a minimum of 450 mm in height. Width of alphanumeric characters shall be appropriate for the font. PCMS shall be capable of displaying 3 lines of 8 characters per line with a minimum of 1 pixel separation between each line.
5. PCMS message, using 450 mm characters, shall be legible by a person with 20/20 corrected vision from a distance of not less than 240 m centred on an axis perpendicular to the sign face.
6. Sign display shall be covered by a stable, impact resistant polycarbonate face. Sign face shall be non-glare from all angles and shall not degrade due to exposure to ultraviolet light.
7. Be capable of simultaneously activating all pixels for the purpose of pixel diagnostics. Any sign that employs flip disk or shutter technology shall be programmable to activate the disks/shutters once a day to clean the electrical components. This feature shall not occur when the sign is displaying an active message.
8. Light source shall be energized only when the sign is displaying an active message.
9. Primary source of power shall be solar power with a battery backup to provide continuous operation when failure of the primary power source occurs.
10. Sign controller software shall be NTCIP compliant. PCMS panels and related equipment shall be permanently mounted on a trailer with all controls and power generating equipment.

PCMS shall be operated by a controller that provides the following functions:

1. Select any pre-programmed message by entering a code
2. Sequence the display of at least five messages
3. Blank the sign;
4. Program a new message, which may include animated arrows and chevrons
5. Mirror the message currently being displayed or programmed

c. Advance Warning Arrow Board

The Contractor shall be responsible for furnishing, installing and maintaining all advance warning arrow boards in areas as determined by the Engineer or shown on the Contract plans. Location of the advance warning arrow boards shall be as directed and or approved by the Engineer and the type shall be Type 600-LED 12 V as supplied by M/s. Nissan or equivalent, approved by the Engineer, with the following salient features:

1. Running or sequenced flashing light
2. Static directional arrow function
3. Warning sign from right to left and vice versa
4. Six led arrow symbols, each with 40 leds
5. Pointing left and right with 5 m cable and one remote with 10 m cable
6. Size shall be 1,537 mm by 355 mm by 80 mm
7. Weight shall be 15 kg
8. Signal size shall be 1,400 mm by 250 mm
9. Arrow size shall be 250 mm high by 200 mm wide
10. Light intensity shall be 450 cd/arrow symbols
11. Voltage shall be 12 volts

12. Brightness adaptor shall be continuous and automatic from 100 % to 10 %

d. Temporary Barriers

The Contractor shall be responsible for furnishing, installing and maintaining all temporary barriers in areas as determined by the Engineer, where construction operations result in a condition that is considered to be hazardous to the general public, or to separate the work area from pedestrian areas. Location and extent of the temporary barriers shall be as directed and approved by the Engineer. Temporary barriers shall remain the property of the Contractor and shall be removed from the site of the works as approved by the Engineer when no longer required. Temporary barriers may be of the following:

1. Temporary concrete barriers
2. Temporary concrete barriers with screens
3. Water filled portable barriers
4. Safety barrier fence system

1. Temporary Concrete Barriers

Temporary concrete barrier shall be new or used precast barrier complying with the requirements of the Contract plans for precast barrier and meeting the requirements of Section 7.5 of Chapter 7, Incidental Construction, except for the following:

- Lengths may differ from those shown in the Contract plans
- Permanent lifting holes less than 100 mm in diameter may remain
- Lifting loops are permitted
- A stamp or stencil reading “temporary” shall be visible on each barrier segment

Permanent barriers that will be removed and reset per the Contract plans or the direction of the engineer may be used as temporary concrete barrier without being stamped or stencilled “temporary.” Any permanent barrier damaged during its use as a temporary barrier will become the property of the Contractor and be replaced with an undamaged permanent barrier at no expense to the Owner when the permanent barrier is reset to its location.

All barriers shall be in good condition, without cracks, chips, spalls, dirt, or traffic marks. If any barrier segment becomes damaged during or after placement, the Contractor, at no expense to the Owner, shall immediately repair it to the engineer’s satisfaction or replace it with an undamaged section.

As soon as the temporary barrier is no longer needed, the Contractor shall remove it from the site of the works. Owner-furnished barrier shall remain Owner property, and the Contractor shall deliver it to a stockpile site noted in the contract or to locations approved by the engineer. The Contractor-furnished barrier shall remain the property of the Contractor.

2. Temporary Concrete Barriers with Screens

Temporary concrete barriers shall meet the requirements of Paragraph 1 above. The Contractor shall be required, when directed by the Engineer, to provide warning lights and reflective painted markings on continuous temporary barriers in areas where detour pavement is poorly illuminated.

Screen shall be constructed of painted metal and shall be neat in appearance. Screen shall be fixed over the temporary concrete barriers. Screen shall be solid and continuous, not less than 1.2 m in height. Supplemental screens shall be connected with the metal screen as indicated on the Contract plans and as directed by the Engineer. Details of construction shall be as indicated on the Contract plans and approved by the Engineer. Screen shall be of substantial construction such that it will not be damaged or displaced by wind or other normal natural or manmade forces.

Slots shall be provided in temporary concrete barriers for fixing screens as indicated on the Contract plans.

3. Water Filled Portable Barriers

Barrier shall be a highly portable and crashworthy longitudinal barrier. Barrier section shall be constructed of a lightweight, recyclable, virgin linear low density polyethylene plastic shell, with ultraviolet stabilisers and antioxidants, designed to accept water ballast. End of each barrier section shall be constructed with vertically aligned knuckles which interlock with adjacent sections by means of a steel connecting pin. Connecting pin shall be constructed to securely connect adjoining sections.

Barrier sections shall be constructed in white or work zone safety orange colours for high visibility. Each barrier section shall include an internal galvanised steel framework to provide additional rigidity during handling and impacts. Barrier section shall have ribbed sidewalls to interact with an impacting vehicle in a manner that resists penetration, vaulting and under riding.

Barrier sections shall have elevated forklift openings to allow for mechanical lifting when empty or full. Barrier shall have arrangements like quick fill openings with covers, and a rapid release gate valve to allow quick draining of the water ballast. A reflectorised fill level indicator shall be constructed in the top of each section to allow quick verification that the section is adequately full of water ballast.

4. Safety Barrier Fence System

Safety barrier fence system type A shall have the following salient features:

i. Constructed of galvanised steel, with red/white banner planks
ii. Overall dimensions: 2,000 mm by 1,000 mm
iii. Universal base plate K1 weighing approximately 28 kg
iv. Galvanised steel support posts
v. Complete with a transport and storage box for up to 20 barrier elements having 2,000 mm by 1,000 mm dimension
vi. System shall be supplied by M/s Nissan or approved equivalent

Safety barrier fence system type b shall have the following salient features:

i. Constructed of high quality plastic, with upright tubes made from galvanised steel parts with red/white barrier planks and blind man's rail with retroflective foil, Type 1
ii. Include facility to mount warning lamps
iii. Banner element shall be 2,000 mm by 1,000 mm
iv. Universal base plate K1 weighing approximately 28 kg
v. Galvanised steel support posts
vi. Complete with a transport and storage box for up to 20 safety barriers elements having 2,000 mm by 1,000 mm dimension.
vii. System shall be supplied by M/s Nissan or approved equivalent
viii. This system shall also include monolight LED warning lamp and battery. Salient features of the monolight shall be as follows:
    a) Light type: Flashing/constant
    b) Light Intensity: 15 cd
    c) Light Colour: Amber
    d) Light Flash Rate: 60 f/min to 70 f/min
    e) Light Direction: 2 sided
    f) With LED roadwork lamp with one battery, LED unlimited life

g) With bracket for mounting on 54 mm diameter vertical tube
h) Salient features of 1 dry cell battery shall be as follows:
    1) Continuous light: 300 hours
    2) Flashing light: 1,200 hours
i) Salient features of the 1 battery konstant 25 shall be as follows:
    3) Continuous light: 950 hours
    4) Flashing light: 3,800 hours

e. Temporary Crash Cushions Systems (Attenuators)

The Contractor shall be responsible for furnishing, installing and maintaining all temporary detour crash cushions in areas as shown on the Contract plans and required by the Engineer. Location of the crash cushions shall be as directed and approved by the Engineer. The Contractor shall dissemble and remove the temporary detour crash cushions as directed by the Engineer. All crash cushion systems shall meet the requirements of the relevant sections of NCHRP 350.

The Contractor shall be responsible for maintaining local stock of routine impact kits for all types of crash cushions, which are as part of the temporary safety design features.

1. Truck-mounted Attenuator

Truck-mounted attenuators (TMAs) shall be mounted on a vehicle with a minimum weight of 6,800 kg and a maximum weight in accordance with the manufacturer's recommendations. Ballast used to obtain the minimum weight requirement, or any other object that is placed on the vehicle shall be securely anchored such that it will be retained on the vehicle during an impact. The Contractor shall provide certification that the unit complies with NCHRP 350 Test level 3 requirements.

TMAs shall have an adjustable height so that it can be placed at the correct elevation during usage and to a safe height for transporting. If needed, the Contractor shall install additional lights to provide fully visible brake lights at all times. TMA units shall have a chevron pattern on the rear of the unit. Standard chevron pattern shall consist of 100 mm yellow stripes, alternating non-reflective black and retro-reflective yellow sheeting, slanted at 45 degrees in an inverted-V with the V at the centre of the unit.

2. Type 1 Crash Cushions: Redirective, Non-grating

Crash cushions at gore position as shown on the Contract plans shall be redirective, non-grating, comprising of a cartridge assembly units, meeting NCHRP 350, Quadguard® from M/s Quixote Corporation or equivalent as approved by the Engineer.

If required, the Engineer shall review the structural and performance based integrity of a crash cushion after an accident, and shall determine the number of elements to the crash cushion which need to be replaced. Elements and assembly units of a crash cushion shall be replaced by the Contractor with genuine parts from the original manufacturer, as approved by the Engineer. All replaced elements/assembly units after an accident shall be such that the reconstructed crash cushion system meets the NCHRP 350 standards in accordance with the manufacturer's recommendations and Engineer's approval.

3. Type 2 Crash Cushion: Non-redirective

Crash cushion at the gore positions next to the temporary portable barriers on detours shall be shall be React 350 (Reusable Energy Absorbing Crash Terminal) from M/s. Quixote Corp., or an equivalent as approved by the Engineer. This crash cushion shall be redirective, not-gating, reusable make up from arrays of cylinders that have the ability to recover a major portion of their shape, position and capabilities after being impacted meeting NCHRP 350.

f. Portable Steel Barrier Gate

The Contractor shall be responsible for furnishing, installing and maintaining all portable steel barrier gates at emergency median crossovers and in detour areas as shown on the Contract plans or as directed by the Engineer. Portable steel barrier gates shall be Vulcan Barrier/Gate System from M/s. Quixote Corp. or equivalent as approved by the Engineer. Portable steel barrier gate shall be steel longitudinal barriers pinned securely to each other and shall meet the NCHRP 350 standards.

All fabrication, metal work, bolts, nuts, and washers shall be galvanised. If required, the Contractor shall replace damaged elements of portable steel barrier gate with genuine parts from the original manufacturer, approved by the Engineer.

g. Directional Safety Beacon System

Furnishing, installing, and maintaining all directional safety beacon systems in areas as determined by the Engineer shall be the responsibility of the Contractor. Locations of the directional safety beacon systems shall be as directed and or approved by the Engineer.

Directional safety beacon system shall have the following salient features:

- Safety beacons shall be one sided, either left or right with an integrated, amber warning light
- Warning light shall be 5 joules, 180-mm-diameter, high-luminous intensity, with an integrated fault indicator
- Auto solar switch and 1- 6V battery in the beacon housing unit.
- Stripe sheeting shall be red/white, Type 2, in accordance with EN 12352-L7
- Black base plate weighing minimum 28 kg

Systems shall be as pro9vided by M/S Nissan or an equivalent, as approved by the Engineer.

h. Temporary Signage

All temporary signs and appurtenances shall be furnished, installed, maintained, and removed on completion of the works where shown on the Contract plans or required by the Engineer, including the following locations:

1. Where roads are closed, partially closed, or where work is in progress
2. Where required to direct, inform or assist traffic in the area of construction

Temporary signs shall be placed at locations shown on the Contract plans and as directed by the Engineer to direct traffic smoothly and safely.

The Contractor shall submit specimens of signs for approval by the Engineer. The Contractor shall relocate all temporary signs as required by the construction stages or steps and his sequence of construction operations.

Drawings and signs as specified herein are stated in the English language. The Contractor shall provide equal signs in size and description in Arabic at the same locations. Signs in Arabic shall be mounted adjacent to the English signs and as directed by the Engineer.

Temporary signs, panels, and supports shall be either wood or metal and shall be substantially constructed to withstand the climatic conditions of Abu Dhabi. All types of sign panels shall be high intensity grade reflective sheeting. The Contractor shall submit samples of the proposed types of sign panels and supports for approval of the Engineer prior to the fabrication and erection of temporary signs. All posts shall be suitably anchored and as approved by the Engineer.

This item shall be in accordance with Abu Dhabi’s Manual of Uniform Traffic Control Devices (AD-D-11), and shall be of the exclusive colours as illustrated in the Contract plans. All temporary warning signs for detour arrangements and work zones adjacent to live road traffic shall be made from high intensity reflective sheeting, in accordance with ASTM Type III.

Type III reflective sheeting shall consist of spherical or prismatic lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, weatherproof plastic having a smooth outer surface.

Sheeting shall conform to the applicable day time colour and luminance factor requirements of ASTM D 4950 when tested instrumentally or the diffuse day colour of the reflective sheeting shall be visually evaluated by comparison with the applicable highway colour tolerance chart.

Reflective sheeting shall have the following minimum coefficient of retroreflection values at 0.2 degrees and 0.5 degrees observation angle expressed as average candelas per foot-candle, per square foot of material. Measurements shall be conducted in accordance with ASTM E 810.

Table 1-3: Type III glass bead retroreflective element material for temporary signs

Observation Angle	Minimum Retroreflection (candelas/ft-cd/ft^2)							
	Entrance Angle	Silver White	Yellow	Orange	Green	Red	Blue	Brown
0.2^0	-4^0	250	170	100	45	45	20	12
0.2^0	+30^0	150	100	60	25	25	11	8.5
0.5^0	-4^0	95	62	30	15	15	7.5	5.0
0.5^0	+30^0	65	45	25	10	10	5.0	3.5

Sheeting shall conform to the applicable daytime colour and luminance factor requirements of ASTM D4956 when tested instrumentally. Or the diffuse day colour of the reflective sheeting shall be visually evaluated by comparison with the applicable Highway Colour Tolerance Chart. Colour comparison shall be made under north daylight or a scientific daylight having a colour temperature from 6,500 kelvin to 7,500 kelvin. Daytime colour evaluation shall be illuminated at 45 degrees and viewed at 90 degrees. There shall be no significant colour shift when viewed under night-time (retroreflective) conditions.

Reflective sheeting shall have a pre-coated pressure sensitive adhesive (Class 1) or a heat-activated adhesive (Class 2) either of which will adhere to flat, clean surfaces without necessity of additional adhesive coats on the reflective sheeting or application surface. Chemical activators shall not be used to activate Class 2 adhesive.

Pre-coated adhesive shall be protected by an easily removed liner which, when removed, shall not have a staining effect on the reflective sheeting and shall be mildew resistant. Protective liner attached to the adhesive shall be removable by peeling without soaking in water or other solvents and shall be easily removed after storage for 4 hours at 815^o C under weight of 1482 kPa. Sheeting with liner removed, conditioned for 24 hours at 382^o C and 50 % relative humidity, shall be sufficiently flexible to show no cracking when bent around a 30.5-mm-diameter mandrel with the adhesive side contacting the mandrel. For ease of testing, talcum powder may be spread on the adhesive to prevent sticking to the mandrel.

Sheeting surface shall be smooth and flat to facilitate self-cleaning in the rain, regular cleaning, and wet performance, and exhibit 85 degrees glossmeter rating of not less than 50 when tested in accordance with ASTM D523. Sheeting surface shall be readily processed and compatible with transparent and opaque process colours and show no loss of the colour coat with normal handling, cutting, and application. Sheeting shall permit cutting and colour processing at temperatures of 315^o C to 538^o C and 20 % to 80 % RH.

Sheeting shall be heat resistant and permit force curing without staining of unapplied sheeting or applied sheeting at temperatures recommended by the manufacturer not to exceed 815^o C for unapplied sheeting or 1,093^o C for applied sheeting. Sheeting surface shall be solvent resistant to permit cleaning by wiping with a clean soft cloth dampened with VM & P Naphtha or mineral spirits.

Adhesive shall form a durable bond to smooth, corrosion and weather resistant surfaces and permit the reflective sheeting to adhere securely, 48 hours after application at temperatures of -184^o C to

1093º C. Adhesive bond shall be sufficient to render the applied sheeting vandal-resistant and prevent its shocking off when subjected to impact energy of 13.6 joules applied with a hemispherical tipped object 25 mm in diameter at -18º C. Test specimen shall be applied to aluminium backing not less than 2.0mm thick and having a dimension of not less than 2,580 mm2. During testing, the specimen shall be supported on a 75 mm diameter ring. Adhesion test shall conform to ASTM D4956 with the addition of the temperatures noted herein.

Resistance to accelerated weathering shall be as described in ASTM D4956 except the weathering apparatus and procedure shall be in accordance with ASTM G 154.

Reflective sheeting shall be sufficiently flexible to be cut to shape easily and permit application over, and conform to, moderate shallow embossing characteristic of certain sign borders and symbols. Following liner removal, the reflective sheeting shall not shrink more than 0.79 mm in 10 minutes or more than 3 mm in 24 hours in any dimension per 5,800 mm2 at 382º C and 50 % relative humidity.

Sheeting, when applied according to manufacturer's recommendations to cleaned and etched 0.50 mm by 50 mm by 200 mm aluminium, conditioned (24 hours) and tested at 382º C and 50 % humidity, shall be sufficiently flexible to show no cracking when bent around a 19mm diameter mandrel.

Reflective sheeting shall be applied in the manner specified by the sheeting manufacturer. Applied sign face shall not have bubbles, wrinkles, or foreign material beneath the reflective sheeting.

All edges and splices of reflective sheeting signs shall be coated with an edge sealer when recommended by the manufacturer of the reflectorised sheeting.

Splicing of reflective sheeting shall not be permitted on signs or panels with dimensions up to and including 1.2 m in height or width unless the reflective sheeting specified does not come in this width, then the widest width material shall be used. When sheeting joints are required, they shall be lap-jointed with the top sheet overlapping the bottom sheet by no less than 4.75 mm. Fabricator shall endeavour to use the least number of seams possible with the horizontal lap preferable. Roller applied or reverse screened sheeting may be butt-jointed with joint gap not to exceed 0.8 mm. Colour matching of adjacent sheets of reflective sheeting comprising a sign shall be accomplished without a noticeable difference in colour. No borders shall be spliced other than the splice of the tangent border to the corner radius.

Demountable prismatic reflectorised message and borders shall have the following characteristic:

Letters, digits, and alphabet accessories shall consist of embossed 10.2 mm thick sheet aluminium frames confirming to ASTM B209 grade 3003-H14 in which prismatic reflectors are installed to prevent their displacement in handling or service. Letters in which reflectors are assembled by means of tape are unacceptable. Plastic reflectors face shall be colourless and be entirely smooth to present a water repellent and dirt resistant surface. Area indicating the letter shape that is not reflectorised shall be white for maximum daytime contrast with the sign background. All letters shall be free of any imperfections and shall present a high quality appearance. Demountable prismatic border shall be comprised of a minimum length of 600 mm with allowance of one shorter section between each corner radius.

Letters shall be fastened to the sign with aluminium screws or blind rivets conforming to ASTM B209 grade 2024-T4.

Co-efficient of retroreflection of each reflex reflector intended for use in cut-out letters, symbols, and accessories shall be equal to or exceed the following minimum values with measurements made with reflectors spinning.

Table 1-4: Coefficient of retroreflection of reflex reflectors for use in cut-out letters and symbols

Observation angle (degrees)	Entrance angle (degrees)	Coefficient of retroreflection candle power/square inch/foot candle
0.1	0	14.0
0.1	20	5.6

Failure to meet the specific minimum values shall constitute failure of the reflector being used. Upon failure of more than 2 of the 50 samples tested, a resample of 100 reflectors shall be tested. Failure of more than 4 of these samples shall be cause for rejection of the lot.

Maintenance of all signs furnished shall include, but not by way of limitation, all restoration or replacement of reflective sheeting, replacement or other work required to maintain the signs in a condition and position as approved by the Engineer.

At the completion of construction or when directed by the Engineer, all signs shall be removed and disposed of by the Contractor.

i. Construction Identification Signage

The Contractor shall provide and maintain and remove, when directed by the Engineer, construction identification signs for the site as per the requirements of Section 1.15.8. These wooden signs shall be constructed of 7 separate panels as shown on the Contract plans with an overall size of 2.60 m wide by 3.15 m high, all painted with 2 coats of white oil paint back and front and supported 0.60 m above the ground with galvanised steel angle, pipe or tubular framing and struts painted gray or silver and set into the ground and fixed in concrete foundations for adequate support.

Boards shall be lettered in both Arabic and English to include the information as indicated on the Contract plans and as approved by the Engineer.

A large scale layout shall be submitted for approval before manufacture. No advertising material, other than the above, will be permitted. Temporary construction identification signs shall be maintained in good condition, repainted as directed by the Engineer and removed from the site at the end of the Contract to be disposed of as approved by the Engineer. Siting and layout of subcontractors’ and manufacturers' signs shall be approved by the Engineer.

Construction identification signs shall be placed at approaches or the beginning of construction on roads as directed by the Engineer.

j. Temporary Light Standards

Temporary lighting for detour pavements or other detour areas shall be as required or as directed by the Engineer. In all possible cases, the Contractor shall make use of the existing or newly installed permanent lighting system to provide temporary lighting for the detour pavements or areas. When directed by the Engineer, the Contractor shall furnish and install, or install, temporary light standards complete as specified herein.

Temporary light standards (poles) shall be 10 m high with one 250 watt High Pressure Sodium (HPS) lantern and shall be installed staggered on both sides of the temporary detour pavement or as approved by the Engineer. The lighting levels and uniformity for temporary light standards shall be as included in Section 10.8, Lanterns (HID and LED) and Ornamental Lighting, of Chapter 10, Lighting and Electrical Distribution Works. The pole height and wattage of the lantern included herein are for guideline only. The Contractor can propose the lighting system as per detour areas. Temporary light standards shall be furnished and installed by the Contractor as approved by the Engineer.

The Contractor shall make all necessary arrangements for power supply for the temporary lighting system including furnishing and installing all cables, control switches and all related appurtenances required per Abu Dhabi Water and Electricity Authority (ADWEA) regulations for the power supply and all electric power required to operate the temporary light standards. The Contractor shall submit shop drawings with all details of the proposed temporary lighting system to the Engineer for approval.

The Contractor shall furnish and install 10 m high temporary light standards for areas as shown on the approved detour/staging drawings, complete with all components, including but not limited to, single 250 watt HPS lanterns, ballasts, lamps, cables, concrete foundations, base plates, anchor bolts, reinforcement steel, concrete, PVC conduit, controllers, control cabinets, all related appurtenances and power supply. Temporary lighting system shall be maintained by the Contractor at all times until removal is directed or approved by the Engineer.

The Contractor shall maintain the temporary light standards and all light standards damaged by accidents or for any other reason shall be replaced at the Contractor's expense and at no cost to the Owner.

When temporary light standards and all related appurtenances as specified herein are no longer required on the site or when directed or approved by the Engineer, the Contractor shall remove all such temporary light standards from the site which shall become the property of the Contractor and be disposed of as approved by the Engineer.

Existing or newly installed street lighting system shall be incorporated wherever possible for lighting of temporary detour pavement and other detour areas as required or as directed by the Engineer. The Contractor shall make all necessary arrangements with ADWEA; make all payments of any fees or power charges; make modifications to the existing lighting system if required; and maintain and operate the existing or newly installed lighting system for all required temporary detour areas.

The Contractor shall install and supply any additional temporary light standards, cables, controllers, control cabinets and appurtenances as necessary to provide for the complete temporary detour lighting system, while incorporating existing or newly installed street lighting standards where possible, as approved by the Engineer.

The Contractor shall relocate temporary or existing light standards as indicated on the Contract plans, as specified herein and as directed by the Engineer. Relocation of temporary or existing light standards shall be complete with light standard, lantern, cable, power, and all appurtenances.

k. Temporary Signals for Traffic and Pedestrians

The Contractor shall furnish, install, maintain, and remove temporary traffic signals as indicated on the Contract plans, as specified herein, and as directed by the Engineer. All temporary traffic signal poles shall be furnished and maintained with the number of traffic signal units (heads) consisting of red, amber and green signals as directed by the Engineer. Traffic signal units (heads) proposed by the Contractor shall be capable of manual operation as well as standard fixed phase operation from a local controller.

Installation of temporary traffic signals shall be complete with all poles, traffic signal units, conduit, wiring, electric power to all control units and traffic signal units and all appurtenances required for the operation of all units as approved by the Engineer.

The Contractor shall submit all details of proposed temporary traffic signals to the Engineer for approval prior to construction. The Contractor shall maintain all temporary traffic signals and replace any defective or damaged units at no cost or expense to the Owner.

Owner reserves the right to direct the Contractor to obtain all materials, except cables and wiring, for the temporary traffic signals from the Owner. The Contractor shall obtain poles, traffic signal units (heads), controls, and appurtenances, as directed by the Owner, from the designated Owner store yard. The Contractor shall load, transport, unload, and install all such temporary traffic signal poles, complete.

The Contractor shall furnish and install all conduit, cables and/or wiring and electric power to all temporary traffic signal poles and control units required for the operation of all units as approved by the Engineer.

When the temporary traffic signals and all related appurtenances are no longer required on the works or when directed or approved by the Engineer, they shall be removed by the Contractor and materials obtained from the Owner returned to the Owner. All such temporary traffic signals and appurtenances shall be carefully removed, cleaned and suitably protected. Such equipment shall be loaded, transported, unloaded and placed in storage where directed by the Engineer or the Owner.

Temporary traffic signals supplied by the Contractor shall remain his property at completion of the Contract, and shall be removed from the site and/or disposed of as approved by the Engineer unless otherwise specified in the particular specifications.

1. Relocate Temporary Traffic Signals

The Contractor shall relocate temporary traffic signals as indicated on the Contract plans, as specified herein and as directed by the Engineer. Relocation of temporary traffic signals shall be complete with all poles, signal units, wiring, conduits, power, and appurtenances.

2. Temporary Traffic Signal Controllers

The Contractor shall furnish, install and maintain temporary traffic signal controllers and associated equipment as specified herein and as approved by the Engineer. Local intersection control equipment shall perform all functions necessary for the control of traffic signals such as to safely assign rights-of-way to vehicular traffic. Intersection control equipment shall be uniform throughout the Contract unless otherwise approved by the Engineer.

The Contractor shall include all conduit, wiring and appurtenances and all electric power to all temporary traffic signal controllers.

Local control equipment shall include, but not by way of limitation, the following major components:

i. Traffic signal controller
ii. Local intersection controller
iii. Local intersection controller cabinet;
iv. Solid state load switches or electro-mechanical load switches (relays)
v. Intersection conflict monitor;
vi. External flash device
vii. Device so that when red is absent, the signal will automatically switch to flash red (minor traffic flow) and amber (major traffic flow)

Descriptions for each of the major components above are provided herein. The Contractor shall provide any additional equipment necessary to make the system perform in accordance with good traffic engineering practices, and to the satisfaction of the Engineer.

3. Traffic Signal Controllers

All traffic signal controllers shall be pretimed solid state devices. The Contractor shall supply all devices necessary to fully program the solid state as well as the source and object code for the traffic control programs. Timing shall be digital in nature and based on a 50 hertz supply frequency. Number and sequence of phases at each intersection shall be as required, as indicated on the Contract plans or by the traffic patterns and traffic volumes, and as directed by the Engineer.

Controllers shall be capable of withstanding the local temperature and humidity conditions and provide continuous, uninterrupted service under all conditions.

It shall be possible to change controller timing parameters manually from the front of the controller cabinet. All controllers shall provide the following features:

i. Signal indication sequence: Vehicular signal indication sequence shall be green-amber-red. No amber indication shall appear between red and green indications. Capability shall be included to provide all-red clearance intervals for each phase.

ii. Dials: Controllers shall contain a minimum of 4 timing dials.

iii. Cycle length: Signals shall have a cycle length range of 0 seconds to 99.9 seconds, adjustable at 5-second steps.

iv. Number of phases: Capability to accommodate 4 separate phases.

v. Signal intervals: Number of intervals shall range from 1 to 16. Interval timing shall range from 0 seconds to 99.9 seconds, adjustable in 0.1-second steps.

vi. Manual control: Manual controls shall be provided to permit vehicular signals to switch to any related phase, or to display red indication in all directions, or to switch from one time plan to another. When red is absent, the signal shall switch to flash red (minor traffic flow) and amber (major traffic flow).

vii. Flashing mode: For late night operation, signals shall have the capability of operating in a flashing mode whereby vehicular signals controlling the main road shall flash showing amber indication, and vehicular signals controlling the cross road shall flash showing red indication.

The Contractor shall bring electric power to the local controllers in accordance with the ADWEA requirements.

4. Controller Cabinets

All local control equipment at a given intersection shall be mounted in a single waterproof cabinet made of approved materials. All cabinets shall include a ventilation fan and filter. It shall be possible to operate the controller in a manual mode without opening the large door (e.g., via a "police panel"). All equipment necessary to properly mount the cabinets (including mounting poles or foundations if required) and to install the local control equipment in the cabinet shall be provided by the Contractor. An electric power outlet shall be provided in each controller cabinet.

5. Load Switches

Signal light circuits shall be controlled by solid state load switches or electro-mechanical load switches (relays). Each circuit shall have a minimum rating of 600 watts for tungsten lamp or gas tubing transformer load at 240 volts, AC. Switches shall be capable of operating in all local climatic conditions.

6. Intersection Conflict Monitor

An intersection conflict monitor shall be provided for each intersection which shall monitor the output of the green load switches. In the event a conflict condition exists, the conflict monitor shall cause the intersection to go to the emergency flash condition. Intersection shall also go to the emergency flash condition under any of the following occurrences:

i. Absence of required red or amber signal

ii. Absence of security program

iii. Signals hanging indefinitely in one state

iv. Processor fault condition

7. External Flash Units

Each local controller cabinet shall contain a solid state flasher unit to drive the signal lights during periods of controller maintenance or controller malfunction. When operating, the flasher shall flash all red or amber and red indications in designated directions at a rate of 60 flashes per minute. It shall be possible to remove control of the signal lights from the local controller and give control to the flasher unit in the following manner:

v. Manually changing position of a single switch

vi. Action of a conflict monitor

vii. Action of a watchdog timer, as applicable

8. Watchdog Timer

A watchdog timer shall be provided and installed, and shall be used with solid state based controllers. Purpose of this timer is to prohibit faulty controller operation from causing the signal light indication to "hang" indefinitely in one state. When used, the controller shall reset the timer periodically. If allowed to time out, the watchdog timer shall cause the signal lights to be put in the flash mode. Watchdog timer may be either part of the hardware of the local controller or an external device. All switches, solid state components and other ancillary equipment necessary to provide the operation just described shall be provided and installed by the Contractor.

9. Temporary Traffic Signal Controllers, Supplied by Owner

Owner reserves the right to direct the Contractor to obtain all temporary traffic signal controllers, except cables and/or wiring, from the Owners store yards. The Contractor shall obtain the temporary traffic signal controllers, as directed by the Owner, from the designated store yard. The Contractor shall load, transport, unload, and install all such temporary traffic signal controllers, complete. The Contractor shall furnish and install all conduits, cables and/or wiring and electric power to all temporary traffic signal controllers required for the operation of all units as approved by the Engineer.

10. Relocate Temporary Traffic Signal Controllers

The Contractor shall relocate temporary traffic signal controllers as indicated on the Contract plans, as specified herein and as directed by the Engineer. Relocation of temporary traffic signal controllers shall be complete with all associated equipment and electric power to the relocated controllers, wiring, conduits, and appurtenances.

l. Flaggers

Where directed by the Engineer, the Contractor shall provide and station competent flaggers whose sole duties shall consist in directing the movement of pedestrians and traffic through or around the works. Flaggers, flagging stations, equipment, and operations shall be consistent with the MUTCD treatment of these topics and shall meet the requirements stated therein.

m. Temporary Utility Protection and Removal at Detour Roads

The Contractor shall furnish and install temporary concrete slab protection and/or temporary concrete encased split PVC duct at detour road and construction equipment crossings of utilities as indicated on the Contract plans or as directed by the Engineer. All such temporary utility and service protection shall be as detailed on the Contract plans and as specified in the applicable sections of Chapter 11, Utilities.

The Contractor shall be responsible for all costs, expenses and other expenditures required repairing or restoring any damaged utility, service property, and/or structure. In the event the concerned governing agency or owner of such damaged utility, service, property, and/or structure elects to make necessary repairs or restoration with their own forces or designated Contractor, the Contractor shall bear all costs, expenses or other expenditures involved or incurred by said governing agency or owner. The Contractor shall directly resolve with the concerned agency, Owner, or owner the extent of repairs, costs, expenses, or other expenditures as required.

Unless otherwise directed by the governing agency or owner of the utility and/or service that the temporary protection shall remain in place, the Contractor shall remove and dispose of all temporary utility protection slabs and split ducts as required per the relevant sections in Chapter 11, Utilities, as soon as the temporary crossing is removed from service.

n. Temporary Electrical Work

All temporary electrical work shall be protected by ground fault circuit Interrupters (GFCI) and shall be in accordance with the AGC Manual of Accident Prevention in Construction.

All connections and installation shall be in compliance with ADWEA Regulations.

If portable generators are used to supply temporary power needs, the generators shall be grounded, inspected and documented on a regular basis for proper operation.

All temporary electrical work shall be inspected on a weekly basis and audited by a certified electrician and results documented.

o. Accommodation of Existing Conditions

1. Existing Informational, Guide, Street Name and Numbering Signs

In locations where existing informational, guide street name and numbering signs conflict with proposed improvements, the Contractor shall adopt the following procedure for their removal, storage and reinstatement.

i. The Contractor shall obtain the applicable forms from the appropriate authority to apply for permission to remove the signs.

ii. Only after permission has been granted, the Contractor shall proceed with the removal of the sign.

iii. It is the Contractor’s responsibility to remove, store and reinstate the signs upon completion of the works, to the satisfaction and approval of the relevant authority and the Engineer. The Contractor shall be responsible for the safety of the sign and shall replace and/or repair signs damaged by him or through his negligence.

iv. If the sign is not to be reinstated in the same location, the foundation shall be demolished or removed along with all associated cabling, conduit, pull boxes and other appurtenances with the resulting excavations being properly backfilled in accordance with the specifications.

v. When appropriate, the Contractor shall have any new locations approved by the relevant authority before commencing the reinstatement works.

vi. The Contractor shall construct new foundations, all necessary ducting and pull boxes, reinstall the previously removed signs, and if applicable, reconnect the sign to a suitable power source.

vii. The Contractor shall obtain a clearance certificate from the relevant authority to record that the signs have been reinstated to their satisfaction.

2. Existing Roadside Structures and Street Furniture

In locations where existing roadside structures and street furniture (includes such items as bus stop shelters, fountains, shade structures, play equipment, benches and other miscellaneous. roadside items as identified on the Contract plans or as directed by the Engineer) will conflict with roadway improvements, the Contractor shall advise the relevant authority and then proceed to carefully remove those structures when required for construction. The removed structures shall be stored in a manner and at a location acceptable to the relevant authority while construction proceeds.

After removal of the structures, their foundations shall be demolished (or removed if such can be suitably done) with the ensuing excavations being properly backfilled.

In coordination with the relevant authority and with the approval of the Engineer, locations for the reinstatement of the removed structures compatible with roadway improvements shall be determined. The Contractor shall then construct new foundations and/or reinstate removed foundations and reinstall the previously removed structures.

All work related to the removal, storage and reinstatement of the existing structures shall be done in accordance with the requirements of the relevant authority. The Contractor shall be responsible for the safety of the structures and shall replace and/or repair any damage caused by him or through his negligence.

3. Removal, Protection and Transportation of Trees, Palms and Shrubs for Transplanting

Where directed by the Engineer the Contractor shall carefully excavate and protect all existing trees, palms and shrubs identified for transplanting on the Contract plans or by the Engineer and transport to other locations specified by the Engineer, and replanted. All removal, transporting and replanting shall meet the applicable requirements of Chapter 13, Landscaping and Irrigation.

p. Rumble Strips

The Contractor shall be responsible for furnishing; installing and maintaining all rumble strips on approaching roadways, detour pavement, other temporary roadways and on service roads as directed by the Engineer. Maintenance shall include all labour, materials, tools, equipment and appurtenances to remove deteriorated rumble strips and to furnish and install replacement or new rumble strips as approved by the Engineer. The Contractor shall remove all rumble strips from the site and disposed of as approved by the Engineer when no longer required.

Material, execution, layout, machinery and equipment utilised in application of rumble strips for the works as described above shall conform to Section 8.4.5 of Chapter 8, Traffic Marking and Signs. Width, colour, length, and location of rumble strips shall be indicated on the Contract plans for the intended use on the detour pavement, other temporary roadways and on service roads as directed by the Engineer.

Rumble strips shall be 6 mm thick and 200 mm wide. Rumble strips material shall be applied in 2 equal layers, with glass beads applied uniformly on the top layer only.

q. Temporary Pedestrian Access and Safety Items

The Contractor shall be responsible for furnishing, installing and maintaining all temporary pedestrian access and safety items in areas as determined by the Engineer, where construction operations result in a condition that is considered to be hazardous to the general public, to maintain pedestrian access or to separate the work area from pedestrian areas. Location and extent of the temporary access and safety items shall be as directed and approved by the Engineer. Temporary pedestrian access and safety items shall remain the property of the Contractor and shall be removed from the site of the works as approved by the Engineer when no longer required. Temporary pedestrian access and safety items may be of the following:

- Temporary sight screen
- Temporary pedestrian wire fence
- Temporary pedestrian bridges
- Temporary sidewalks

1. Temporary Sight Screen

In areas as determined by the Engineer, where sensitive construction operations are to be screened from the general public, the Contractor shall construct temporary sight screen fencing to separate the work area from public view. Location and extent of the fencing shall be as directed and approved by the Engineer.

Fencing shall be solid and continuous, not less than 3.0 m in height. Screen shall be constructed of painted wood or metal and shall be neat in appearance. Details of construction shall be as proposed by the Contractor and approved by the Engineer. Fencing shall be of substantial construction such that it will not be damaged or displaced by wind or other normal natural or manmade forces. Fence shall be maintained by the Contractor until such sensitive operations are complete as approved by the Engineer.

Maintenance and upkeep of the screens shall be the responsibility of the Contractor throughout the duration of their use.

2. Decorative Painting on Temporary Sight Screen

If directed, the Contractor shall apply a decorative painted finish to the temporary sight screens used on the project. Decorative painted finish shall be applied only to the surface exposed to the general public view.

Form of the decoration shall be a multi-coloured, maximum 3 colours, geometric or free flowing pattern, with simple stencilled details such as a tree, Municipality logo or similar item, at an interval of approximately 20 m.

3. Temporary Pedestrian Wire Fence

Where pedestrians must be separated from the work site, or directed through work zones and detour traffic, the Contractor shall install temporary pedestrian wire fences as directed or approved by the Engineer. Temporary pedestrian wire fences shall meet the requirements of Section 7.7 of Chapter 7, Incidental Construction.

4. Temporary Pedestrian Bridges

In areas as determined by the Engineer, the Contractor shall construct temporary pedestrian bridges to maintain the access. These areas include, but not by way of limitation:

i. Locations where trench excavations obstruction pedestrian access to buildings

ii. Bridges over the proposed detour routes and work areas

Bridge shall be solid and continuous, not less than 1.5 m in width, with rigid hand rails. Bridge shall be constructed of wood and/or metal and shall be neat in appearance. Details of construction and the installation locations shall be proposed by the contactor and approved by the Engineer.

The Contractor shall maintain the bridge until the trench excavations are backfilled and public right of way is no longer obstructed as directed and approved by the Engineer.

Bridges shall be multi-span, providing a clear span of 40 m to 45 m, and provide a minimum vertical clearance of 6.5 m. Walkway width shall be in the range 1.8 m to 2.0 m.

Bridge shall be of modular steel construction with aluminium or other approval deck, and shall have wooden access stair treads. All walking surfaces shall be non-slip. Actual span configuration of each bridge shall be as determined by the site conditions. All support towers and stairs shall be adequately protected from impact by passing traffic.

These bridges shall not be used by the Contractor for any construction activities.

The Contractor shall submit fully detailed shop drawings of all proposed temporary pedestrian bridges for the Engineer's review and approval. Bridges shall be fully compliant with the design requirements of the Abu Dhabi Road Structures Design Manual (AD-D-06). Details provided shall include the proposed foundation details.

5. Temporary Sidewalk

Temporary sidewalk shall be installed at the locations as shown on the Contractor's approved detour plans, or as directed by the Engineer. Construction shall meet the applicable installation requirements of Section 7.6.3 of Chapter 7, Incidental construction, except as noted herein. Temporary sidewalks shall meet the general requirements of Article 7.6.3.1 for slopes and grades.

Prior to placement of pavement for temporary sidewalks, the Contractor shall prepare a foundation in accordance with Article 7.6.3.2 of Chapter 7, Incidental construction, or as approved by the Engineer.

On the prepared subgrade, the Contractor shall place and compact either 5 cm of asphaltic concrete base course as specified in Section 3.3 of Chapter 3, Pavement, or Class C20/20 concrete as specified in Section 7.6.4 of Chapter 7, Incidental construction, for use as temporary sidewalk. Installation of asphaltic concrete temporary sidewalks shall meet the applicable installation requirements of Section 3.3.3, with the provision that hand placement and compaction may be used for areas inaccessible to the approved asphalt paving equipment, if approved by the Engineer. Installation of concrete temporary sidewalks shall meet the requirements of Section 7.6.4.

When no longer required, the Contractor shall remove all construction of temporary sidewalks and restore the site as required by applicable Articles of the Department of Transport Conditions of Contract and Schedule of Further Requirements, as indicated on the Contract plans and as directed by the Engineer.

All materials resulting from removal of temporary sidewalk shall be considered the Contractor's materials to be removed from site and/or disposed of in accordance with Section 2.3 of Chapter 2, Earthworks.

r. Detour Shop Drawings

The Contractor shall follow maintenance of traffic (detour plans) plans included in the Contract, unless otherwise directed by the Engineer, and shall obtain all necessary approvals from the appropriate local agencies. If modifications are proposed by the Contractor to the maintenance of traffic Contract plans, the Engineer shall have the right to reject any proposed modifications that are not acceptable to the Owner or do not comply with the requirements of the Contract documents.

The Contractor shall submit shop drawings complete with all details and description of construction staging and temporary construction for the maintenance of traffic as indicated on the Contract plans and as necessary for the proposed construction sequence, and obtain the approval of the Engineer prior to reviewing with and obtaining local agency and authorities approvals.

Vehicular and pedestrian access to facilities within the local area affected by the construction works must be maintained at all times.

The Contractor shall construct detours and install temporary traffic control devices in accordance with the approved shop drawings, standard specifications, and the Contract plans. The Contractor shall be responsible for coordinating the relocation and removal of all greenery which obstructs the construction of the detour route. Similarly, it shall be the Contractor's sole responsibility to obtain the necessary clearances and approvals for detours which conflict with existing or proposed utility installations.

The Contractor shall consider the use of additional sub-stage detours to facilitate any utility installations in service reservation crossings that pass under existing roads or detour routes. All such utility installations shall be fully reviewed with the Engineer prior to commencing each detour phase.

1. Criteria for Revising Detour Shop Drawings

Flow of traffic shall be maintained at all times. Traffic will not be permitted to pass under bridges which are under construction, unless adequate protective cover is provided.

Temporary roadway cross sections and pavement structure sections shall be as detailed in the Contract plans.

Temporary roadway widths for main road detours shall be a minimum of 2 lanes in each direction, each lane 3.5 m wide, plus a paved shy distance on the inside and outside edge of pavement as detailed on the Contract plans unless specifically directed or approved otherwise by the Engineer.

All construction staging or substaging shall be approved by the Engineer in writing prior to commencing construction. After approval by the Engineer, the Contractor shall obtain approvals in writing from the concerned authorities.

The Contractor shall provide and maintain vehicle and pedestrian access to adjacent buildings, commercial establishments, facilities, or areas during all work. Such access and its maintenance shall be subject to approval by the Engineer.

Single lane traffic may be proposed by the Contractor when no other means of detouring is available and when approved by the Engineer.

In general, one lane of traffic shall be maintained on the service roads and detour roads on isolated sections and the lengths of isolated approved single lanes (along a multi-lane road) shall not exceed 500 m and, in the event work is proceeding at more than one place, the distance between lengths of single lanes shall be no less than 500 m unless otherwise approved by the Engineer.

The Contractor shall propose his detour to offer the least possible obstruction, inconvenience and delay to public traffic, and shall be responsible for providing adequate control of public traffic using these single lane lengths as previously specified.

Existing roadways shall be used for detours whenever possible.

Works shall be scheduled in accordance with the Contract staging plans as approved by the Engineer.

1.16 Temporary Works

This section describes the design, construction, maintenance, and removal of temporary works, which are generally designed and employed by the Contractor to execute a work. Failure of such temporary works can negatively affect project work and endanger adjacent facilities, property, or the public. Temporary works for structure include falsework, forms, cofferdams, shoring, water control systems, and temporary bridges.

Safety and adequacy of all temporary works shall be solely the responsibility of the Contractor.

Forms are enclosures or panels that, containing concrete, resist contrary forces due to their weight, rate of/ and placement. Forms may themselves reside on top of falsework for additional support. Falsework is any temporary structure that supports structural elements, such as concrete slabs, girders, steel, and masonry, during their construction. Falsework is no longer needed after a structure is complete and can support itself including surcharge load.

1.16.1 Working Drawings for Temporary Works

The Contractor shall provide working drawings with design calculations and supporting data and assumptions in sufficient detail to permit a structural review of the proposed design of a temporary work. The Contractor shall submit working drawings and design calculations sufficiently in advance of proposed use, typically at least 14 days before the Engineer's approval is required, to allow time for review, possible revision, and approval without delaying work.

The Contractor shall design and show the details for constructing the temporary works including falsework that provides the necessary rigidity and supports the loads to be imposed on them. The Contractor shall engage the services of a Specialist Engineer to design, sign, and seal the drawings. Design calculations shall show the stresses and deflections in load supporting members.

The Contractor shall submit three sets of working drawings and one set of design calculations for approval.

1.16.2 Design Details for Temporary Works

The Contractor shall include the information and details necessary to enable temporary works construction without reference to any supplemental drawing, calculation sheet, design standard, or other source document. For falsework, the Contractor shall show all dimensions that control the design and erection of falsework, including beam lengths, distances between beams, post locations, distances between posts, vertical distances between connections in diagonal braces, and the heights of falsework bents (braced frames).

The Contractor shall show the maximum applied dead and live structural loads on each foundation. Information from the Contractor shall include a drainage plan that describes how work structures will protect foundations from saturation, erosion, and scouring.

The Contractor shall show anticipated total settlements of falsework and forms, including falsework footing settlement, joint take-up and elastic deformation. By design, anticipated settlements shall not exceed 20 mm. Each falsework shall be designed and constructed to elevations that include anticipated settlement during concrete placement and required camber to compensate for member deflections during construction.

Temporary waterway bridges shall span the desired water opening and have dimensions that avoid constricting any stream's flow while such bridges are in use. To meet basic design criteria, the bridge system shall be sufficient for a 5-year frequency storm (that is, the worst storm that is anticipated within any five-year period), with allowance for 150 mm of backwater. The plans shall show the minimum bridge lengths between abutment piling and the resultant water elevation caused by a five-year frequency storm. To determine a minimum low superstructure elevation, the Contractor shall use the given high water elevation and consider local conditions. A temporary work for structure shall have the minimum roadway width specified in the particular project specifications, as measured between the faces of the railings or curbs and at right angles to the centreline. Vertical abutments shall, by design, prevent spilling fill material into the water. Any temporary crossing over sea water that is subject to boating shall provide horizontal and vertical clearance in accordance with the appropriate jurisdictional agency.

1.16.3 Materials for Temporary Works

The Contractor shall precisely describe all materials for proposed temporary works, including materials that are not designated by standard nomenclature (such as AASHTO or ASTM specifications), based on manufacturer‘s tests and recommended working loads. The Contractor shall evaluate materials for temporary works and ascertain whether their physical properties and conditions are sufficient to support the design's assumed loads.

1.16.4 Concrete Placement for Temporary Works

The Contractor shall provide an outline of the proposed concrete placement operation with a list of the equipment, labour, and procedures to be used for the duration of each operation. The Contractor shall include details, such as proposed placement rates and design pressures, etc for each pour. Information from the Contractor shall include a superstructure placement diagram that shows the sequence of concrete placements and construction joint locations.

1.16.5 Openings in Temporary Works

The Contract plans shall show the locations of all openings through a falsework that enable public traffic to pass. The Contract plans shall include all horizontal and vertical clearances and the locations of temporary railing. For falsework over traffic, the Contract plans shall show the sequence of falsework erection and removal. The Contractor shall submit separate falsework drawings for each structure, except for structures with entirely identical falsework designs and details. Construction of any unit of falsework shall not begin until the project Engineer has reviewed and approved the drawings for that unit including requirements for height warning structures and locations.

1.16.6 Requirements for Temporary Works

Temporary works must, by design, support all loads imposed and provide the necessary rigidity to enable the production of final structures. Temporary work designs shall conform to AASHTO LRFD Bridge Design Specifications or AASHTO Guide Design Specifications for Bridge Temporary Works.

When a temporary work includes manufactured devices, the design shall ensure that loads on such devices do not exceed the strength load recommended by each device's manufacturer, and verified by test certificates.

For equipment where the rated capacity is determined by load testing, the design load shall be as stated in the generally accepted design code or specification for such work.

Load ratings for special equipment, such as access scaffolding, may be under the jurisdiction of local regulations. However, in no case shall the load on an item of equipment exceed eighty percent (80%) of maximum load sustained during its load testing.

When so required or specified in Contract documents, a professional Engineer shall prepare and sign designs and drawings for temporary works. Professional Engineer shall be otherwise licensed as a structural Engineer or have documented experience and training that can be verified by the Engineer for approval as having the necessary recognized qualifications.

Temporary works shall be constructed in agreement with the approved working drawings.

The Contractor shall verify that materials and workmanship meet or exceed the level of quality indicated in the designs.

1.16.7 Removal of Temporary Works

Unless otherwise specified, all temporary works shall be removed and shall remain the property of the Contractor upon completion of their use. The Contractor shall clean the project area and restore it to its original or planned condition. Final cleanup of a work site includes completely removing all temporary works, unless the project Engineer directs otherwise, and cleaning the work site of all debris.

1.16.8 Falsework and Forms

Falsework and forms shall be sufficiently rigid and strong to safely support all loads imposed on them and to produce in the finished structure the lines and grades indicated in the Contract documents. Forms shall impart the required surface texture and rustication and shall not detract from the uniformity of colour of the formed surfaces.

1.16.8.1 Materials for Falsework

Materials to be used in falsework construction may be new or used manufactured components. Concrete, reinforcing steel and structural steel that will be part of falsework shall conform to the relevant chapters in these standard specifications, other Abu Dhabi Owner specifications and standards, and any specific Contractual project requirements. When used materials are proposed, fatigue shall be considered in design calculations.

If so directed, the Contractor shall supply material certifications for new materials. Concrete tests should be performed as described in Chapter 4, Concrete Works, and Chapter 21, Concrete Structures, of these standard specifications. All salvaged and used material and manufactured components are subject to approval.

a. Salvaged Steel for Falsework

Falsework may include used structural steel for surface imperfections at the allowable working stresses for new material if the grade of steel can be identified and the used steel meets the criteria outlined in ASTM's Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling (ASTM A6 / A6M). Falsework shall not include unidentified steel.

b. Timber for Falsework

All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are not long enough to cap at the desired elevation for the horizontal members, the Contractor shall cap them and construct frames to the proper elevation. The Contractor shall cut the ends of vertical members so that they are square and support the full bearing without the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, with square-cut ends for full bearing, and the Contractor shall scab the splices in a manner proscribed and approved by the project Engineer.

All wood species for which the National Design Specification for Wood Construction (NDS ANSI/AF&PA NDS-2005), published by the National Forest Products Association in the U.S., assigns allowable stresses are acceptable for use in falsework construction for the Owner.

c. Used Lumber for Falsework

Used lumber of known species may be used in falsework construction if the grade is known and the lumber is in good condition. Owner does not permit the use of lumber of unknown grades, unless the Contractor performs appropriate standard tests to establish the grade of lumber.

d. Manufactured Components for Falsework

Temporary works may include manufactured components of the following proprietary product classes:

a. Vertical shoring systems, including tubular welded frame shoring, tube and coupler shoring, and components thereof

b. Manufactured assemblies, including single-post shores, brackets, jacks, joists, clamps, and similar devices manufactured for commercial use

1.16.8.2 Materials for Forms

Forms used for concrete shall be wood, steel, or other approved material and shall be cement grout tight, true to the dimensions, lines, and grades of the structure, and of sufficient strength to prevent appreciable deflection during placement of concrete. Unless otherwise specified, variations must comply with the values in Table **1-5** to be permissible.

Table 1-5: Maximum dimensional tolerance for cast-in-place formed concrete(*)

Item	Tolerance (mm)
Deviation from plan line(**)	±25 mm
Cross-sectional dimensions of columns, piers, beams, slabs, and walls	+25 - 12 mm
Bridges desk thickness	+12 - 6 mm

* Variations are to be compared with dimensions shown on the Plans or directed by the Engineer.

**Tolerance measurement is perpendicular to the plan line or surface. This tolerance includes measurement of alignment, plumb, grade and level. Plumb (or batter) of retaining walls will be inspected both before and after backfilling.

a. Sheathing for Forms

For exposed concrete surfaces, the Contractor shall use class I plywood as defined in the U.S. Department of Commerce National Institute of Standards and Technology (NIST) Voluntary Product Standard PS 1, Structural Plywood. Such material produces a smooth and uniform concrete surface. Form panels to be used should be in good condition without any defects on exposed surfaces. If the Contractor uses form panel material other than plywood, it shall have flexural strength, modulus of elasticity, and other physical properties equal to or greater than the physical properties of class I plywood.

b. Structural Support for Forms

Materials for structural support of forms shall comply with the materials requirements for falsework. Owner classifies vertical side forms, wall forms, and column forms, as well as related studs and waler brackets, as formwork or structural support for formwork.

c. Prefabricated Formwork

If the Contractor uses prefabricated formwork, they shall furnish shop drawings and technical data that substantiate the formwork's load-carrying capacity and detail application instructions and limitations. The Contractor shall use prefabricated products in accordance with their manufacturers' recommendations.

d. Stay-in-place Steel Deck Forms

The Contractor may use stay-in-place steel deck forms if such are permitted in the Contract documents or with the Engineer's approval. In such cases, the Contractor shall furnish design calculations with shop drawings. Stay-in-place steel deck forms and supports shall be fabricated from grade 275 or grade 340 steel that conforms to the specifications in ASTM's Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process (ASTM A 653 / A653M). Such forms shall have a coating class of G165 in accordance with the same specification.

e. Stay-in-place Prestressed Concrete Deck Forms

The Contractor may use stay-in-place prestressed concrete deck forms if such are permitted in the Contract documents or with the Engineer's approval. In such cases, the Contractor shall furnish complete deck design calculations with the shop drawings. Stay-in-place concrete deck forms shall be fabricated in accordance with the requirements outlined in Chapter 21, Concrete Structures, and Chapter 22, Prestressing Systems, of these standard specifications.

f. Steel Formwork

Where external vibrators are likely to come into contact with forms, the Contractor shall use steel formwork. All joints and holes shall be caulked or covered with tape, which shall be firmly fixed by means of spirit glue or other oil and grease resistant adhesive. All rivets and bolts on the inside of the formwork shall be countersunk. Steel formwork shall be painted white on the outside.

For precast concrete beams, the Contractor shall use only steel forms that are in good condition. They should be sufficiently thick and stiff, with effective braces and anchors, to withstand the forces that result from placement and vibration of the concrete without losing correct alignment. The Contractor shall thoroughly clean forms and coat them with a bond breaker before each use. Joints must fit tightly to avoid loss of grout and to avoid rough blemishes on the concrete.

1.16.8.3 Falsework Design and Construction

A falsework shall provide the necessary rigidity to support all loads placed upon it without appreciable settlement or deformation. When falsework cannot be founded on rock, shale, or thick deposits of other compact material in their natural beds, wood or metal bases shall support the columns of such falsework. Falsework shall not be supported on any part of the structure, except the footings, without written permission from the Engineer. The number and spacing of false work columns, the adequacy of sills, caps, and stringers, and the amount of bracing in the falsework framing shall be subject to approval of the Engineer. Engineer may not permit the Contractor to proceed with other phases of the work if he deems any falsework unsafe or inadequate to properly support all loads to which it will be subjected.

Engineer's approval of falsework plans or permission to proceed with the project work shall not relieve the Contractor of the responsibility to successfully erect falsework and to otherwise produce satisfactory results.

a. Designs for Falsework

The Contractor shall complete and submit designs for all falsework, with detailed proposals, to the Engineer or an appropriate representative of the project Engineer for agreement before commencing any work on the project.

Design loads and allowable stresses for falsework shall conform to the AASHTO LRFD Bridge Construction Specifications.

Falsework design calculations shall show all of the following details:

1. Stresses, strains and deflections in load supporting members
2. Anticipated total settlements of falsework and forms, which shall not exceed 20 mm, including falsework footing settlement and joint take-up
3. Details of falsework supporting deck slabs and overhangs on girder bridges that will ensure consistent settlement between the girders and the deck forms during the placement of deck concrete
4. Elevations of falsework, including anticipated settlement during concrete placement and required camber to compensate for member deflections during construction
5. Details of strengthening and protecting falsework over or adjacent to roadways and railroads during each phase of erection and removal
6. Intended steel erection procedures with calculations in sufficient detail to substantiate that the girder geometry will be correct
7. Falsework spans that support T-beam girder bridges, which shall be limited to 4.3 meters plus 8.5 times the overall depth of related T-beam girders

b. Manufactured Assemblies for Falsework

For jacks, brackets, columns, joists and other manufactured devices, the ultimate load carrying capacity of a falsework assembly shall not exceed the manufacturer's recommendations or forty percent of the ultimate load carrying capacity that has been determined by actual destructive testing.

The Contractor shall furnish catalogue or equivalent data that shows the manufacturer's recommendations. Otherwise, the Contractor shall perform tests, as necessary, to demonstrate the adequacy of any manufactured devices proposed for use. The Contractor shall not substitute components from another manufacturer unless the primary manufacturer's data encompasses such substitutions or field tests affirm the integrity of such substitutions.

If a component of the falsework system consists of a steel frame tower that is two or more tiers high, the differential leg loading within the steel tower unit shall not exceed a 4 to 1 ratio. Engineer may approve an exception, if the manufacturer of the steel frame certifies, based on manufacturer's tests, that the proposed differential loadings are not detrimental to the safe load carrying capacity of the steel frame.

c. Foundations for Falsework

Falsework shall be founded on a solid footing, safe against undermining, protected from softening, and capable of supporting the loads imposed on it. When so requested by the Engineer, the Contractor shall conduct suitable load test to demonstrate that the soil bearing values assumed for the design of the falsework footings do not exceed the supporting capacity of the soil. Falsework that cannot be founded on a satisfactory footing shall be supported on piling which shall be spaced, driven, and removed in an approved manner, if or as required. Before designing a falsework, the Contractor shall verify, in the field, all ground elevations at proposed foundation locations.

Footing edges shall not be closer than 300 mm from the intersection of the bench and the top of a slope. Unless the excavation for footings is adequately supported by shoring, the edge of the footings shall not be closer than 1.2 m or the depth of excavation, whichever is greater, from the edge of the excavation.

When falsework is supported by footings placed on paved, well-compacted slopes of berm fills, such falsework shall not be strutted to columns unless the column is founded on rock or supported by piling.

When individual steel towers have maximum leg loads that exceed 130 kN, the Contractor shall provide for uniform settlement under all legs or each tower under all loading conditions.

For the duration of its use, a falsework's foundation shall be protected from adverse effects. The Contractor shall take necessary precautions to protect the foundation of a falsework.

d. Deflections for Falsework

For cast-in-place concrete structures, calculated deflections of falsework and formwork members shall be limited as follows:

1. Vertical deflection for falsework members shall not exceed 1/360 of the span under the dead load of the concrete only, regardless of whether deflection is compensated for by camber strips.
2. Deflections for formwork (other than sheathing) shall not exceed 1/360 of the span under the dead load of the concrete only or the lateral pressure of fluid concrete only.
3. Deflection for sheathing formwork shall not exceed 1/270 of the centre-to-centre distance between studs, joists, form stiffeners, form fasteners, or waler brackets.

e. Clearance

Clear horizontal openings for roadways that are to remain open to traffic during construction shall be at least 1.5 m wider than the travelled approach way, between barriers, and be at least 6.50 m high to ensure minimum vertical clearance over roads.

f. Construction

Falsework shall be constructed and set to grades that allow for anticipated settlement and deflection. Falsework shall allow for the vertical alignment and camber indicated on project plans or as ordered by the project Engineer for the permanent structure. Camber shall be provided for the falsework to account for the falsework's deflection and the anticipated deflection of the main structure. To assure appropriate camber, when so directed by the Engineer, the Contractor shall use variable depth camber strips between falsework beams and soffit forms.

The Contractor shall use suitable screw jacks, pairs of wedges, or other devices at each post to adjust falsework to grade, to permit minor adjustments during the placement of concrete or structural steel if observed settlements deviate from those anticipated, and to allow for the gradual release of the falsework. The Contractor shall provide telltales attached to the forms and extending to the ground, or other suitable means, to accurately measure settlement of a falsework during the placement and curing of concrete. Screw jacks, if used, shall be adequately braced and secured to prevent their tipping in any direction.

Falsework or formwork for deck slabs on girder bridges shall be supported directly on the girders so that there will be no appreciable differential settlement during placement of the concrete. The Contractor shall brace and tie girders to resist any forces including uplift that would cause rotation or torsion of the girders that could be caused by the placement of concrete for diaphragms or decking. Unless given specific permission from the project Engineer to do so, the Contractor shall not weld falsework support brackets or braces to structural steel members or reinforcing steel.

The Contractor shall systematically and sufficiently locate telltales and attach them to soffit forms to enable the Contractor and Engineer to determine, from the ground, the total settlement of a structure while concrete is being placed.

Unless so authorized, the Contractor shall not apply dead loads, other than forms and reinforcing steel, to any falsework.

If unanticipated events occur, the Contractor shall discontinue concrete placement and take corrective action to correct settlements that deviate more than 10 mm from those shown on the falsework drawings. The Contractor shall remove all unacceptable concrete that results from a failure to take corrective action before the initial set.

g. Testing and inspection of Falseworks

All falseworks shall be tested and inspected by the Contractor and approved by the Engineer before any load is placed on it, but such approval shall not relieve the Contractor of his responsibility for the safety, accuracy or efficiency of the falsework.

1.16.8.4 Formwork Design and Construction

Forms shall be wood, steel, or other approved material and shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads that are incidental to the construction, including vibration. Forms shall be constructed and maintained to prevent the opening of joints due to shrinkage of the lumber; forms shall permit easy removal without damage to the concrete. Before using a form lining, the Contractor shall submit samples, specifications, and other pertinent information to the Engineer to secure written permission to use the lining.

Forms for concrete surfaces that are exposed to view shall be new and shall produce a smooth surface of uniform texture and colour that is substantially equal to that which would be obtained with the use of plywood that conforms to the requirements outlined in the U.S. Department of Commerce National Institute of Standards and Technology (NIST) Voluntary Product Standard PS 1, Structural Plywood.

Form lining material shall not bulge, wrap, or blister. It shall not stain concrete. To minimize joints, the Contractor shall use form lining in the largest practicable panels. Small panels of the lining material shall not be permitted. Joints in the lining shall be tight and smoothly cut. Arrangement of panels that line forms shall ensure that joint lines form a symmetrical pattern that conforms to the general lines of the structure. Placement of adjacent panels of form lining shall ensure that wood grain lies in the same general direction (either all horizontal or all vertical). The Contractor shall not use thin metal form lining. Undressed lumber of uniform thickness may serve as backing for a form lining.

As an alternative to such lined forms, the Contractor may use wooden ply forms of adequate thickness and with proper support to meet the requirements outlined in this section.

A single structure shall have the same type of form-lining material throughout. Such forms shall be sufficiently rigid so that the undulation of the concrete surface shall not exceed 3 mm when checked with a 1500 mm straightedge or template. The Contractor shall chamfer all sharp corners approximately by 20 mm x 20 mm.

The Contractor may use metal forms, which are subject to the same requirements and approvals as wood forms. Metal shall be sufficiently thick to ensure that such forms remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins, or other connecting devices shall hold metal forms rigidly together and allow removal without damage to concrete. Metal forms shall present a smooth surface and line up properly. The Contractor shall keep metal forms free from rust, grease, and other foreign matter. If the performance of such metal is not satisfactory, the Engineer may require their discontinuance at any time. Engineer will not approve the use of steel panels, panels with metal frames and wood, or panels with combination facings that leave permanent impressions or ridges.

a. Designs for Forms

The Contractor shall complete and submit designs for all forms, with detailed proposals, to the project Engineer or an appropriate representative of the Engineer for agreement before commencing any work on the project.

Structural design for formwork shall conform to the standards outlined in the American Concrete Institute (ACI) Guideline to Formwork for Concrete (ACI 347) or an equivalent generally accepted standard. In selecting the hydrostatic pressure to be used in the design of forms, the Contractor shall consider the maximum rate of concrete placement, the effects of vibration, concrete temperature, and any expected use of set-retarding admixtures or pozzolanic materials in the concrete mix. Form designers should assume a minimum weight of 2,400 kg per cubic metre when computing vertical loads and a minimum weight of 1,360 kg per cubic metre when computing horizontal pressure.

When determining lumber widths and thicknesses, the sizes of studs and waler brackets, and the distances between studs and waler brackets, a form designer shall give due regard to the nature of the construction work project and shall ensure that forms are sufficiently rigid to prevent distortion caused by the pressure of concrete.

Bolts, rods, and ties for forms shall be steel and of a type that permits the major part of the tie to remain permanently in the structure. Devices attached to the waler brackets that can develop the strength of the ties hold the ties in place. Engineer may permit the use of wire on irregular sections and incidental construction if concrete pressures are nominal and other means maintain the alignment of forms.

Fittings for metal ties shall be of such design that, upon their removal, only the smallest possible cavities remain. Such cavities shall be filled with cement mortar to leave the surface sound, smooth, even, and uniform in colour.

Forms shall not have form ties that serve as handrails. Pipe spreaders shall not be used unless they can be removed during the placement of concrete, as determined by the project Engineer. Wood or metal spreaders shall be removed as concrete is placed. Forms shall not include cofferdam braces or struts that extend through the forms for any concrete section, except in unusual situations and with the project Engineer’s explicit approval.

All forms for beams, slabs, and similar members shall have sides that can be removed without disturbing the bottom boards or related supports.

b. Construction of Forms

Before the placement of concrete, the Contractor shall set forms that mirror the dimensions, lines, and grades of the structure under construction. Such forms shall hold true to these dimensions throughout the placement of concrete. Forms may have bevels or drafts at projections, such as copings, to ensure easy removal. Before reusing a form, the Contractor shall clean it, inspect it for damage, and, if necessary, repair it. When forms appear to be defective in any manner, either before or during the placement of concrete, a project Engineer may order the work stopped until the Contractor corrects the defects.

Formwork arrangements shall facilitate ready dismantling and removal from the cast concrete without shock, disturbance, or damage. Where necessary, an arrangement of formwork shall enable retention of the soffit form, properly supported on props only, in position for such period as may be required. If a component is to be prestressed whilst still resting on the soffit form, form construction shall resist elastic deformation and variations in the distribution of weight.

The Contractor shall treat forms with form oil or another approved release agent before placing any reinforcing steel. Forms shall not include materials that will adhere to or discolour concrete. Release agents shall be applied strictly in accordance with their manufacturers’ instructions and shall not come into contact with any reinforcement. The Contractor shall not use different release agents in formwork for concrete that will be visible in the finished work. Concrete surfaces shall not have adverse residual effects from release agents. Release agents shall not leave any residue that is detrimental to painting or coating concrete.

Other than any specific exceptions described in these standard specifications, constructions of metal ties or anchorages within forms shall permit their removal to a depth of at least 25 mm from concrete faces without damage to the concrete. A form may use ordinary wire ties only when concrete will not be exposed to view and where concrete will not contact salts or sulphates. When removing forms, the Contractor shall cut such wire ties at least 6 mm from the face of the concrete with chisels or nippers; for green concrete, the Contractor shall use nippers.

When a form requires epoxy-coated reinforcing steel, all metal tics, anchorages, or spreaders that remain in the concrete shall be corrosion-resistant or coated with a dielectric material.

The Contractor shall maintain forms after erection to eliminate warping and shrinkage. Immediately before placing concrete, the Contractor shall check a form's dimensions and condition. At any time, the Engineer may require the revision or reconstruction of forms and may refuse permission to place concrete within any form until its construction is satisfactory. If at any period of a project during or after the placement of concrete, forms show signs on sagging or bulging, the Contractor shall remove concrete to the extent directed by the Engineer, bring the forms to their proper positions, and place new concrete. The Owner will make no allowance or compensation to the Contractor for such extra work.

Unless directed to do otherwise, the Contractor shall paint the exterior sides of all forms with an approved high gloss white oil base enamel of good quality before placing concrete. When one coat of this enamel does not provide complete coverage, the Engineer shall order additional coats as necessary to obtain complete coverage. Upon order from the Engineer, the Contractor shall repaint forms.

To prevent shrinkage cracks, the Contractor shall moisten forms with water before placing concrete.

Forms that are to be reused shall be thoroughly cleaned and reoiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber will be condemned by the Engineer; the Contractor shall remove such lumber from the project site. The Contractor shall keep metal forms clean and free from rust to prevent discolouration of concrete surfaces. After each use with power operated tools, the Contractor shall clean plywood forms before coating them again.

Where the bottom of a form is inaccessible, the Contractor shall leave the lower form boards loose or make other provisions so that extraneous material may be removed from the forms immediately before concrete placement. Unless a project plan indicates otherwise or the Engineer directs otherwise, the Contractor shall use dressed, milcut, triangular moulding with 20 mm sides to level all exposed edges. All curved surfaces shall be formed with approved plywood or steel.

Concrete shall not be deposited in the forms until all work connected with constructing the forms has been completed, all dust, debris, loose wire, and other detritus have been removed, all materials to be embedded in the concrete have been placed for the unit to be cast, and the project Engineer has inspected and approved the forms and materials.

Further requirements of formworks construction shall be in accordance of Section 4.6.2 of Chapter 4, Concrete Works, of these standard specifications.

c. Testing and inspection of Forms

All formwork shall be tested and inspected by the Contractor and approved by the Engineer before any concrete is placed in it, but such approval shall not relieve the Contractor of his responsibility for the safety, accuracy or efficiency of the work.

d. Wrought Formwork

Wrought formwork shall produce a concrete face with a finish that is true, sound, and smooth and that is free from board marks and other disfigurements. The Contractor shall use wrought formwork for surfaces that are exposed in the finished work. Panel joint arrangements in wrought formwork shall match an approved regular pattern. Wrought formwork alignments shall be within a tolerance of ±3mm along 3 meter line. Plus and minus tolerances will not be permitted in close proximity to each other.

e. Rough Formwork

Rough formwork shall be grout proof and may be used for surfaces that are not exposed in the finished work. Rough formwork may be timber, as sawn at a mill. Boards shall have identical widths. Outer surfaces of walls shall be formed so that the boards shall be vertical.

f. Tube Forms

Tubes used as forms to produce voids in concrete slabs shall be properly designed and fabricated or otherwise treated to make the outside surface waterproof. Before concrete placement, such tubes shall be protected from weather and stored and installed by methods that prevent distortion or damage. The Contractor shall cover tube ends with mortar-tight and waterproof caps. If the Contractor uses wood or other material that expands when moist to cap tubes, they shall place 6 mm thick pre-moulded rubber joint filler around the perimeter of caps to permit such expansion. A polyvinyl chloride (PVC) vent tube near both ends of each tube shall ventilate voids. After removing the exterior form, the Contractor shall trim the vent tube to within 15 mm of the bottom surface of the finished concrete.

Anchors and ties for tube forms shall prevent displacement of the tubes during concrete placement.

g. Stay-in-place Forms

The Contractor may use stay-in-place deck soffit forms, such as corrugated metal or precast concrete panels, if Contract documents indicate such forms or with the Engineer's approval. Before using such forms, the Contractor shall provide a complete set of details to the Engineer for review and approval. Contract documents typically specify the use of removable forms. Any changes to the dimensions of structures that are necessary to accommodate stay-in-place forms, if approved, shall be at the Contractor's expense.

h. Permanent Forms

The Contractor shall not use permanent forms, of any material, that are proposed to remain in place at the completion of construction unless particular project specifications expressly allow the use of such forms.

i. Void Formers

All void-forming material shall be expanded polystyrene with the properties indicated in Table **1-6**, or extruded polystyrene.

Table 1-6: Properties of expanded polystyrene for forming materials

Property	Value
Cross breaking strength – kN/m² minimum	140
Compressive stress kN/m² minimum at 10% compression	70
Water vapour transmission at 38 Co and 90% relative Humidity, microgram metres/Newton hour, maximum per 50 mm sample thickness	25
Thermal conductivity W/m² C at 10 Co mean temperature, maximum	0.037
Dimensional stability at 80 C per cent maximum	0.5

j. Forms for Beams and Slabs

All forms for beams, slabs, and similar items shall enable removal of such forms' sides without disturbing the bottom boards or related supports.

k. Forms for Precast and Prestressed Girders

Each casting bed shall have a concrete deck to which the bottom forms shall be adequately anchored. Placement of bottom forms shall provide for camber and allow automatic cambering that result from the transfer of tendon prestress to the concrete. Bottom forms shall remain in true alignment and be sufficiently stiff to prevent excessive deflection under the load of wet concrete.

Forms and all related supports shall, by design, accommodate the shortening of members due to concrete shrinkage and the transfer of pre-tensioning or post-tensioning forces to the concrete.

Forms shall compensate for this shortening so that the centre-to-centre bearing distance of a completed beam under full dead load will be as indicated on the Contract plans.

Side forms shall be steel. Support for side forms shall not require ties or spreaders within the body of the member. The Contractor shall brace and stiffen side forms to ensure that no undesirable deflection or curvature takes place under concrete pressure. Side form designs shall facilitate proper cleaning between uses.

For adjacent sections of forms that are butt-joined, ends and sides shall come together smoothly and tightly with proper alignment. Side forms shall have cross-ties above any member's finished surface with spacing that is sufficiently close to maintain true cross-sectional dimensions.

The Contractor shall bevel or chamfer all of a form's exposed outside edges as indicated on the Contract plans. Forms shall not leak mortar. Joints between soffit, side forms, and bulkheads shall be tight; as necessary, forms shall include rubber gaskets to prevent leakage. The Contractor may use rubber to provide the corner chamfers. Plugging of holes and slots in the forms shall be neat and shall ensure that finished members have a workmanlike appearance that is acceptable to the Engineer.

Before beginning concreting operations, the Contractor shall treat forms and casting beds with a suitable form lacquer or oil to prevent bonding of the concrete. Such form lacquer or oil shall leave no stains or discoloration on concrete. The Contractor shall be careful not to coat tendon conduits or reinforcement steel with such form lacquer or oil. The Contractor shall either clean any tendon conduits or bars that are so contaminated to the satisfaction of the Engineer or replace them.

Forms shall be free from paint or any other protective substance can cling to the surfaces of finished precast members. The Contractor shall not reuse any form without cleaning it thoroughly.

No form ties, spreaders, or forming facilities shall penetrate the body of a member, except when doing so is necessary to provide openings that are indicated on the Contract plans.

If, during the casting of members, any forms have deteriorated to the degree that finished precast members cannot be constructed without approaching or exceeding the dimensional tolerance limits, the Engineer may suspend production of structures related the unsatisfactory forms until the Contractor has completely renovated or replaced the deficient forms.

l. Lined Formwork

The Contractor shall use sawn tongued-and-grooved timber boards to make formwork. Such boards shall have the same thicknesses and same widths, unless the Contract documents specify otherwise or in accordance with additional requirements in these standard specifications.

Boards on the visible outer surfaces of piers and walls shall be vertical, except where formwork is lined as specified in this section.

Unless the Contract plans indicate otherwise, exposed faces of wing walls, retaining walls, and abutments shall have lined forms that will achieve the surface textures that have been approved by the project Engineer. Before ordering form liners, the Contractor shall submit sample form liner panels to the project Engineer for approval; such liners shall be at least 50 cm by 50 cm and otherwise in accordance with Contract requirements. Form liners shall produce surface textures that match the textures approved by the Engineer. Form liners shall be elastomeric material in accordance with their manufacturer's recommendations and approval from the project Engineer.

m. Sawn Formwork

Formwork for unexposed concrete surfaces may be of timber as sawn at the mill. Boards shall be of the same width. Outer surfaces of walls shall be formed so that the boards shall be vertical.

n. Special Formwork

The Contractor shall include all special formwork that is required to produce surface ornamental patterns on all concrete surfaces, including the fronts of wing walls, piers, abutments, and parapets, as indicated on the Contract plans and as approved by the Engineer.

o. Slip-form Formwork

The Contractor shall receive Engineer's approval of slip-form formwork prior to fabrication or bringing the slip-form equipment to the site of the works. Slip-form formwork shall comply with the requirements of Section 4.6.1 of Chapter 4, Concrete Works, of these standard specifications.

p. Damage to Concrete

The Contractor shall make good any damage to concrete work and any damage caused by or from the removal and striking of forms and supports. The Contractor shall notify the project Engineer of any such damage, who shall inspect and evaluate the Contractor's proposals for remedial works. Engineer may reject any concrete surfaces that have been remedially treated in any way before such inspection and approval from the project Engineer.

q. Openings in Formwork

Formwork may have openings to facilitate internal inspection and to allow wash water to escape. Such openings, by design, shall be easy and convenient to close before concrete placement.

Access openings into hollow substructures and box girders shall be formed at locations and in accordance with the details shown on the Contract plans.

Whenever the concreting of narrow members has to be carried out within formwork of considerable depth, the Contractor shall consider making temporary openings in the sides of forms to facilitate concrete placement and consolidation. The Contractor shall provide small temporary openings, as necessary, at the bottom of forms of narrow members to permit the expulsion of water, wire, rubbish, and other deleterious materials.

r. Shutters for Forms

To enable the proper placement of concrete, forms shall include shutters for all slopes that exceed 15 degrees to the horizontal. Formwork shall be constructed so that the side shutters of members can be removed without disturbing the soffit shutters and, if the Contractor wishes to leave some of the props in place when the soffit shutters are removed, these props shall not be disturbed during the striking. Detailed arrangement of the props shall be submitted to the Engineer in advance for his approval.

s. Chamfers for Forms

Unless otherwise specified or shown on the Contract plans, all exposed arises shall have 20 mm x 20 mm chamfers.

1.16.8.5 Removal of Falsework and Forms

The Contractor shall not remove falsework or forms without the Engineer's approval. Removal of falsework and forms shall be in accordance with the requirements of Section 4.6.3, Chapter 4, Concrete Works, and Section 21.7.10, Chapter 21, Concrete Structures, of these standard specifications.

1.16.9 Cofferdams

Cofferdams are temporary structures that provide the following functions:

a. Keep water and soil out of excavations in which substructures are to be built
b. Protect adjacent property and facilities during construction of permanent works

c. Give workers a dry work environment

Usually, cofferdams are dewatered so that the substructures can be built under dry conditions. After the substructures have been completed, the cofferdams are removed.

To design cofferdams and dewatering systems, as specified above, the Contractor shall engage a professional Engineer who specializes in such design to prepare and sign such plans. Engineer shall approve both the professional Engineer and the designs. Engineer’s approval of designs and shop drawings, however, shall not relieve the Contractor of responsibility for the adequacy and performance of such temporary works.

A cofferdam shall be sufficiently deep and high to seal of all water. Cofferdams usually have depths that are well below the bottom of an excavation. The Contractor shall design and construct cofferdams to be safe and as watertight as is necessary for the proper performance of the permanent works. They shall be sufficiently large to give easy access to all parts of a foundation form and pumping equipment, with dimensions equal to or greater than the related excavation. If cofferdams are tilted or moved laterally during the process of sinking, the Contractor shall right, reset, and enlarged them as needed to provide the necessary clearance. Such correctional adjustments shall be solely the Contractor’s expense.

The Contractor shall ensure that a cofferdam prevents the penetration of water to ensure the placement of footing concrete in a dry environment. When a cofferdam’s bottom is of sandy or porous material that, in the opinion of the project Engineer, will not permit a concrete footing to be poured in a dry environment, it shall be sealed with sufficient Class C28/20 concrete so that it may be pumped dry. If a seal is required, the Contractor shall determine the depth of seal and the required cure time. Engineer may approve other satisfactory methods of sealing out water.

Under ordinary circumstances, Class C28/20 concrete for a cofferdam shall have 10 % more cement content and the slump of the concrete shall be approximately 150 mm. A cofferdam shall not use a seal course unless such is shown on project plans or is authorized in writing by the Engineer. If the Engineer deems that a cofferdam’s construction is inadequate or improper, the Engineer may order the removal or reconstruction of the cofferdam or permit the Contractor, at their own expense, to place a seal course. After such a seal has cured, the Contractor shall pump all water out of the cofferdam and place the balance of the masonry in the dry environment. When the Contractor use a weighted cofferdam to partially overcome hydrostatic pressure that acts against the bottom of a foundation seal, special anchorages, such as dowels or keys, shall transfer the entire weight of the cofferdam onto the foundation seal. During the placement and curing of a foundation seal, the elevation of the water inside a cofferdam shall be controlled to prevent any flow through its seal; if a cofferdam is to remain in place, it shall be vented or ported at or below low water level.

Cofferdams shall be adequate to support all loads imposed on them and shall comply with any applicable safety regulations.

1.16.9.1 Protection of Concrete by Cofferdams

Cofferdams shall protect green concrete against damage from any sudden rising of water and shall prevent damage by erosion. Timber or bracing in cofferdams shall not extend into the permanent work except where permitted, in writing, by the Engineer.

1.16.9.2 Removal of Cofferdams

Unless an alternative has been approved by the Engineer, the Contractor shall remove cofferdams and shoring, with all sheeting and bracing, after the completion of the substructure, without disturbing or marring finished works.

1.16.10 Shoring

Shoring involves the use of excavation support structures to allow the excavation and backfilling of trenches or excavations for the installation of sanitary or storm sewers, watermains, forcemains, and their associated appurtenances.

The Contractor shall provide, place, and maintain shoring and bracing at the necessary locations and elevations to meet the following requirements:

a. Support and protect the sides and bottom of an excavation
b. Prevent undue disturbance or weakening of the supporting material below or beside project works
c. Prevent ground movement that may disturb or damage project works, adjacent pavements, property, structures, or other works

Shoring and bracing shall be driven and placed so that it can be removed as backfilling takes place without damaging pipeline or appurtenances and without settlement of or damage to adjacent pavements and structures.

The Contractor shall remove all shoring and bracing as the excavation is backfilled, unless a project specifies that such shoring and bracing is to remain in place.

The Contractor's procedure for extracting shoring and bracing and placing backfill shall ensure that the backfill load is applied gradually and avoids disturbing works or foundation materials.

Bracing shall not be removed until backfill has reached the level of the bracing. Shoring shall be removed in 150 mm increments until safely clear of project works.

The Contractor shall cut off all shoring that remains in place, as specified for the project or as directed by the Engineer.

1.16.11 Temporary Water Control Systems

A temporary water control system can include one or more of the following components:

1. Dikes
2. Bypass channels
3. Flumes and other surface water diversion works
4. Cut-off walls
5. Pumping systems, including well point and deep well systems, that prevent water from entering excavations for structures

1.16.11.1 Working Drawings for Water Control Systems

Working drawings for temporary water control systems, when required, shall include details of the design and the equipment, operating procedures to be employed, and the locations of points of discharge. Design and operations shall conform to all applicable water pollution and erosion control requirements.

1.16.11.2 Operation of Water Control Systems

Pumping from the interior of any foundation enclosure shall prevent the movement of water through fresh concrete. Engineer will not permit pumping during the placement of concrete or for a period of at least 24 hours thereafter, unless it is done from a suitable sump that is separated from concrete work by a watertight wall or other effective means, and only with the approval of the Engineer.

The Contractor shall not pump water from a sealed cofferdam until the seal has set sufficiently to withstand the associated hydrostatic pressure.

The Contractor shall regulate pumping from wellpoints or deep wells to avoid damage by subsidence to adjacent property.

1.16.12 Temporary Bridges

Temporary bridges include detour bridges for use by the public, haul road bridges, and other structures, such as conveyor bridges, used by the Contractor. The Contractor shall design, construct, maintain, and remove temporary bridges in a manner that does not endanger project works or the public.

1.16.12.1 Detour Bridges

A design for a detour bridge shall provide the following elements:

1. Bridge length
2. Bridge width
3. Bridge surface type
4. Bridge clearances
5. Alignment
6. Load capacity
7. Bridge railing type
8. Design speed
9. Road surface type
10. All project specific requirements (such as utilities and sidewalks)
11. Other design parameters specified or approved in Contract documents

To design temporary detour bridge, the Contractor shall follow all the required steps for designing a permanent bridge. Detour bridges shall carry all anticipated loads and forces and resist lateral loads caused by hydraulics, debris, wind, and other intermittent forces. Detour bridges over waterways shall apply scour depths and design flood in accordance with the project's particular specifications.

Any detour bridge design shall conform to the AASHTO LRFD Bridge Design Specification. If design live loads are not otherwise specified in Contract documents, a temporary bridge's design load must match that of a permanent bridge.

The Contractor shall submit working drawings and design calculations that have been sealed by a professional Engineer to the Engineer for review two weeks before on-site construction of a detour bridge is scheduled to commence. After constructing a detour bridge, the Contractor shall provide a letter signed by a professional Engineer that states that the detour structure has been constructed in accordance with its design.

During the design, installation, maintenance, and removal of a temporary detour bridge, the Contractor shall strictly adhere to all environmental guidelines and the requirements of relevant environmental agencies.

Temporary detour bridges shall be constructed according to the applicable sections of these specifications and the requirements of applicable permitting agencies. Structural steel welding shall comply with the welding specifications outlined in Sections 23.4.11 and 23.6.10 of Chapter 23, Steel Structures. Welding shall not begin until all of the following have been approved:

1. Welding Procedure Specification (WPS)
2. Procedure Qualification Records (PQR)
3. Welder Qualification Test Records (WQTR)
4. Material Test Report (MTR)
5. Certified Welding Inspector (CWI-AWS)

Engineer will not permit field welding to girders, beams, stringers, crossbeams, or floor beams.

Construction of a bridge's end fill shall match the approved working project drawings and comply with the material, placement, and compaction requirements of these specifications. The Contractor shall perform all quality control, sampling, and testing that is needed to verify that a completed bridge's end fill meets the specified requirements. At a minimum, such verification shall include materials sampling, sieve analyses, laboratory proctor density testing, and in-situ density testing.

The Contractor shall maintain the detour throughout the period of its use and shall provide interim inspections by a professional Engineer for long-term detour bridges. Signs confirming load capacity shall be erected prior to opening to traffic.

After traffic has been routed onto the new permanent road or bridge, the Contractor shall remove the detour bridge and restore the detour area to its natural condition to the satisfaction of the Engineer.

When temporary detour bridges are no longer needed, the Contractor shall remove them according to applicable specifications herein. Unless Contract documents show or specify otherwise, all temporary bridge materials shall remain the property of the Contractor. The Contractor shall satisfy all requirements of applicable permitting agencies during bridge removal, and shall restore all areas occupied by the temporary bridges to original condition or as shown in project plans.

a. Materials for Detour Bridges

The Contractor shall furnish new material for temporary detour bridges according to the applicable requirements in these standard specifications.

b. Spread Footings for Temporary Bridges

For temporary bridges supported on spread footings, the Contractor shall provide the following information:

1. Soil or rock properties, ground water levels, and all assumptions used to characterize the subsurface conditions for footing design
2. Estimated global and local scour depths used in the analysis
3. Bearing capacity design calculations and recommendations
4. Recommended footing elevations
5. Estimated footing settlements and differential settlement, if applicable, based on the service conditions
6. Global stability analysis of spread footing locations
7. Method of providing adequate footing scour protection

c. Driven Piles for Temporary Bridges

For temporary bridges supported on driven piles, the Contractor shall include the following information on project drawings:

1. Pile type, size, and steel grade
2. Pile layout and spacing
3. Required ultimate bearing capacity (nominal resistance)
4. Method for field determination of ultimate (nominal) bearing capacity (dynamic formula, wave equation, or dynamic load test)
5. Minimum pile tip elevations
6. Subsurface material properties, ground water levels and all assumptions used to characterize the subsurface conditions for pile design
7. Estimated global and local scour depths used in the analysis

8. Pile bearing capacity design calculations and recommendations

The Contractor shall also provide the following analyses and recommendations, when applicable:

1. Lateral pile load analysis
2. Pile tip protection
3. Pile uplift capacity

d. Haul Bridges

When the Contractor proposes the construction of haul road bridges or other bridges that are not for public use over any right-of-way that is open to the public or that is over any railroad, they shall submit working drawings that show complete design and details, including the maximum loads to be carried, to the Engineer for approval. Such drawings shall be signed by a professional Engineer. Such designs shall conform to AASHTO LRFD Bridge Design Specification, when applicable, or to other appropriate standards.

1.16.12.2 Maintenance for Temporary Bridges

Maintenance of temporary bridges for which working drawings are required shall include their replacement in case of partial or complete failure. In case of the Contractor delays to the project or makes inadequate progress on repairs and replacement or fails to furnish such labour, materials, and supervisions of the work as may be necessary to restore the structure to a proper condition suitable for movement of traffic, the Owner will make such repairs and the full costs for such restoration and repairs shall be charged back to the Contractor.

1.17 Sediment and Pollution Control

1.17.1 Description

Work under this section shall include furnishing, installing, maintaining, removing and disposing of temporary sediment and pollution control measures such as wind and rain erosion control silt fences, check dams, straw barriers, and other devices or methods as otherwise may be required for the Contractors environmental sediment and pollution control plan as specified in Section 1.15.9, as shown in the Drawings as required in the Particular Specifications as may be required by Abu Dhabi EAD or as directed by the Engineer.

This work also includes the fencing and construction avoidance of areas to be protected as may be shown on the Drawings, included in the Particular Specifications, directed by the Engineer or required by Abu Dhabi EAD.

Design requirements on all temporary sediment and pollution control measures shall be in accordance with Chapter 14 of the Abu Dhabi Road Drainage Manual, AD-D-07, and as specified herein.

1.17.2 Protective Fencing

Contractor shall install high visibility fencing around all areas to be protected from construction personnel and equipment intrusion as shown on the drawings, included in the particular specifications, directed by the Engineer or required by Abu Dhabi EAD, which may include vegetated agriculture, trees and landscaping areas, environmentally sensitive areas, historic areas, archaeology sites, public access areas, inhabiting species habitats, and protected coral/mangrove areas. Contractor shall conduct training for all construction personnel about necessity to protect and avoid those protected sites.

1.17.3 Sediment Controls

Sediment control involves both control of sediment at a dewatering or temporary stormwater discharge location as well as erosion control caused by wind or rain on open unprotected soils in the construction area. Sediment and erosion controls, both temporary and permanent, shall be installed in accordance with Contractor’s approved staging and phasing plans and coordinated with the related construction work.

Control of sediment and erosion, caused by both wind and precipitation runoff and dewatering operations require the Contractor to perform temporary work items including but not limited to the following items:

1. Providing ditches, berms, culverts, temporary drainage diversions and other measures to control surface water
2. Building berms, settling basins, diversions, and other measures, to control movement of sand and sediments to downstream locations carried by the stormwater flows
3. Managing dewatering methods to avoid sediment discharge
4. Covering or otherwise protecting soil slopes and stockpiles until permanent erosion control measures can be applied
5. Providing measures to control sand movement and dust caused by construction operations and wind

To the degree possible, the Contractor shall coordinate this temporary work with permanent drainage and erosion control work the Contract requires.

Engineer may require additional temporary control measures if it appears pollution or erosion may result from weather, the nature of the materials, or progress on the work.

When natural elements rut or erode the slope, the Contractor shall restore and repair the damage with the eroded material where possible, and clean up any remaining material in ditches and culverts.

If the Engineer anticipates water pollution or erosion, the Contractor shall schedule the work so that grading and erosion control immediately follows clearing and grubbing.

Engineer may also require erosion control work to be done with or immediately after grading. Clearing, grubbing, excavation, borrow, or fill within the project limits shall never expose more erodible earth than required for the immediate work, without approval by the Engineer: During the winter months of 15 October through 15 April, unprotected soil surfaces in a active work area shall be stabilized by either the permanent erosion control measures or temporary measures, as approved by the Engineer, prior to opening up another open soil work site.

Contractor shall be responsible for maintaining all erosion control measures in proper functioning condition at all times.

When deficiencies in the erosion control devices or other elements of work listed herein are noted by inspection or other observation, corrections shall be made by the Contractor by the end of the day or work shift when directed by the Engineer.

Work specified herein which is lost, destroyed, or deemed unacceptable by the Engineer as a result of the Contractor's operations shall be replaced by the Contractor at no additional cost to the Department.

Work specified herein which is lost or destroyed as a result of natural events, such as excessive rainfall, which is replaced by the Contractor at the direction of the Contractor, will be paid for in accordance with the requirements of the bills of quantities.

1.17.4 Pollution Controls

Pollution control measures shall be installed in accordance with phasing provisions in the approved plans and coordinated with the related construction.

Controlling pollution requires the Contractor to perform work items including but not limited to the following items:

1. Provide for dust and wind born sand and sediment controls to control air pollution
2. Implement spill and leak prevention procedures for paints, chemicals and hazardous substances stored on the job site. Have in place a plan for emergency spill containment and cleanup, including the providing and convenient access storage on-site of cleanup and containment materials.
3. Provide positive containment and oil/water separation for stormwater runoff from equipment maintenance, storage and refuelling yards and depots
4. Manage stormwater on a temporary basis to avoid movement of sediments and roadway pollutants to downstream locations, in particular where such sediment will cause problems such as discharge to environmentally sensitive mangrove and coral areas or damaging other structures or plugging existing storm drain systems
5. Managing dewatering or providing sediment traps or filters prior to discharge to avoid sediment discharges to sensitive areas or existing storm drains.

In cases of serious or wilful disregard for the protection of protected areas by the Contractor, the Engineer will immediately notify the Contractor of such non-compliance. If the Contractor fails to remedy the situation within 24 hours after receipt of such notice, the Engineer may immediately place the erosion and/or other pollution control elements in proper condition and deduct the cost thereof from moneys due the Contractor.

1.17.5 Materials

1.17.5.1 Submittals

The Contractor shall provide an environmental, sediment and pollution control (SPC) plan in accordance with Sections 1.15.1 and 1.15.9, and per the additional requirements as follows:

a. Generally the SPC plan should be submitted at the same time as the Contractors staging and detour plans, since the SPC plan must be coordinated with the work staging location and schedule.
b. Contractor shall provide a schedule for SPC plan implementation and incorporate it into the Contractor’s construction schedule.
c. Contractor shall obtain the Engineer’s approval of the SPC Plan and schedule before any work begins.
d. SPC plan shall cover all areas the Contractor’s work may affect inside and outside the limits of the project (including all borrow and disposal sites, and haul roads, and staging areas which shall show:
    1. Location of disturbed soil areas, areas to be protected from construction, existing storm drains and those to be constructed as part of that work stage, dewatering facilities and discharge locations
    2. Show locations of specific sediment and pollution control measures
    3. Describe in detail the design, installation, maintenance, repair, and removal of proposed specific sediment and pollution control measures
    4. Describe in detail the design, installation, maintenance, repair and removal of proposed general site sediment and pollution control measures (i.e. for general dust and spill control measures)

5. Show the locations and types of specific temporary sedimentation and pollution control practices that will be used in the work for each construction phase
6. Show the locations and types of wind and water pollution control practices that will be installed permanently under the Contract.
7. If dewatering, submit dewatering and discharge work plan. Work plan shall include:
    i. Description of dewatering and discharge activities detailing locations, quantity of water, equipment, type of dewatering and discharge point
    ii. Estimated schedule for dewatering and discharge start and end dates of intermittent and continuous activities
    iii. Sediment avoidance measures at discharge, which may include discharge alternatives, such as infiltration, filtration or sediment traps
    iv. Visual monitoring procedures with inspection log
    v. Obtain approval to discharge into a existing storm drain system
8. Items as otherwise required herein.

Contractor shall amend and resubmit the SCP plan to match any revisions to his program, staging, detouring and schedule that effects the proper implementation of the approved SCP plan.

Contractor shall submit catalogue cuts, manufacturer's installation and maintenance recommendations and specifications and material test results for all materials and items used for temporary sediment and pollution control measures. Contractor shall provide samples and specific testing of the materials if required by the Engineer.

1.17.5.2 Geotextile

Temporary geotextile covering shall meet the requirements of Article 2.7.3.2 of Chapter 2, Earthworks.

1.17.5.3 Plastic

Temporary plastic covering shall meet the requirements of the NIST Voluntary Product Standard, PS 17-69, for polyethylene sheeting having a minimum thickness of 6 mils

1.17.5.4 Erosion Control Blankets/Mats

a. Temporary erosion control blankets shall consist of temporary, degradable, rolled erosion-control products composed of natural fibres mechanically or structurally bound together with natural or polymer netting to form a continuous matrix. Erosion control blankets are classified as to two types, as follows:
    1. Short – term duration
    2. Extended-term duration
b. Short - term duration blankets shall have a minimum one-year degradation period for both the netting and fibres, and be composed of 100 % virgin aspen excelsior wood fibres or 100 % agricultural straw.
c. Extended-term blankets shall have a minimum two-year degradation period for the netting and fibres, and be composed of heavy-duty excelsior blankets, or a mix of 70 % straw and 30 % coconut fibres, or 100 % coconut fibres. Heavy-duty excelsior blankets used in the extended-term category shall have a minimum weight of 0.38 kg/m^2.

d. All other types of blankets, whether for short - term or extended-term use shall have a minimum weight of 0.27 kg/m^2.

   Fibres for short-term erosion control blankets shall be encased top and bottom with photodegradable polypropylene or 100-percent biodegradable natural organic fibre netting, as specified on the plans.

e. Should the plans not specify type of netting for short-term blankets, fibres shall be encased with photodegradable polypropylene. Fibres for extended-term blankets shall be encased within either a heavy duty UV stabilized top netting (black) and bottom nettings (green), or two UV stabilized nettings (black). All nettings for extended-term blankets shall be photodegradable polypropylene.

Erosion control blankets shall also conform to the following requirements:

Table 1-7: Erosion control blanket requirements

Property	Test method ASTM	Short-term duration	Extended-term duration
Minimum mass per unit area	D6475	271 g/m^2	271* g/m^2
Minimum thickness**	D5199	6.35 mm	6.35 mm
Minimum tensile strength (kg/m)***	D5035	111	148
*Heavy duty blankets shall have a minimum mass per unit area of 372 g/m^2 **Numerical value represents total thickness of blanket, including netting. ***Numerical value represents minimum average test result in either direction.			

Fibre colour shall be natural unless otherwise specified in the Particular Specifications.

a. Fibres shall be free of weed seed, and shall be locked in place to form a mat of consistent thickness. Fibres shall remain evenly distributed over the entire area of the blanket after being placed on the slope.

b. Erosion control blankets shall be furnished in 1.2 to 2.4 m wide rolls, and shall be wrapped with suitable material to protect against moisture and extensive ultraviolet exposure prior to placement.

Each roll shall be labelled to provide sufficient identification for quality control purposes.

a. All biodegradable ECPs must be anchored using wire staples.

b. Contractor shall provide certificates of compliance from the manufacturers, for all erosion control blankets.

1.17.5.5 Anchors

Staples shall be made of 3.05 mm steel wire and shall be U-shaped with 200 mm legs and 50 mm crowns.

Metal stake pins shall be 5-mm-diameter steel with a 40 mm steel washer at the head of the pin.

All anchors shall be a minimum of 150 mm long and have sufficient penetration to resist pullout. Longer anchors may be required for loose soils or by the manufacturer’s installation guidelines.

1.17.5.6 Pipe Slope Drains

Pipe materials shall conform to Articles 12.1.3.6 and 12.1.3.7c of Chapter 12, Stormwater Drainage for corrugated metal and PVC pipe.

Loose riprap rock and bedding shall conform to Section 7.4.3 of Chapter 7, Incidental construction, of these standard specifications.

1.17.5.7 Fabric Fence

a. Fabric

Fabric or silt fence fabric shall be supplied in accordance with the material requirements of Section 2.7.2 of Chapter 2, Earthworks.

b. Posts

Posts for silt fence can be wood or steel conforming to the requirements of Article 7.7.2.4. Posts shall be a minimum of 1 metre plus the burial depth in length and may be made of either wood or steel. Soft wood posts shall be at least 75 mm in diameter, or nominal 50 mm by 100 mm and straight enough to provide a fence without noticeable misalignment. If oak posts are used, the size may be reduced to 38 mm by 38 mm with a minus tolerance of 3 mm, provided that the cross sectional area is a minimum of 1450 mm^2. Steel posts shall have a minimum weight of 1.95 kg/m, and have projections for fastening the wire and fabric to the fence.

c. Wire Supported Fence

Wire support fence shall be a minimum of 830 mm high composed of 2.8 mm diameter steel wire mesh fencing material.

Wire staples shall be 1.2 mm diameter and shall have a crown at least 19 mm wide and legs at least 13 mm long. Staples shall be evenly spaced with at least five per post.

Nails shall be 2 mm in diameter, 25 mm long with 19 mm button heads. Nails shall be evenly spaced with at least four per post.

d. Fabric Packaging, Handling, and Storage

Identification, packaging, handling, and storage of the geotextile fabric shall be in accordance with ASTM D4873. Fabric rolls shall be furnished with suitable wrapping for protection against moisture and extended ultraviolet exposure prior to placement.

Each roll shall be labelled or tagged to provide product identification sufficient to determine the product type, manufacturer, quantity, lot number, roll number, date of manufacture, shipping date, and the project number and name to which it is assigned. Rolls will be stored on the site or at another identified storage location in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof, light colour, opaque cover.

1.17.5.8 Rock and Aggregate

Geotextile fabric for riprap shall meet the requirements of Article 7.4.3.2 of Chapter 7, Incidental construction.

Gradation of the loose rock for erosion control shall meet the requirements of Sub-article 7.4.3.2.a of Chapter 7, Incidental construction, for hand placed riprap and Sub-article 7.4.3.2.c, for pit run or quarry spalls rock.

Riprap bedding aggregate shall meet the requirements of Article 7.4.3.2 of Chapter 7, Incidental construction.

Crushed rock or gravel for temporary or permanent ground surface coverings shall consist of hard, durable rock, with at least two fractured faces of size ranging from 6 to 50 mm nominal diameter.

1.17.5.9 Gravel Bags

Gravel bags consist of a heavyweight fabric (synthetic or canvas materials), sewn sack filled with gravel and the opening closed with a wrap of twine or wire. Weight of the filled sack shall not exceed 50 kg, so that it can be handled by two people, one on each end.

Bags, when filled shall measure approximately 600 mm long by 400 mm wide by 100 mm thick. Bag dimensions are nominal and may vary locally but shall not be significantly different. Alternate bag sizes shall be submitted to Engineer for approval.

Gravel shall be between 10 mm and 20 mm in diameter.

Gravel shall be clean and free from clay balls, organic matter and deleterious material.

Bags shall be manufactured from polypropylene, polyethylene, or polyamide woven fabric with the following characteristics:

Table 1-8: Gravel bag requirements

Unit weight, minimum	135 g/m^2
Mullen burst strength, as per ASTM D3786, exceeding	2 mPa
Ultraviolet stability, as per ASTM D4355, exceeding, %	70 %

1.17.5.10 Fibre Rolls

Erosion control blankets used to construct fibreroll shall meet the requirements of Article 1.17.5.4.

Wooden stakes shall be made from wood of type and density to withstand the driving process, as approved by the Engineer. Stakes shall be 19 mm by 19 mm and maximum 1.2 m long.

Erosion control blankets used to construct fibre rolls shall be between 2 m and 2.4 m wide by approximately 15 m long. Wood excelsior blankets shall have 80 % of its fibres equal to or greater than 150 mm. Blankets used to construct the fibre rolls shall have photodegradable plastic or biodegradable natural netting, with a maximum 25 mm by 25 mm grid, on at least one side.

Contractor shall produce fibre rolls by rolling the blankets along their width to produce 15 m lengths, and securing the rolls with jute twine spaced at 2 m intervals along the roll for the full length and at 150 mm from each end. If shown on the plans or directed by the Engineer, the Contractor may cut the blankets before rolling to produce completed fibre roll lengths of between 4 and 15 m as applicable for the location. Nominal diameter of the finished rolls shall be 220, 300, or 450 mm, as shown on the plans. Overlapping of more than one blanket may be required to achieve larger diameters. When overlapping is required, the end of one blanket shall overlap 150 mm onto the end of the next blanket prior to rolling.

1.17.5.11 Temporary Fence

High visibility fence shall be used by Contractor as temporary fencing to mark protected area boundaries as shown in plans such as for demarcating areas of vegetation protection.

High visibility fence shall be at least 1.2 m tall UV stabilized, construction orange colour, high-density polyethylene or polypropylene mesh with mesh openings approximately 50 mm by 50 mm. Colour shall be construction orange. Fence posts shall be wood or steel and shall meet the requirements of Sub-article b of Article 1.17.5.7

High visibility fence fabric shall have a minimum tensile strength of 145 kg per ASTM D5735.

1.17.6 Construction Requirements

1.17.6.1 Preservation of Existing Vegetation and Topsoil

Contractor shall comply with the following requirements:

1. Contractor shall preserve existing vegetation, topsoil and other existing soil covering materials at areas on a site where no construction activity is planned or will occur at a later date.
2. Temporary fencing shall be provided around areas designated for being maintained from inadvertent disturbance by the Contractor's operations.
3. Clearing and grubbing operations should be staged, with the area limited to the area that will be immediately under construction. Final surface covering (paving, decorative pavers, landscaping, gravel, etc.) should be provided prior to moving to the next stage of the work.
4. Minimise the disturbed areas by locating temporary roadways to avoid stands of trees and shrubs and to follow existing contours to reduce cutting and filling.
5. Consider the impact of grade changes to existing vegetation and the root zone.
6. Keep equipment away from trees and shrubs to be retained, to prevent trunk and root damage.
7. Maintain existing irrigation systems.
8. Employees and subcontractors shall be instructed to honour protective fences.
9. No heavy equipment, vehicular traffic, or storage piles of any construction materials shall be permitted within the drip line of any tree to be retained.
10. Removed trees shall not be felled, pushed, or pulled into any retained trees.
11. Prior to excavation and trenching, remove topsoil to a depth of 200 to 300 mm, and stockpile it for later re-application per requirements of Article 2.2.2.5 of Chapter 2, Earthworks.
12. Trenching shall be as far away from tree trunks as possible, usually outside of the tree drip line or canopy. Curve trenches around trees to avoid large roots or root concentrations. If roots are encountered, consider tunnelling under them.
13. When trenching and/or tunnelling near or under trees to be retained, tunnels shall be at least 450 mm below the ground surface, and not below the tree centre, to minimise impacts to the roots.
14. Tree roots shall not be left exposed to air. They shall be covered with soil as soon as possible, protected, and kept moistened with wet burlap or peat moss until the tunnel and/or trench can be completed.
15. Smoothly cut off the ends of damaged or cut roots.
16. Trenches and tunnels shall be filled as soon as possible. Careful filling and tamping will eliminate air spaces in the soil that can damage roots.
17. Remove any trees intended for retention if they are damaged seriously enough to affect their survival. Such trees shall be replaced as directed by the Engineer at the Contractors expense.
18. After all other work is complete, temporary fences shall be removed last, because protected trees may be destroyed by equipment operator carelessness during the final cleanup and landscaping.

1.17.6.2 Soil Surface Coverings

This measure involves the placement of geotextile, plastic covers, erosion control blankets or gravel to stabilise disturbed areas and protect soils from erosion by wind or water.

These measures are used as a temporary surface covering for the following situations:

1. Steep slopes, generally steeper than 1:3 velocity to height (V:H) in areas to be landscaped to hold the soil until the plant root zone is established.
2. Slopes of cuts and compacted embankments to be protected during the rainy season until the permanent slope protection measures can be installed.
3. Stockpiles of topsoil or other fine-grained construction materials to avoid erosion by rain or wind.
4. Temporary channels with flow velocities exceeding 1 m per second.
5. Slopes adjacent to environmentally sensitive areas.

a. Geotextile, Plastic and Blanket Installation

Prior to laying of the covering, Contractor shall:

1. Grade and shape the area of installation.
2. Remove all rocks, clods, vegetation, or other obstructions so that the installed blankets or mats will have complete, direct contact with the soil.
3. When using a fabric or mat that is designed to be used in conjunction with seed or vegetation, follow the manufacturer’s guidelines for proper installation. Prepare the planting bed by either loosening the existing 50 to 75 mm of topsoil or placing new 150 to 200 mm thick topsoil per requirements of Article 13.1.3.10 of Chapter 13, Landscaping and irrigation.

Installation should be in accordance with the manufacturer's recommendations. In general, these shall be as follows:

1. Begin at the top of the slope and anchor the blanket in a 150 mm deep by 150 mmwide trench. Backfill the trench and tamp the earth firmly.
2. Unroll the blanket down slope in the direction of water flow.
3. Overlap the edges of adjacent parallel rolls 50 mm to 75 mm and staple every 1.0 m.
4. When blankets must be spliced, place blankets end over end (shingle style) with 150 mm overlap. Staple through overlapped area, approximately 300 mm apart.
5. Lay blankets loosely and maintain direct contact with the soil. Do not stretch.
6. U-shaped wire staples, metal stake pins, or triangular wooden stakes can be used to anchor mats and blankets to the ground surface
7. Staple blankets sufficiently to anchor the blanket and maintain contact with the soil. Staples shall be placed down the centre and staggered with the staples placed along the edges. Steep slopes, 1:1 to 2:1 require a minimum of two staples per square meter. Moderate slopes, 2:1 to 3:1, require a minimum of one-and-a-half staples per square meter, placing one staple per meter on centres. Gentle slopes require a minimum of one staple per square meter.
8. Seed (if specified); fill turf reinforcement matting with soil; and insert plantings.
9. Do not drive tracked or heavy equipment over matting.
10. Avoid any traffic over matting if loose or wet soil conditions exist.

11. Use shovels, rakes, or brooms for fine grading and touch up.
12. Smooth out soil filling, just exposing the top netting of the mat.

When no longer required, Contractor shall remove and dispose of all non-degradable temporary coverings in a manner approved by the Engineer.

b. Aggregate Installation

Crushed aggregate shall be spread over the sand to increase the surface roughness and prevent sand movement and erosion. It may be applied as a temporary wind and water erosion control measure or as shown on the Drawings as the permanent soil covering method. Unless otherwise shown on the Drawings or approved by the Engineer, crushed aggregate shall be installed as follows:

1. Prepare ground surfaces as described in Sub-article a above. Take care to avoid compaction of the final ground surface to maintain as much surface soil permeability as possible for precipitation infiltration.
2. Minimum gravel thickness should be 150 mm . Where shown on the drawings for permanent gravel coverings, provide and install a geotextile filter fabric under the gravel surfacing.
3. Do not use crushed rock or gravel in areas of pedestrian or vehicle traffic, which will disperse the rock. Provide temporary paved walkways and paved driveways through the gravel area.
4. Rock or gravel should be clean, free of weeds, debris, and trash.
5. Slopes on which gravel covering is placed shall not be steeper than 3:1 slopes, unless otherwise approved by the Engineer. Provide an blanket type covering for steeper slopes.

1.17.6.3 Concentrated flow diversions

This measure consists of temporary ditches, swales, and dikes that intercept, divert, and convey surface runoff to provide protection from flooding and sedimentation of the Contractors works and provide for the public safety in the case of rainfall. These temporary measures shall be constructed and maintained for the winter season of 15 October through 15 April of configurations as appropriate for the Contractor’s staging and detour plans during that time period. The Contractor shall design and construct concentrated flow diversions in accordance with Chapter 14 of the Abu Dhabi Road Drainage Manual, AD-D-07, and as follows:

a. Care shall be applied to correctly size and locate earth dikes, swales, and ditches. Excessively steep, unlined dikes and swales are subject to erosion and gully formation
b. Refer to Chapter 4 of the Abu Dhabi Road Drainage Manual, AD-D-07, for the hydraulic design of ditches and swales
c. Conveyances shall be stabilised
d. Use a lined ditch for high-flow velocities
e. Select flow velocity based on a careful evaluation of the risks due to the erosion of the measure, soil types, over-topping, flow backups, washout, and drainage flow patterns for each project site
f. Compact any temporary dike fills to prevent unequal settlement
g. When possible, install and use permanent stormwater facilities early in the construction process for the collection and conveyance of construction site runoff and dewatering flows
h. Provide stabilised outlets.

1.17.6.4 Pipe slope drain

Slope drains are pipes used to intercept and direct surface runoff or groundwater into a stabilised watercourse, trapping device, or stabilised area. Slope drains are used with ditches, swales, and dikes to intercept and direct surface flow away from slope areas to protect cut or fill slopes. Slope drains may also be used at construction sites where slopes may be eroded by surface runoff. Slope drains shall be hydraulically design in accordance with the requirements of Chapter 4 of the Abu Dhabi Road Drainage Manual, AD-D-07, and as follows:

a. When using slope drains, limit the drainage area to 4 ha per pipe.

b. Direct surface runoff to the entrance of a slope drain with interceptor dikes, swales, or ditches.

c. Slope drains may be placed on or buried underneath the slope surface.

d. When installing slope drains:

   1. Install slope drains perpendicular to slope contours.
   2. Compact the soil around and under the entrance, outlet, and along the length of pipe.
   3. Securely anchor and stabilise pipe and appurtenances into soil.
   4. Check to ensure that pipe connections are watertight.
   5. Protect the area around the inlet with geotextile fabric or erosion control blanket. Protect the outlet with riprap. Ensure that high velocities/energy are dissipated at the outlet.
   6. Protect the inlet and outlet of slope drains with a standard flared-end section at the entrance for pipe slope drains 300 mm and larger.

1.17.6.5 Sediment trapping

Sediment trapping measures function by slowing water velocities thereby allowing soil particles to settle out or by attenuating the peak flow by detaining flow and releasing water at a slower rate.

a. Fabric fence

Fabric fence or silt fence is a temporary linear sediment barrier of permeable fabric designed to intercept sediment laden runoff. Silt fences may consist of a wire supported geotextile silt fence or a self supporting geotextile silt fence.

Contractor shall place fabric fences at the following general locations, or as otherwise shown on the Drawings or required by the Engineer:

1. Between the perimeter of a project and an environmentally sensitive area
2. Below the toe of exposed and erodible slopes
3. Along slope contours for longer slope lengths
4. Downslope of exposed soil areas
5. Around temporary stockpiles

Installation shall meet the following requirements:

1. At the time of installation, the fabric will be rejected if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufacture, transportation, storage or installation
2. Fence height shall not exceed 900 mm above ground surface.
3. Geotextile fabric shall be attached on the upstream side of the posts by wire, cord, button head nails, pockets, staples, or other acceptable means

4. Geotextile fabric shall be installed in such a manner that 200 to 250 mm of fabric is left at the bottom to be buried. The fabric shall be installed in the trench such that 150 mm of fabric is against the side of the trench and 50 to 100 mm of fabric is across the bottom of the trench in the upstream direction. The trench shall then be backfilled and compacted so that no flow can pass under the barrier
5. A minimum overlap of 450 mm shall be provided at all splice joints with posts at the ends of each fabric roll.
6. Contractor shall be responsible to maintain the integrity of silt fences as long as necessary to contain sediment runoff or as directed by the Engineer
7. Sediment deposits shall be removed when the deposit reaches approximately one-half of the height of the silt fence.
8. Silt fence shall remain in place during the duration of the Contractors work and that winter season or until the Engineer directs that it be removed. Upon removal, the Contractor shall remove and dispose of any excess silt accumulations, grade the area to leave a generally smooth appearance.

b. Sediment traps

A sediment trap is a temporary basin formed by excavating and/or constructing an embankment so that sediment-laden runoff is temporarily detained under quiescent conditions, allowing sediment to settle out before the runoff is discharged. Contractor shall design and install sediment traps as needed for control of downstream sedimentation, as may be shown on the drawings or where directed by the Engineer. Design shall meet the applicable requirements of Chapter 14 of the Abu Dhabi Road Drainage Manual, AD-D-07, and as follows:

1. Limit the contributing area to the sediment trap basin to only the runoff from the disturbed soil areas. Use temporary concentrated flow conveyance controls to divert runoff from undisturbed areas away from the sediment trap basin.
2. Provide the minimum surface area required for the sediment basin as per the formulas and procedure in Chapters 6 and 14 of the Abu Dhabi Road Drainage Manual, AD-D-07.
3. Basin length shall be more than twice the dimension as the width
4. For safety purposes, the maximum depth shall be no greater than 1.5 m unless otherwise protected from public access
5. Outlet structures shall be placed on a firm, smooth foundation, with the base securely anchored with concrete, or by another means, to prevent floatation
6. Discharge from the basin shall be accomplished through a corrugated metal or a high-density polyethylene riser pipe. A riser is sized so that the top opening acts as an overflow weir of total circumference to accommodate the design storm frequency flows. A riser should also be perforated and wrapped with a geotextile filter fabric around the base to allow for low-flow dewatering
7. Perforated sections should be designed to drain the basin within 72 hours after a storm
8. Attach the riser pipe with a watertight connection, to a horizontal pipe which outlets to a stabilised outfall or to a storm drain system
9. Cleanout level shall be clearly marked on the riser pipe

10. Remove accumulated sediments when the depth reaches one-third the depth of the sediment storage in the basin.

c. Check dams

Check dams shall be used where applicable to reduce scour and channel erosion by reducing flow velocity and encouraging sediment settlement. Check dams are small devices constructed of rock, gravel bags, sandbags, fibre rolls, or other proprietary products, placed across small open channels, in steep channels where stormwater runoff exceed 1.5 m per second and in temporary ditches. Contractor shall place check dams per the following guidelines:

1. Check dams shall be placed at a distance and height to allow small pools to form behind them. Install the first check dam approximately 5 m from the outfall device and at regular intervals based on slope gradient and soil type.
2. For multiple check dam installation, spacing shall be such that backwater from the downstream check dam shall reach the toe of the upstream dam.
3. High flows (typically a two-year storm or larger) shall safely flow over the check dam without an increase in upstream flooding or damage to the check dam, channel, or bank.
4. Rock should be placed individually by hand or by mechanical methods (no dumping).
5. Fibre rolls may be used as check dams (more temporary than rock)
6. Gravel bags may be used as check dams
7. Install check dams along a level contour, placed approximately perpendicular to the centreline of the ditch or drainage line
8. Tightly abut and stack rock, gravel bags or fibre rolls using a pyramid approach
9. Check dams shall not be any higher than 1 m. Midpoint of the rock check dam shall be a minimum of 150 mm lower than the sides in order to direct across the centre and away from the channel sides. Base of the check dam shall be entrenched approximately 150 mm
10. Where the check dam is constructed of rock, the rock shall be placed so that it completely covers the width of the channel. Stone placement shall be performed either by hand or mechanically as long as the center of check dam is lower than the sides and extends across entire channel. Side slopes of the check dam shall be no steeper than 2:1.
11. Where gravel bags are used, upper rows of gravel bags shall overlap joints in lower rows
12. If a temporary check dam is to be placed in the same area as an erosion control blanket, install the blanket before placing the dam.
13. Check dams shall remain in service until the permanent stabilization work commences or until they are no longer needed, as approved by the Engineer. When a rock check dam is discontinued, the materials shall be removed and disposed of as approved by the Engineer

d. Fibre rolls

Fibre rolls are placed on the toe and face of slopes to intercept runoff, reduce its flow velocity, release the runoff as sheet flow, and provide a removal of sediment from the runoff. Fibre rolls may also be used for inlet protection and as check dams. Fibre rolls shall be installed at the following general locations

1. Located along the toe, top, face, and at-grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow

2. Place below the toe of exposed and erodible slopes
3. Place around storm drain inlets to trap sediment before entering the inlet
4. Use downslope of exposed soil areas
5. Place around temporary stockpiles and along the perimeter of a project
6. Installation shall meet the following guidelines:
   i. Slope inclination of 1:4 or flatter: fibre rolls shall be placed on slopes 6 m apart
   ii. Slope inclination of 1:4 to 1:2: fibre rolls shall be placed on slopes 4.5 m apart
   iii. Slope inclination 1:2 or greater: fibre rolls shall be placed on slopes 3 m apart
   iv. Stake fibre rolls into a 50 to 100 mm deep trench
   v. Drive stakes at the end of each fibre roll
   vi. Use wood stakes 19 mm by 19 mm and a minimum length of 600 mm
   vii. If more than one fibre roll is placed in a row, the rolls shall be overlapped, not abutted
7. Removal:
   viii. Fibre rolls are typically left in place and will degrade and compost in areas used for landscaping or other agricultural plantings
   ix. If fibre rolls are removed, collect and dispose of sediment accumulation, and fill and compact holes, depressions, or any disturbance to blend with adjacent ground.

e. Gravel bag berms

A gravel bag berm consists of a single row of gravel bags that are installed end-to-end to form a barrier across a slope to intercept runoff, reduce its flow velocity, release the runoff as sheet flow, and provide some sediment removal. Contractor shall use gravel berms at the following locations:

1. Where flows are moderately concentrated, such as ditches, swales, and storm drain inlets
2. Where control or redirect runoff on detour pavement is needed to avoid concentrated flow across adjacent traffic lanes
3. When site conditions or construction sequencing requires adjustments or a relocation of the barrier to meet changing field conditions and needs during construction
4. At grade breaks of exposed and erodible slopes to shorten slope length
5. As check dams using stacked bags

When used as a linear control for sediment remova, berms shall be installed as followsl:

1. Install along a level contour
2. Install with ends tightly abutting each other to eliminate gaps
3. Turn the ends of the gravel bag row upslope to prevent flow around the ends
4. Install with a setback of at least 1 m from the toe of a slope
5. Bags in the vicinity of curbs and inlets shall be installed to 50 mm below the height of the adjacent curb to allow drainage into the inlet. When sediment depth behind the bags reaches 75 mm the sediment shall be removed

When used for concentrated flows, such as for a check dam, berms shall be installed as follows:

1. Stack gravel bags to the required height using a pyramid approach
2. The upper rows of gravel bags shall overlap joints in the lower rows

Sand or gravel bag features shall remain in service until disturbed areas have been stabilized, as directed by the Engineer. During removal, all sediment shall be disposed of, and the area restored to a finished condition as shown on the plans, or as directed by the Engineer.

f. Storm drain inlet protection

Storm drain inlet protection measures are used at storm drain inlets that are subject to runoff from construction activities. These devices are used to detain and/or to filter sediment-laden runoff in order to allow sediment to settle and/or to filter sediment prior to discharge into storm drainage systems. Installed protection shall not be used where ponding may encroach into highway traffic. Storm drain inlet protection shall be installed and maintained during the winter season of 15 October through 15 April for the following conditions:

1. Sediment-laden surface runoff may enter an inlet.
2. Disturbed drainage areas have not yet been permanently stabilised.

Inlet protection shall consist of one of the following types:

1. Inlet protection Type 1 – fabric fence: Filter fabric fence protection is similar to constructing a fabric fence. Do not place filter fabric underneath the inlet grate because the collected sediment may fall into the drain inlet when the fabric is removed or replaced.
2. Inlet protection Type 2 - excavated drop inlet sediment trap: Applicable for existing inlets in open areas, where a sediment trap can be excavated adjacent to the inlet, using the inlet as the open top overflow structure. Refer to the requirements for sediment traps, in the subsection above.
3. Inlet protection Type 3 – gravel bag: Install gravel bags in accordance with the requirements for gravel bag berm described in the subsection above, around the inlet opening. Gravel bags are generally used due to their high permeability.
4. Inlet protection Type 4 – fibre rolls: Fibre roll is placed around the inlet and keyed and anchored to the surface. Fibre rolls are intended for use as inlet protection where the area around the inlet is unpaved and the fibre roll can be secured to the surface by staking.

1.18 Basic Product Requirements, Product Options

This Section specifies general requirements for materials and equipment and includes, but is not limited to, the following:

1. Products
2. Transportation, delivery, receiving, and handling
3. Storage and protection
4. Products list
5. Substitutions
6. Product acceptance

1.18.1 Products

Term “product” shall mean any material, including proprietary goods, equipment or services that are incorporated into the final works.

Products do not include materials, machinery, or equipment that is used for the preparation, fabrication, conveyance, or erection of works.

If possible, products of a similar nature shall be standardized, interchangeable and supplied by the same manufacturer.

All products shall comply with the specifications and referenced standards, unless otherwise approved by the Engineer.

1.18.2 Transportation and Handling

All products shall be transported, stored and handled at all times in accordance with the requirements of Sections 1.18.5 and 1.18.6.

1.18.3 Products List

Products shall be delivered according to the construction schedule in order to avoid construction delays or undue storage requirements. Submit four copies of a list of all products which are proposed for installation, not later than 30 calendar days after the start of the Contract. The list shall include the following items:

1. Include the name of manufacturer and supplier, the trade name, and the model number of each product.
2. List shall identify products that are specifically listed by manufacturer or product model, those which are not referenced and those that are proposed as a substitute to a listed product model or manufacturer.
3. The Contractor shall ensure that the listed products comply with the requirements of the Contract documents.
4. Product list shall be arranged according to specification section number.
5. Include the specification title and the paragraph number.

Engineer will notify the Contractor in writing of any product deemed to be unacceptable. Notification shall be made no later than 30 days after submission of the products list. Engineer's objection or failure to object to a listed item shall not constitute a waiver of the requirements of the Contract documents.

1.18.4 Product Substitutions

Substitution requests shall be in conformance with the requirements of Section 1.19 and the requirements in this section.

The Contractor must submit requests for substitution within 60 days of starting the Contract. After that date, substitutions will only be considered when a product becomes unavailable, due to no fault of the Contractor.

Document each request with complete date substantiating that the proposed substitution complies with the Contract documents. Substitutions will not be considered in either of the following situations:

1. Substitution is indicated or implied on shop drawings or product data submittals without separate written request complying with the above requirements.
2. When acceptance will require substantial revisions to the Contract documents.

1.18.5 Product Acceptance

All products shall be tested as required by the specification, as follows:

1. Product testing shall be by an approved site laboratory, independent laboratory or a recognized testing organization
2. The Contractor shall be responsible for all costs associated with product testing including labour, transportation and the cost of the test itself, except as specified elsewhere in the specifications.

3. Samples shall be taken at the place of origin, place of fabrication or from the site, as required by the Engineer or as otherwise specified.
4. Samples after testing shall remain the property of the Contractor.
5. Samples used for testing may only be incorporated into the work with the written approval of the Engineer.
6. The Contractor shall provide all necessary facilities required for onsite testing of products.
7. The Contractor shall ensure that products are made available for testing sufficiently in advance of intended use, to allow adequate time for testing and evaluation.
8. Delays resulting from the time taken to test a product shall not be acceptable as cause for a Claim.
9. Before final inspection, all components, systems and subsystems shall be tested, to demonstrate compliance with the specified performance requirements.

1.18.6 Utility Coordinator

All submittals for mechanical, electrical and other utility products shall be approved by the utility coordinator before submittal to the Engineer.

1.18.7 Operation and Maintenance Data

Operation and maintenance data and manuals shall be prepared in accordance with Section 1.26. All data supplied for the operation and maintenance data or manuals shall be licensed to the Owner.

1.18.8 Submittals

All submittals shall be in compliance with the requirements of Section 1.11.

1.19 Product Substitution Procedures

This section includes administrative and procedural requirements for handling requests for substitutions made after award of the Contract.

1.19.1 Definitions

Term “product” shall mean any material including proprietary goods, equipment, and manufactured items.

1.19.2 Product Substitution Requirements

The Contractor shall comply with the following requirements:

1. Specifying of manufacturers or their products by name, trade name, catalogue number, etc., shall not act to relieve the Contractor either from his responsibility to meet other specification requirements, or from his responsibility to make material submittals for approval.
2. Substitute products, where permitted and approved, must conform to the Engineer’s designed space requirements. Any such substitute product that does not meet such space requirements, whether approved or not, shall be replaced at the Contractor’s expense and any modification of replaced systems thereby arising shall also be made at his expense.
3. References to “approved equal” of similar terms shall mean that the approval of the Engineer is required for any alternative product to be considered for use in the project by the Contractor.
4. Where products are specified by propriety designation, the Contractor shall not be permitted to procure ‘approved equal’ or ‘approved alternative’ products, but must procure the product from the selection of manufacturers or suppliers listed.

5. Substitute products: If the Contractor is unable to obtain the specified product in spite of his best endeavours, and if he is unable to find and propose a suitable equal alternative he may propose a substitute for the Engineer's review and approval, which substitute shall be similar to, and as near as possible equal if not better than the quality, durability and performance characteristics of the specified product. A substitute product will only be considered if the Contractor has proven to the Engineer's reasonable satisfaction that the specified product is unobtainable.
6. Identification of Abu Dhabi Emirate produced products: Tenderer must certify that this tender reflects the tenderer's best, good faith effort to identify and incorporate the Emirate produced products and manufactured goods for every component contained in the tender documents where such Emirate-made components are available and meet the requirements set forth in these Specifications.

1.19.3 Engineer Approval of Alternatives and Substitutes

Substitution request submittal: The Engineer will consider requests for substitution as follows:

a. Submit 3 copies of each request for substitution for consideration. Submit requests in the form and according to procedures required for variation proposals.
b. Identify the product or the fabrication or installation method to be replaced in each request. Include related specification section and Contract plan numbers.
c. Provide complete documentation showing compliance with the requirements for substitutions, and the following information, as appropriate:
    1. Coordination information, including a list of changes or modifications needed to other parts of the work and to construction performed by the Owner and separate Contractors that will be necessary to accommodate the proposed substitution.
    2. A detailed comparison of significant qualities of the proposed substitution with those of the work specified. Significant qualities may include elements, such as performance, weight, size, durability, and visual effect.
    3. Product data, including drawings and descriptions of products and fabrication and installation procedures.
    4. Samples, where applicable or requested.
    5. A statement indicating the substitution's effect on the Contractor's construction schedule compared to the schedule without approval of the substitution. Indicate the effect of the proposed substitution on overall Contract time.
    6. Cost information, including a proposal of the net saving, in the Contract sum. Additional costs are not accepted. This should be substantiated by comparative quotations with complete rate breakdown for both the proposed alternative/substitute item and the specified item.
    7. The Contractor's waiver of rights to additional payment or time that may subsequently become necessary because of the failure of the alternative and substitution to perform adequately.
    8. Warranty shall be equal to or greater than that specified for the original specified item.
    9. Reimbursement for review and redesign services of the Engineer.
d. Engineer's action: Approval of any substitute product shall be solely at the direction of the Engineer and such approval shall in no way relieve the Contractor of any of his liabilities and obligations under the Contract. Burden of proof in satisfying the Engineer as to the suitability of any proposed substitute product shall rest with the Contractor. Engineer may request and the Contractor shall provide such supporting data, carryout such tests, etc., as the Engineer may reasonably require in order to satisfy him as to such suitability. Any extra costs of delay

by the Contractor, because of his failure to propose substitutes in a timely manner, so as to allow the Engineer reasonable time to review, or because of rejection of substitutes found by the Engineer to be unsuitable, shall be the responsibility of the Contractor, and he shall not be entitled to additional payment nor to extra time for completion in this respect.

e. Cost effect in approving substitutes: Should any substitute product be approved by the Engineer, any net increase in cost over and above the specified product shall be borne by the Contractor and, any net saving in cost shall be to the benefit of the Owner.

1.19.4 Product Storage and Handling Requirements

a. Products shall be delivered according to the construction schedule, in order to avoid construction delays or undue storage requirements.

b. Transport and handle products in a suitable manner at all times to avoid product damage.

c. Deliver dry and in undamaged condition in the manufacturer's unopened containers or packaging.

d. The Contractor shall inspect shipments upon delivery, to ensure that the products:

1. Are properly labelled and identified
2. Comply with the requirements of the specifications
3. Quantities are correct
4. Inspect all products upon delivery and report any damage to the Engineer
5. Any products damaged during delivery, storage or installation shall be marked and set aside
6. Proposals for repair of any damaged products shall be submitted in writing to the Engineer for approval.
7. No repairs to damaged products shall be attempted, without the Engineer's approval.
8. Any damaged products deemed unsuitable for repair by the Engineer shall be removed from site and replaced at the Contractors expense.

e. Comply with specific transportation and handling requirements specified in individual specification sections and as directed by the Engineer.

1.19.5 Storage and Protection

a. Store products in accordance with manufacturer's instructions, with seals and labels intact and legible.

b. Store sensitive products in weather-tight enclosures.

c. Where product manufacturer recommends storage under controlled temperatures, the Contractor must provide an enclosed, insulated, cool store maintained at the proper temperature, 24 hours a day.

d. Exterior storage of fabricated products:

1. Place on supports above ground
2. Cover products subject to deterioration with canvas tarpaulins and provide for air circulation to prevent condensation

e. Store products so as to allow ready access for inspection

1. Date of manufacture and date of expiry shall be clearly visible
2. The Contractor shall periodically inspect the products to ensure that they are stored under required conditions and are free of damage or deterioration

f. Provide electrical connections to energize heaters or internal climate control units in electrical machinery, motors, panels and the like while the unit is in storage and after installation until the unit is placed into service.

g. The Contractor shall develop a method statement that identifies the equipment within the project that will need rotation and operation during storage and after installation to maintain its function before the start of the facility and during the warranty period.

1.20 Testing of Systems, Start-up and Commissioning

This section includes the following:

1. Requirements for system and facility start-up
2. Requirement for operational, field and performance testing
3. Exceptions to these requirements are in individual technical sections and only modify the individual article and topic
4. Other articles and topics in this section remain in force unless specifically deleted by the related specification section

1.20.1 Definitions

Definitions of key terms used in this specification are as follows:

1. Component: An individual item, piece of equipment, or equipment group as specified in a single section of these specifications.
2. Start-up Plan: A single and complete plan incorporating all requirements of this section.
3. Subsystem: A grouping or assembly of components, all of which operate together to produce the specified performance.
4. System: An assembly of subsystems and components.
5. Validate: To support, substantiate, and authenticate specified operation on a sound and authoritative basis.

1.20.2 Quality Control

The Contractor shall comply with the following quality control items.

a. Utility coordinator: Utility coordinator duties shall continue throughout the testing, start-up and commissioning phase until all electrical and mechanical equipment and other installed utilities is fully commissioned and accepted by the Engineer.

b. Start-up foreman:

   1. Submit qualifications for approval.
   2. Minimum experience:
      i. Minimum 10 years experience in utility operations and maintenance including water and waste water treatment and pumping stations and collection and distribution systems
      ii. Minimum 3 years experience starting up, operating and maintaining equipment
      iii. Academic or factory training
      iv. Combination of training and experience
   3. Owner and Engineer reserve the right to reject start-up foremen lacking the experience and education necessary to start up, operate and maintain the treatment facility

c. Pre-start-up conference:
   1. Schedule conference not less than 15 calendar days before beginning start-up of any part of the works
   2. The Owner, the Engineer, the Contractor, start-up foreman, utility coordinator and other responsible parties (e.g. equipment manufacturers) to attend
   3. Submit an agenda 5 working days before conference. Include: Start-up, testing and equipment demonstration/training schedule

1.20.3 Submittals

All submittals shall be as specified in Section 1.11. The Contractor shall submit the following for approval:

a. Start-up plan
   1. Submit not less than 30 days before first pre-start-up conference
   2. Provide step-by-step procedures for starting up each element of each system
   3. The Contractor is responsible for means, methods, techniques, sequences, procedures, coordination, completeness, accuracy, and validity of the plan.
   4. The Contractor may submit individual sections of the start-up plan as they are developed.
      i. Upon approval, incorporate these individual sections into the overall facility start-up plan
      ii. Rejection of individual sections of the start-up plan by the Engineer shall not be considered a cause for delay.
   5. Identify each person and organization participating in the start-up. Identify their duties and responsibilities.
   6. Provide for contingencies if problems develop during start-up or if a component fails to perform as specified.

b. Temporary connections to facilitate start-up and testing
   1. Submit working drawings showing necessary temporary connections.
   2. Submit written description of how temporary connection will be used.
   3. Provide separate drawings and descriptions for each item or subsystem identified in the start-up plan.

c. Start-up validation procedures
   1. Submit a complete, step-by-step description of each test, simulation, and start-up.
   2. Submit start-up schedule by system or subsystem as appropriate.
   3. Identify individuals and organizations involved in the start up as well as their duties and responsibilities
   4. Identify test equipment required
   5. Include accuracy and calibration information
   6. List data requirements and identify proposed methods of demonstrating compliance with specified performance requirements.

d. Validation report:
   1. Submit validation report within seven working days of completing performance testing
   2. Include test procedures, specified performance requirements, performance data, and data evaluation.

1.20.4 Sequencing and Scheduling

Provide start-up schedule for each system and subsystem. Address each subsystem individually. Include required submittals in schedule. Update schedule as necessary.

1.20.5 Start-up Requirements

The Contractors shall comply with the start-up requirements outlined in this section.

a. Start-up Prerequisites

Prerequisites for start-up include the following:

1. Building enclosures are complete, weather-tight, and all painting has been completed
2. All system components have been checked by the manufacturer (where required in the specifications) and are certified as "ready to operate".
3. Electrical and instrumentation components are connected to the permanent power supply.

b. Design

Design requirements include the following:

1. Design temporary process and utility connections to meet the specified design requirements of the component, subsystem, and system to which they are connected
2. Design temporary supports and restraints
3. Do not place structural loads on the permanent facility beyond its design capacity
4. Provide dielectric unions on temporary connections wherever dissimilar metals connect
5. Provide safety devices on temporary connections wherever they would be required if the connections were permanent

c. Performance

Performance requirements include the following:

1. Tests each system and all of its components
2. Demonstrate compliance with the performance specified in the individual sections of the specifications. This includes operation in all available modes (e.g. manual and automatic)
3. Collect operating data for all system components: Refer to Section 1.11.10.

d. Maintenance

Maintenance requirements include the following:

1. Maintain all components through completion of start up and testing
2. Follow manufacturer's recommendations
3. Record all maintenance performed
4. Submit maintenance records to the Engineer with validation report.

1.20.6 Temporary Connections

Provide all materials necessary for temporary connections. Materials shall be adequate for the application. Engineer shall be the sole judge of suitability.

1.20.7 Operating Fluids

Operating fluids shall meet the following requirements:

a. Provide operating fluids required for duration of start-up and performance testing.

b. All operating fluids shall be as specified.

c. Items provided are in addition to those provided under the specifications.

d. The Contractor shall provide all water (treated sewerage effluent or potable as appropriate) required for all tests including all trucking at no additional cost to the Owner. Availability of water on site for testing purposes is not guaranteed.

   1. All testing shall be performed with clean particulate free water acceptable to the Engineer.
   2. Irrigation and drainage system testing may be with treated sewerage effluent or potable, as available.
   3. All potable water system components shall be tested only with potable water.

1.20.8 Spare Parts

Provide all maintenance and replacement parts required during start-up and testing. Maintenance and replacement parts used by the Contractor before the start of the specified operations and maintenance period are in addition to those required by the specifications. All spare parts required by the specifications shall be catalogued, inventoried and entered into electronic data terms.

1.20.9 Component and System Validation

Component and system validation shall comply with the following:

a. Validate each component and each system using one or more of the methods described below:

   1. Testing to show compliance with the specifications.
   2. Simulate actual operation using a method certified as acceptable and valid by both the component manufacturer and the Engineer.
   3. Certification by an independent testing laboratory that the component meets the specified industry standard.
   4. Where test procedures are specified, substitute procedures will not be accepted without prior written approval from the Engineer.

b. Validate components before system start-up and testing. Component validation shall include but is not necessarily limited to:

   1. Operate each component over its full design range
   2. Demonstrate manual and automatic operation of all components
   3. Demonstrate all emergency shut down and safety devices
   4. Demonstrate normal start-up and shut-down procedures
   5. Demonstrate “out of parameter” corrections
   6. Document actions taken and procedures developed which are not covered in the operation and maintenance manual. Provide this information as an appendix to the manuals

c. Validate each system to demonstrate that components operate together to produce the specified system performance. Validation shall require the same items as required for the individual components.

1.20.10 Validation Prerequisites

Testing shall meet the following validation prerequisites:

1. Start-up submittals have been accepted
2. Manufacturer’s have certified component installations wherever required

3. Specified manufacturer’s field services have been completed
4. Auxiliary and support systems are operating properly
5. No safety defects exist
6. Arrangements for waste disposal (both solid and liquid) have been made.
7. All manual and automatic controls are operational
8. All equipment has been lubricated and serviced, and it is ready for continuous operation.

1.20.11 Validation Preparation

Implement safeguards and procedures to protect equipment and facilities from damage during start-up and performance testing.

Construct approved temporary connections. Test all temporary connections using the same procedures that would be required if the connection were permanent.

1.20.12 Preliminary Testing

Preliminary testing shall meet the following requirements:

a. Where appropriate (for example, where doing so will not cause damage), conduct tests using either potable water, treated sewage effluent, or particulate free water acceptable to the Engineer before performance testing.
b. Test components and subsystems before testing the complete system.
c. Conduct each test in accordance with the approved testing procedures.
    1. Engineer shall observe all tests in their entirety
    2. Schedule testing and coordinate with the Engineer
    3. Notify Engineer at least 24 hours before re-scheduling a test
d. Repair or modify components, subsystems, and systems which do not meet specified performance criteria.
    1. Cost of repairs or modifications shall be at the Contractor’s expense
    2. Repeat testing until acceptable performance is achieved
    3. A maximum of two re-tests will be allowed (3 tests total) unless the Engineer agrees in writing that additional tests are justified
    4. Equipment which does not meet the specified performance shall be removed and replaced with equipment which can meet the criteria
        i. All such work shall be at the Contractor’s expense
        ii. Alternatively the Owner may elect to withhold retention money and Claim against the Contractor’s performance security in lieu of replacing the faulty equipment
e. Collect operating data as appropriate, for each system component. Include the information as specified in Section 1.11.
f. At the conclusion of start-up and testing:
    1. Replace or clean all filters, pipes, structures, etc.
    2. Remove any temporary supports, plugs or testing equipment used for the testing
    3. Perform equipment services recommended by the manufacturer
    4. Place equipment controls on “automatic” setting as appropriate

1.20.13 Field Quality Control

Calibrate test equipment used for performance testing immediately before testing. Confirm calibration immediately after testing. Re-testing will be required whenever test equipment is out of calibration at the conclusion of performance testing.

1.20.14 Performance Testing

Performance testing shall meet the requirements listed in this section.

1.20.14.1 Description

This section includes procedure for performance testing. Following completion of the installation and start-up, and after all construction and preliminary testing and validation is complete, the Contractor shall test each item to demonstrate compliance with specified performance requirements.

1.20.14.2 General

After all construction and preliminary testing and validation is complete and before taking-over of any part of the works, the Contractor shall perform performance tests as called for in the specifications.

a. The Contractor shall demonstrate operation of the facilities to the Engineer showing proper sequence of operation as well as satisfactory performance of the system and individual components.

b. Any improper operation of the system or any improper, neglected or faulty construction shall be repaired or corrected to the satisfaction of the Engineer.

c. The Contractor shall make such changes, adjustments or replacement of equipment as may be required to make same comply with the specifications, or replace any defective parts or material.

1.20.14.3 Performance

a. At the time of testing, failure of the system or unit process to perform at the specified level will be the responsibility of the Contractor.

b. In the event of failure of equipment to meet the specified performance, the Owner reserves the right to:

   1. Not accept such equipment or system
   2. Withhold retention money
   3. Make Claims on the performance security/bond

c. Test schedule:

   1. Prepare and submit a consolidated schedule of performance tests not later than 90 calendar days before the scheduled start of the first test.
   2. Submit updates at monthly intervals.
   3. Prepare and submit weekly a schedule of tests to be carried out during the following week.
   4. Inform the Engineer not later than twenty-four hours in advance of changes in the scheduling of a test.

d. Submittals: For all specified performance tests, prepare and submit:

   1. Draft test procedure: Submit not later than two months in advance of the scheduled test date
   2. Final test procedure: Submit not later than two months in advance of the scheduled test date.

3. Test report: Submit within fourteen days of the successful completion of the test.

1.20.14.4 Performance Test Execution

a. Prerequisites for performance test:
   1. Component and system preliminary test acceptance
   2. Snag list rectified
   3. Commissioning plan approved
   4. Notification of the Engineer issued at least 14 calendar days before scheduled date of test
   5. Equipment manufacturer representative appointed to supervise the test.
   6. Performance testing shall not commence until equipment has been approved by Engineer as having met all specified requirements.

b. Plant and process control systems and all associated electrical equipment shall be tested to demonstrate that the facility operates as specified, and that all protection devices are working correctly.

c. No test shall commence until all related structures, piping, electrical, instrumentation and controls has been installed, tested, connected and approved by the Engineer in compliance with the specification and manufacturer's requirements. Satisfactory operation shall mean operating safely at the guaranteed duty and efficiency without adversely overheating, overloading, vibrating or exceeding specified noise level.

d. Unless otherwise agreed with the Engineer, each manufacturer's representative shall be present at the start of the operational demonstration to examine their equipment at the beginning and end of the test, and will supervise the start-up, calibration and adjustment procedures and other services necessary for the correct operation.

e. Any component test failure or improper operation of a system or any improper, neglected or faulty construction shall be repaired or corrected to the satisfaction of the Engineer.

f. The Contractor shall make such changes, adjustments or replacement of equipment as may be required to comply with the specifications, or replace any defective parts or material.

g. At the time of testing, failure of a component or system to perform at the specified level will be the responsibility of the Contractor. In the event of failure of equipment to meet the specified performance, the Engineer reserves the right to:
   1. Not accept such equipment or system
   2. Withhold retention money
   3. Make Claims on the performance bond

h. Acceptance of plant and equipment may be dependent on the completion of other Contracts, operation of existing works or a planned commissioning schedule for complex works as determined by the Engineer.

i. Under performance tests, each component facility or item shall meet the acceptance testing as otherwise specified for that item. Separate performance testing may not be required where components and items have successfully passed other field and operational tests as specified, as determined by the Engineer.

j. Unless otherwise indicated, furnish all labour, materials, and supplies for conducting the test and taking all samples and performance measurements.

k. Prepare performance test report summarizing test method and results.

l. When, in Engineer's opinion, equipment meets performance requirements specified, such equipment will be accepted as to conforming to Contract requirements. Such acceptance will be evidenced by Engineer's signature on equipment test report.

m. During the course of initial operation, the Contractor shall instruct the Owner's personnel in proper operation and maintenance of the equipment, as specified herein.

n. The Contractor shall make necessary power connection to conduct an integrated site test. In the absence of permanent power supply, the Contractor shall supply a mobile generator to be used for the duration of the test.

o. The Contractor shall employ services of an approved independent certified testing laboratory to perform sample testing and provide on-site laboratory as required. Owner reserves the right to directly employ services of an independent testing agency or laboratory to perform special testing. Employment of the testing agency in no way relives the Contractor of his obligations to perform the work in accordance with the specifications.

p. Laboratory shall be accredited to a recognized international standard and shall submit a valid accreditation certificate to be approved by the Engineer before the testing program is approved.

q. Testing equipment shall be calibrated at reasonable intervals in accordance with the manufacturer's requirements

r. Tests to verify compliance with the specifications shall conform to the testing procedure and undertaken by the qualified personnel specified. Substitutes to the specified personnel shall be submitted to the Engineer for approval and shall be at least equal in experience and qualifications to those specified

s. The Contractor shall perform additional tests at no extra cost as required by the Engineer to prove full compliance of the performance of the completed works

t. After each test, the Contractor shall promptly submit six copies of a test report to the Engineer. The report shall include as a minimum:

   1. Project identification
   2. Date issued
   3. Name of inspector
   4. Date and time of sampling and testing
   5. Identification of product and specification reference
   6. Type and test method
   7. Test results and interpretation

u. Remotely controlled plant and equipment shall demonstrate suitable operation both from local controls and remote controls. As a minimum this procedure shall include full open and full close positioning and shall demonstrate the ability of each valve to hold the set position under all operational conditions.

v. Variable speed equipment shall demonstrate accurate response to speed controlling devices within the specified operating range. During such tests, actual output shaft speed shall be validated by mechanical measurement of shaft speed to compare actual speed with equipment instruments.

w. Response of automatic control system shall be tested to prove the manual and automatic controls, and combination of both is correct and accurate. Where a component of a control system performs more than one function, each function shall be validated. Under automatic control plant shall respond accurately and reliably to its controlling signals. Automatic alternation and backup functions shall also be validated during the test.

x. Instruments, gauges and other sensors and display devices forming part of the completed installation shall be properly calibrated before the test begin, and may be used to measure and record the test data. Any other test equipment required shall be provided by the Contractor for the duration of the test.

y. All the works shall be examined at the conclusion of the performance test to establish that all the plant and equipment is free from damage and undue wear. This inspection shall be considered as part of the performance test. Plant shall be considered to have failed such test if there is any detectable damage or undue wear.

z. The Contractor shall correct all defects and malfunctions disclosed by test using approved methods and new materials for repairs as required and within the time of test specified in the schedule and at his expense.

aa. Pump stations: In addition to the component testing as otherwise specified the following procedures shall be followed:

1. A record of bearing and coupling clearances and alignments shall be tabulated to show the "as-built" condition of each pump.
2. A record of all overload, timing relay and oil pressure relays shall be tabulated to show the "as-built" condition of each motor starter.
3. All cables shall be "megger" tested to confirm the integrity of the insulation. A tabulated record of results shall be made.
4. Control panel shall be statically tested with motors disconnected to confirm the correct sequence of operation.
5. Each pump shall be operated individually over the range from closed valve to maximum emergency top water level on a recirculation basis using the Contractor water supply and for a minimum of four hours continuously. During this test the following parameters will be recorded:
   i. Motor current
   ii. Pump output
   iii. Bearing temperature (shall be determined by a contact type thermometer, or lubricant temperature may be measured).
   iv. Vibration: Full speed vibration of all pumps shall be equal to or less than the amplitude limits recommended in the Hydraulic Institute Standards and/or the manufacturer's recommendation, whichever is more stringent.
   v. Test trials shall extend until each pump unit has run 'continuously' for at least 3 days under all operating conditions. Term 'continuously' shall include running at various speeds or on a start/stop basis as determined by the control system.
6. Document each unit’s performance by obtaining concurrent readings showing motor voltage and amperage, suction head and discharge head.
   i. Readings shall be documented for at least three conditions to ascertain the actual performance curve
   ii. One test shall be at shutoff conditions
   iii. Each power lead to the motor shall be checked for proper current balance
7. Determine bearing temperatures using a contact type thermometer. Alternatively lubricant temperature may be measured.
   i. Operate the equipment at least two hours at the maximum specified pressure.
   ii. Bearing temperature shall not exceed the limits recommended in the Hydraulic Institute Standards and/or the manufacturer’s recommendation, whichever is more stringent.
8. In the event any equipment fails to meet the above test requirements, it shall be modified and retested in accordance with the requirements of these specifications.

i. Test results shall be recorded for each pump for each test and full report shall be submitted to the Engineer. Cost of re-resting and reporting shall be borne by the Contractor.

9. Equipment manufacturer or his authorized representative shall submit a certified written report with respect to his equipment stating that:
    i. Equipment has been properly installed, wired and connected under his supervision
    ii. Equipment is in accurate alignment and free from stress imposed by connecting piping or anchor bolts
    iii. He was present when the equipment was placed in operation
    iv. He has checked, inspected and adjusted the equipment as necessary
    v. Equipment has been operated under full load conditions and operated satisfactorily
    vi. Equipment is fully covered under the terms of the guarantee
    vii. Is ready for continuous operation under specified operating conditions
    viii. Is per approved drawings, data and material

bb. Other plant, pipes and facilities: Testing in accordance with the applicable specifications

1.21 Execution

This section includes general procedural requirements governing execution of the work including, but not limited to, the following:

1. Construction layout
2. Field Engineering and surveying
3. General installation of products
4. Coordination of Owner-installed products
5. Progress cleaning
6. Starting and adjusting
7. Protection of installed construction

1.21.1 General Requirements

The Contractor shall provide and install materials and equipment necessary for a complete and functioning project as shown on the Contract plans and required in the Contract documents.

The Contractor is responsibility for site safety and quality of all materials and work.

1.21.2 Submittals

The Contractor shall comply with the following submittal requirements:

a. Qualification data: Land surveyor and professional Engineer
    1. Construction layout and survey work shall be performed by a qualified land surveyor and / or professional Engineer.
    2. Land surveyor qualifications: A professional land surveyor who is legally qualified to practice in Abu Dhabi and who is experienced in providing land-surveying services of the kind indicated.
    3. Field Engineer shall be performed by a qualified professional Engineer.

b. Certificates: Submit certificate signed by land surveyor or a professional Engineer certifying that the location and elevation of improvements comply with requirements.

c. Landfill receipts: Submit copy of receipts issued by a landfill facility, licensed to accept hazardous materials, for hazardous waste disposal

d. Certified surveys: Submit two copies signed by land surveyor or professional Engineer

e. Final property survey: Submit 10 copies showing the work performed and record survey data.

1.21.3 Delivery, Storage, and Handling

General requirements for delivery, storage and handling of products and materials shall be as specified in Section 1.18.1 and Section 1.18.3.

Specific requirements shall be as specified in the relevant specification section governing the material or product. Additional requirements may be added by the Engineer.

1.21.4 Examination

The Contractor shall be aware of the following conditions:

a. Existing conditions: Existence and location of site improvements, utilities, and other construction indicated as existing are not guaranteed. Before beginning work, investigate and verify the existence and location of mechanical and electrical systems and other construction affecting the work. Before construction, verify the location and points of connection of utility services.

b. Existing utilities: Existence and location of underground and other utilities and construction indicated as existing are not guaranteed. Before beginning site work, investigate and verify the existence and location of underground utilities and other construction affecting the work.

   1. Before construction, verify the location and invert elevation at points of connection of sanitary all utilities including sewer, storm sewer, and water-service piping; and underground electrical services.

   2. Furnish location data for work related to project that must be performed by public utilities serving project site.

c. Acceptance of conditions: Examine substrates, areas, and conditions, for compliance with requirements for installation tolerances and other conditions affecting performance. Record observations.

   1. Written report: Where a written report listing conditions detrimental to performance of the work is required by other sections, include the following:

      i. Description of the Work

      ii. List of detrimental conditions, including substrates

      iii. List of unacceptable installation tolerances

      iv. Recommended corrections

   2. Verify compatibility with and suitability of substrates, including compatibility with existing finishes or primers

   3. Examine roughing-in for mechanical and electrical systems to verify actual locations of connections before equipment and fixture installation

   4. Examine walls, floors, and roofs for suitable conditions where products and systems are to be installed

   5. Proceed with installation only after unsatisfactory conditions have been corrected

d. Proceeding with the Work indicates acceptance of surfaces and conditions.

1.21.5 Preparation

Prior to starting the work, the Contractor shall comply with the following:

1. Existing utility information: Furnish information to local utility that is necessary to adjust, move, or relocate existing utility structures, utility poles, lines, services, or other utility appurtenances located in or affected by construction. Coordinate with authorities having jurisdiction.
2. Field Measurements: Take field measurements as required to fit the work properly. Recheck measurements before installing each product. Where portions of the work are indicated to fit to other construction, verify dimensions of other construction by field measurements before fabrication. Coordinate fabrication schedule with construction progress to avoid delaying the work. Space requirements: Verify space requirements and dimensions of items shown diagrammatically on the Contract plans.
3. Review of Contract documents and field conditions: Immediately on discovery of the need for clarification of the Contract documents, submit a request for information to the Engineer. Include a detailed description of problem encountered, together with recommendations for changing the Contract documents.

1.21.6 Construction Layout

The Contractor shall comply with the following requirements:

a. Verification: Before proceeding to lay out the work, verify layout information shown on the Contract plans, in relation to the property survey and existing benchmarks. If discrepancies are discovered, notify the Engineer promptly.

b. General: Engage a land surveyor and/ or professional Engineer to lay out the work using accepted surveying practices

   1. Establish benchmarks and control points to set lines and levels at each stage of construction and elsewhere as needed to locate each element of the project
   2. Establish dimensions within tolerances indicated. Do not scale the Contract plans to obtain required dimensions
   3. Inform installers of lines and levels to which they must comply
   4. Check the location, level, and plumb, of every major element as the Work progresses
   5. Notify the Engineer when deviations from required lines and levels exceed allowable tolerances
   6. Close site surveys with an error of closure equal to or less than the standard established by authorities having jurisdiction

c. Site improvements: Locate and lay out site improvements, including pavements, grading, fill and topsoil placement, utility slopes, and invert elevations.

d. Building lines and levels: Locate and lay out control lines and levels for structures, building foundations, column grids, and floor levels, including those required for mechanical and electrical work. Transfer survey markings and elevations for use with control lines and levels. Level foundations and piers from two or more locations.

e. Record log: Maintain a log of layout control work. Record deviations from required lines and levels. Include beginning and ending dates and times of surveys, weather conditions, name and duty of each survey party member, and types of instruments and tapes used. Make the log available for reference by the Engineer.

1.21.7 Field Engineering

The Contractor's field Engineering shall include the following:

a. Identification: Owner will identify existing benchmarks, control points, and property corners

b. Reference points: Locate existing permanent benchmarks, control points, and similar reference points before beginning the work. Preserve and protect permanent benchmarks and control points during construction operations.
   1. Do not change or relocate existing benchmarks or control points without prior written approval of the Engineer.
   2. Report lost or destroyed permanent benchmarks or control points promptly.
   3. Report the need to relocate permanent benchmarks or control points to the Engineer before proceeding
   4. Replace lost or destroyed permanent benchmarks and control points promptly. Base replacements on the original survey control points.
c. Benchmarks: Establish and maintain a minimum of three permanent benchmarks on project site, referenced to data established by survey control points. Comply with authorities having jurisdiction for type and size of benchmark.
   1. Record benchmark locations, with horizontal and vertical data, on project record documents
   2. Where the actual location or elevation of layout points cannot be marked, provide temporary reference points sufficient to locate the work
   3. Remove temporary reference points when no longer needed. Restore marked construction to its original condition
d. Certified survey: On completion of foundation walls, major site improvements, and other work requiring field-Engineering services, prepare a certified survey showing dimensions, locations, angles, and elevations of construction and site work
e. Final property survey: Prepare a final property survey showing significant features (real property) for project. Include on the survey a certification, signed by land surveyor or professional Engineer, that principal metes, bounds, lines, and levels of project are accurately positioned as shown on the survey
   1. Show boundary lines, monuments, streets, site improvements and utilities, existing improvements and significant vegetation, adjoining properties, acreage, grade contours, and the distance and bearing from a site corner to a legal point
   2. Recording: At substantial completion, have the final property survey recorded by or with authorities having jurisdiction as the official property survey.

1.21.8 Installation

The Contractor’s installation of work shall comply with the following items:

a. General: Locate the work and components of the work accurately, in correct alignment and elevation, as indicated
   1. Make vertical work plumb and make horizontal work level
   2. Where space is limited, install components to maximize space available for maintenance and ease of removal for replacement
   3. Conceal pipes, ducts, and wiring in finished areas, unless otherwise indicated
   4. Maintain minimum headroom clearance of 2.4 m in spaces without a suspended ceiling
b. Comply with manufacturer's written instructions and recommendations for installing products in applications indicated
c. Install products at the time and under conditions that will ensure the best possible results. Maintain conditions required for product performance until substantial completion
d. Conduct construction operations so no part of the work is subjected to damaging operations or loading in excess of that expected during normal conditions of occupancy

e. Tools and equipment: Do not use tools or equipment that produce harmful noise levels

f. Templates: Obtain and distribute to the parties involved templates for work specified to be factory prepared and field installed. Check shop drawings of other work to confirm that adequate provisions are made for locating and installing products to comply with indicated requirements

g. Anchors and fasteners: Provide anchors and fasteners as required to anchor each component securely in place, accurately located and aligned with other portions of the work

h. Mounting heights: Where mounting heights are not indicated, mount components at heights directed by the Engineer

   1. Allow for building movement, including thermal expansion and Contraction

   2. Coordinate installation of anchorages. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to project site in time for installation

i. Joints: Make joints of uniform width. Where joint locations in exposed work are not indicated, arrange joints for the best visual effect. Fit exposed connections together to form hairline joints

j. Hazardous materials: Use products, cleaners, and installation materials that are not considered hazardous.

1.21.9 Owner-installed Products

The Contractor shall provide provision for the following owner-installed items:

a. Site access: Provide access to project site for owner's construction forces

b. Coordination: Coordinate construction and operations of the work with work performed by owner's construction forces

   1. Construction schedule: Inform the owner of the Contractor's preferred construction schedule for owner's portion of the work. Adjust construction schedule based on a mutually agreeable timetable. Notify owner if changes to schedule are required due to differences in actual construction progress

   2. Preinstallation conferences: Include owner's construction forces at preinstallation conferences covering portions of the work that are to receive owner's work. Attend preinstallation conferences conducted by owner's construction forces if portions of the work depend on owner's construction.

1.21.10 Progress Cleaning

Progress cleaning shall comply with the requirements stipulated in Section 1.22.

1.21.11 Starting and Adjusting

The Contractor shall comply with the following:

1. Start equipment and operating components to confirm proper operation. Remove malfunctioning units, replace with new units, and retest

2. Adjust operating components for proper operation without binding. Adjust equipment for proper operation

3. Test each piece of equipment to verify proper operation. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment

4. Manufacturer's field service: The Contractor shall provide a factory-authorized service representative when required to inspect field-assembled components and equipment installation.

1.21.12 Protection of Installed Construction

The Contractor shall comply with the following:

1. Provide final protection and maintain conditions that ensure installed work is without damage or deterioration at time of substantial completion
2. Comply with manufacturer's written instructions for temperature and relative humidity.

1.21.13 Correction of the Work

The Contractor shall comply with the following:

1. Repair or remove and replace defective construction. Restore damaged substrates and finishes. Repairing includes replacing defective parts, refinishing damaged surfaces, touching up with matching materials, and properly adjusting operating equipment
2. Restore permanent facilities used during construction to their specified condition
3. Remove and replace damaged surfaces that are exposed to view if surfaces cannot be repaired without visible evidence of repair
4. Repair components that do not operate properly. Remove and replace operating components that cannot be repaired
5. Remove and replace chipped, scratched, and broken glass or reflective surfaces.

1.22 Cleaning

This section includes requirements for site cleaning, as follows:

1. Daily cleaning and disposal of waste materials, debris, and rubbish during construction
2. Weekly removal of debris from the project site

1.22.1 Equipment

The Contractor shall comply with the following:

1. Provide covered containers and chutes for deposit of waste materials, debris, and rubbish and include in s site layout organization plan.
2. Cleaning materials for products to be cleaned shall be according to the manufacturer of the product and as approved.

1.22.2 Cleaning Execution

The Contractor shall comply with the following requirements:

1. Maintain areas, floors and buildings under the Contractor's control free of waste materials, debris, and rubbish at all times. Maintain site in a clean and orderly condition
2. Remove debris and rubbish from pipe chases, plenums, attics, crawl spaces, and other closed or remote spaces, before closing the space
3. Clean interior work areas and all floors (this also includes site offices, Engineers facilities and laboratories) daily to provide suitable conditions for work
4. Broom clean interior areas before start of surface finishing, and continue cleaning on an as-needed basis
5. Control cleaning operations so that dust and other particulates will not adhere to wet or newly coated surfaces
6. The Contractor must keep all working areas clear of obstructions, surplus materials, unused plant and debris that are unsightly, obstructive and/or hazardous to the safety of all persons expected to be on the premises at any time.

7. The Contractor is advised that a clean and organized site is advantageous to his costs and timely progress. This reflects on his management efforts to minimize waste material, improve safety and achieve a smooth flow of labour and materials on site with minimum obstructions. General: Clean project site and work areas daily, including common areas Coordinate progress cleaning for joint-use areas where more than one installer has worked. Enforce requirements strictly. Dispose of materials lawfully.
8. Comply with requirements in NFPA 241 for removal of combustible waste materials and debris
9. Do not hold materials more than 7 days during normal weather or 3 days if the temperature is expected to rise above 27 deg C
10. Containerize hazardous and unsanitary waste materials separately from other waste. Mark containers appropriately and dispose of legally, according to regulations
11. Site: Maintain project site free of waste materials and debris
12. Work areas: Clean areas where work is in progress to the level of cleanliness necessary for proper execution of the work
13. Remove liquid spills promptly
14. Where dust would impair proper execution of the Work, broom-clean or vacuum the entire work area, as appropriate
15. Installed work: Keep installed work clean. Clean installed surfaces according to written instructions of manufacturer or fabricator of product installed, using only cleaning materials specifically recommended. If specific cleaning materials are not recommended, use cleaning materials that are not hazardous to health or property and that will not damage exposed surfaces
16. Concealed spaces: Remove debris from concealed spaces before enclosing the space
17. Exposed surfaces in finished areas: Clean exposed surfaces and protect as necessary to ensure freedom from damage and deterioration at time of substantial completion
18. Waste disposal: Burying or burning waste materials on-site will not be permitted. Washing waste materials down storm and sanitary sewers or into other areas to be protected, will not be permitted
19. During handling and installation, clean and protect construction in progress and adjoining materials already in place. Apply protective covering where required to ensure protection from damage or deterioration at substantial completion
20. Clean and provide maintenance on completed construction as frequently as necessary through the remainder of the construction period. Adjust and lubricate operable components to ensure operability without damaging effects
21. Limiting exposures: Supervise construction operations to assure that no part of the construction, completed or in progress, is subject to harmful, dangerous, damaging or otherwise deleterious exposure during the construction period

1.22.3 Disposal of Waste

Disposal of waste shall comply with the following requirements:

1. Remove waste materials, debris, and rubbish from the island, weekly and dispose of at approved disposal site
2. Comply with regulations of the authorities.

1.23 Contract Close-out

Contract close-out procedures shall be in compliance with the procedures as outlined in the Owner's Construction Contract Administration Procedures, the Construction Supervision Manual, the Procurement and Contracts Manual, and the requirements described in this section.

This section covers Contract close-out activities and includes, but is not limited to, the following:

1. Handing-over
2. Final inspection
3. Close-out procedures
4. Approvals by authorities
5. Final cleaning
6. Project documents
7. Operating and maintenance instructions
8. Guarantees, warranties and bonds.

1.23.1 General Requirements

Preparation for final acceptance includes the following activities:

1. Submission of final application for payment
2. Turnover of facilities to Owner
3. Issue of Taking Over Certificates
4. Issue of Performance Certificate
5. Submission of signed Claim waiver

1.23.2 Prerequisites for Turnover

In preparation for Contract close-out, the Contractor shall complete the following:

1. Complete submittals in accordance with Section 1.231.24.
2. Submit final application for payment, complete with associated releases, consents and supporting documents to the Engineer
3. Submit final manufacturer certifications, guarantees, warranties, and similar documents
4. Submit clearance certificates and approvals from government authorities as necessary to connect to the permanent power supply
5. Submit occupancy permits, operating certificates, final inspection and test certificates and similar releases enabling full and unrestricted use of the facilities and services
6. Submit record drawings, final, damage or settlement surveys, property surveys, and similar physical items
7. Make final changeover of locks and deliver keys to the Engineer
8. Complete testing of systems, and training of the Owner's operations and maintenance personnel
9. Dismantle and remove temporary facilities and services from the project site. This includes utilities, construction tools, buildings and facilities, mock-ups, and similar elements
10. Complete final cleaning
11. Complete all demonstrations and training per Section 1.25

12. Repair and restore exposed finishes which have been marred or otherwise damaged
13. Submit all spare parts, and tools
14. Submit an itemized list of all deviations and non-conformances to the Contract requirements. Include a detailed plan to correct each deviation and non-conformance

Notify the Engineer that facilities and completed work items are ready for the taking-over inspection. Include the itemized list of deviations and non-conformances in the notification letter.

1.23.3 Prerequisites for Final Inspection

To prepare for final inspection, the Contractor shall complete the following:

1. Submit last outstanding list of deviations and non-conformances complete with associated or corrected submittals. State that each item has been corrected or otherwise resolved for acceptance
2. Submit the Engineer's and the Contractor's list of deficiencies from the handing-over inspection. State how each item has been corrected or otherwise resolved for acceptance.
3. Submit final meter readings for all utilities, a measured record of stored fuel and chemicals, and similar data as of the time of final completion
4. Submit complete listing of all consumable stores and spare parts used by the Contractor to service the electro-mechanical works throughout the maintenance period
5. Complete submittal of record documents

Notify the Engineer that a part of the works or the whole of the works are ready for the final inspection. Include the itemized list of deviations and non-conformances in the notification letter

1.23.4 Project Close-out Procedure

Close-out procedure will be as follows:

a. Comply with specified and Contractual procedures necessary for issuance of the "Taking-Over Certificate" and "Taking Over Certificates" for part of the works
b. When the Contractor considers work or part of the works has reached final completion, submit the following:
    1. Certificate that:
        i. Contract documents have been reviewed
        ii. Work has been inspected
        iii. Work is complete and meets the requirements of the Contract documents
    2. Provide all submittals required by governing authorities
    3. Submit an application for payment providing total adjusted Contract sum, previous payments, approved change orders and the sum remaining due.

1.23.5 Approvals from Public Authorities

The Contractor shall comply with the following items:

1. Obtain all clearance certificates and approvals required as a prerequisite to connecting the works to the permanent power supply.
2. Coordinate with the Engineer to obtain the necessary documents from ADWEA regarding connection to the permanent power supply.

1.23.6 Final Cleaning

The Contractor shall perform a final cleaning per the following requirements:

a. Execute before final inspection:
   1. Remove all debris and left-over work materials from the site
   2. Sweep and vacuum clean all pavement surfaces of debris, sediments, dust and sand
   3. Clean all interior and exterior surfaces of office facilities exposed to view. Avoid disturbing natural weathering of exterior surfaces
   4. Remove temporary labels, stains, and foreign substances
   5. Polish transparent and glossy surfaces
   6. Clean or replace all filters for mechanical equipment
   7. Clean roofs, gutters, downspouts, and drainage systems
   8. Remove debris and surface dust from limited access spaces
   9. Clean concrete floors in unoccupied spaces broom clean
   10. Clean light fixtures and lamps so they operate at maximum efficiency
   11. Clean the parking areas and areas located within the right-of-way
       i. Sweep paved areas and rake all other surfaces
       ii. Remove litter and foreign substances
       iii. Remove stains, chemical spills, and other foreign deposits

b. Comply with safety standards and governing regulations for cleaning operations
   1. Do not burn waste materials at the site
   2. Do not bury debris or excess material on the property
   3. Do not discharge volatile or other harmful or dangerous materials into the drainage or sewerage systems
   4. Remove all waste materials from the site and dispose of properly.

1.23.7 Project Record Documents (As-builts)

Project record documents shall comply with the following requirements:

a. The Contractor shall provide all necessary details and at least the following information as work proceeds in a form approved by the Engineer to enable the Engineer to prepare a complete set of the record drawings for all civil Engineering works:
   1. Position and extent of all support construction left in any excavation
   2. Precise location of all services encountered
   3. Soils encountered during all excavation work
   4. Amendments to approved working drawings as a consequence of construction
   5. Measured depths of construction
   6. Measured horizontal and vertical locations of underground utilities and appurtenances, referenced to permanent surface improvements
   7. Measured locations of internal utilities and appurtenances concealed in construction, referenced to visible and accessible features of the work
   8. Field changes of dimension and detail
   9. Details not on original Contract plans

b. Keep documents current throughout the construction period. Do not conceal work until “As-Built” information has been recorded

c. Store documents separate from those used for construction.
    1. Protect from deterioration and loss
    2. Store in a secure, fire resistive location
d. For all mechanical and electrical works, the Contractor or his specialist subcontractor shall prepare a complete set of record drawings of the work as constructed and as erected
e. Format:
    1. Maintain a blue line or black line set of prints of all Contract plans and shop drawings
    2. Keep the Contract plans and drawings clean and undamaged
    3. Mark up drawings to show actual installation if that differs from what is shown on the Contract plans
        i. Mark up changes using a red erasable pencil
        ii. Show “as built” condition fully and accurately
    4. Mark up drawings to show new information of importance which was not shown on either the Contract plans or the shop drawings. Give particular attention to concealed work that will be difficult to measure or record at a later date
    5. Note related Variation Order numbers, as applicable, next to the mark up
f. Submit documents with transmittal letter containing date, project title, the Contractor’s name and address, itemized list of documents, and the Contractor’s signature in the following formats:
    1. 2 CD’s of CAD drawings
    2. A1 size negative/reproducible in film paper with hanging strips (one) set
    3. A1 size hard copies paper print – 3 sets
    4. A3 size hard copies with spiral binding – 1 set.

1.23.8 Equipment Operating Data

Provide operating data for all motor operated equipment specified. Provide the operating data identified below for each motor operated equipment item in the specifications.

a. Data shall be obtained with the equipment operating under design conditions and while handling the process fluid or material specified
b. No readings shall be taken until the equipment has operated as specified for at least one hour
    1. Description of material handled
    2. Material or fluid delivery rate
    3. System operating temperature and pressure
    4. Motor operating speed
    5. Motor current draw under normal operation and under starting conditions
    6. Bearing operating temperatures.

1.23.9 Guarantees, Warranties, and Bonds

The Contractor shall comply with the following:

a. Provide in duplicate, original stamped copies of all specified guarantees, warranties, and bonds including those required of manufacturers, suppliers and sub-Contractors
    1. Assemble documents in a binder with a durable plastic cover

2. Provide table of contents

b. Start of warranty period shall be:

1. Date when equipment is placed into full time operation for the Owner's benefit with the Owner's approval, or
2. Date of taking-over certificate

c. The Contractor may be required to maintain installed landscaping for an extended period beyond the landscaping acceptance date, as required in Chapter 13, Landscaping and irrigation, or in the Particular Specifications. Where permanent irrigation is not available, the Contractor shall supply and warranty that the necessary irrigation equipment and water is available and will be supplied as necessary to maintain the landscaping plants during the landscaping establishment and/or warranty periods.

1.23.10 Spare Parts and Maintenance Materials

The Contractor shall provide spare parts and maintenance materials in conformance with the following and as otherwise stipulated in these specifications.

a. Provide products, spare parts, and maintenance materials as specified in the technical sections of this specification

1. Include itemized list of all items furnished, describing each item and citing the appropriate specification section and paragraph
2. Package each item for long term storage
3. Mark or tag each item for easy identification

b. Deliver items to the project site. Inventory items with the Engineer, and obtain a receipt before final payment

c. Provide complete listing of all consumable stores and spare parts used by the Contractor during the maintenance period.

1.24 Closeout Submittals

This section includes requirements for the following closeout submittals:

1. Substantial completion
2. Closeout submittals
3. Statement of adjustment of accounts
4. The Contractor's obligations
5. Warranties
6. Spare parts and maintenance materials

1.24.1 Closeout Submittal

The Contractor shall comply with the following:

a. Substantial completion:

1. When the Contractor considers work is substantially complete, submit written notice with list of items to be completed or corrected
2. Should Engineer inspection find Work is not substantially complete, he will notify the Contractor in writing, listing observed deficiencies
3. The Contractor shall remedy all deficiencies and send a second written notice of substantial completion

4. The Contractor shall carry out Tests on Completion in accordance with applicable clauses of the Department of Transport Conditions of Contract and Schedule of Further Requirements. The Contractor shall give to the Engineer not less than 21 calendar days notice of the date after which the Contractor will be ready to carry out each of the tests on completion. Unless otherwise agreed, Tests on Completion shall be carried out within 14 calendar days after this date as directed by the Engineer.
5. When Engineer finds work is substantially complete and all Tests on Completion are successful he will prepare a certificate of substantial completion in accordance with the applicable clauses of the Department of Transport Conditions of Contract and Schedule of Further Requirements.

b. Closeout submittals:
   1. Evidence of compliance with requirements of governing authorities, and as requested by the Engineer
   2. Project record documents: Submit in accordance with Section 1.23.7
   3. Operation and maintenance data: Under provisions of Section 1.26
   4. As-built drawings: Submit in accordance with Section 1.11
   5. Spare parts and maintenance materials
   6. Keys and keying schedule
   7. Evidence of payment: In accordance with conditions of the Contract
   8. Certificates of insurance for products and completed operations: In accordance with Department of Transport Conditions of Contract and Schedule of Further Requirements

c. Statement of adjustment of accounts:
   1. Submit final statement reflecting adjustments to Contract Sum indicating:
      i. Original Contract sum
      ii. Previous variations
      iii. Deductions for uncorrected work
      iv. Deductions against advance payment if any
      v. Deductions for delays penalties
      vi. Deductions for Engineer's fees
      vii. Other adjustments to Contract sum
      viii. Total Contract sum as adjusted
      ix. Previous payments
      x. Sum remaining due
   2. Engineer will issue final variation reflecting approved adjustments to Contract sum not previously made by variations, for Owner authorization

1.24.2 Warranties

The Contractor shall comply with the following:

a. Form of submittals:
   1. Bind in commercial quality 210 X 297 mm (A4) four-ring side binders, with hardback, cleanable, plastic covers

2. Label cover of each binder with typed or printed title WARRANTIES AND BONDS, with title of project; name, address and telephone number of the Contractor; and name of responsible principal
3. Table of contents: Neatly typed, in the sequence of the table of contents of the project manual, with each item identified with the number and title of the specification section in which specified, and the name of product or work item.
4. Separate each warranty or bond with index tab sheets keyed to the table of contents listing. Provide full information, using separate typed sheets as necessary. List subcontractor, supplier, and manufacturer, with name, address, and telephone number of responsible principal

b. Preparation of submittals:

1. Obtain warranties and bonds, executed in duplicate by responsible subcontractors, suppliers, and manufacturers, within fourteen days after completion of the applicable item of work. Except for items put into use with Owner's permission, leave date of beginning of time of warranty until the date of substantial completion is determined
2. Verify that documents are in proper form, contain full information
3. Co-execute submittals when required
4. Retain warranties and bonds until time specified for submittal

c. Time of submittals:

1. For equipment or component parts of equipment put into service during construction with Owner's permission, submit documents within fourteen days after acceptance
2. Make other submittals within fourteen days after date of substantial completion, before final application for payment
3. For items of work when acceptance is delayed beyond date of substantial completion, submit within fourteen days after acceptance, listing the date of acceptance as the beginning of the warranty period.

1.24.3 Spare Parts and Maintenance Materials

The Contractor shall comply with the following requirements:

a. Products required:

1. Provide quantities of products, spare parts, special tools, and maintenance materials specified in individual sections to be provided to the Owner, in addition to that required for completion of work
2. Products: Identical to those installed in the work. Include quantities in original purchase from supplier or manufacturer to avoid variations in manufacture
3. Provide manufacturers' recommended spare parts for 2 years operation for each piece of equipment

b. Storage:

1. Store products with products to be installed in the work, under provisions of Section 1.18.2.
2. After delivery of products to site, maintain spare products in same space and condition as products to be installed in the work
3. When adequate, secure storage facilities are available at site, capable of maintaining conditions required for storage and not required for Contract work or storage, spare products may be stored in available space
4. Maintain spare products in original containers with labels intact and legible, until delivery to the Owner

c. Delivery:
    1. Coordinate with the Owner
    2. Deliver and unload spare products to the Owner at project site and obtain receipt from Engineer before final payment.

1.25 Demonstration and Training

This section establishes the requirements for system demonstration, and operation and maintenance training after all construction, starting and testing of any part of the works.

Training required by this section is in addition to, and not a replacement for, the manufacturer's equipment training required by the individual technical sections.

1.25.1 Training Requirements

The Contractor shall meet the following training requirements:

a. Owner reserves the right to videotape and audiotape the instruction
b. Size of the class shall not exceed 15 people
c. The Contractor shall develop individual training courses for each major mechanical/electrical system identified on the Contract plans
d. Separate training sessions shall be provided for operations, maintenance, and electrical/instrumentation personnel
e. The Contractor shall develop and submit the curriculum to the Engineer for approval
    1. Establish curriculum level for high school graduates with journeyman qualifications
    2. Perform a task and skills analysis, identifying the requirements for proper operation, maintenance, and repair of the system and all of its components
    3. Perform a training analysis identifying:
        i. Tasks requiring training
        ii. Logical order of presentation
        iii. Objectives of each training segment
        iv. Methods for measuring achievement of objectives for each segment
        v. Include tests with at least 15 questions on each outline topic
f. Prepare an instructor's manual, including notes to the instructor, for each training session
    1. Manual shall address:
        i. Session objectives
        ii. Session outline
        iii. Session application
        iv. Instructor qualification and knowledge requirements
        v. List of tools and supplies required for instruction
        vi. Include safety and standby equipment
        vii. Student and course evaluation forms
        viii. Audio/visual resources or reproductions
        ix. Session tests and a grading guide

2. References to the source of answers shall be provided in the course material, with additional notes such as references, review questions, demonstration techniques, class exercises, coordination with other sessions and achievement measurements

g. Instruction times:

1. 0730 hours to 1200 hours prevailing time
2. Sunday through Thursday except local legal holidays
3. Provide a 10 minute break after each hour of instruction

h. Minimum curriculum requirements:

1. Theory of operation and control, which includes both classroom and “hands on” training
2. How to use the operation and maintenance manual including the location of information
3. System layout
4. Wiring, instrumentation and controls
5. Control sequence and logic
6. Normal and emergency operating procedures
7. Basic and advanced operation and maintenance
8. Equipment/instrument adjustment and calibration
9. Site walk through to locate and identify equipment
10. Preventive maintenance
11. Major maintenance
12. Safety
13. Trouble shooting
14. How to use special tools
15. Operation and maintenance supplies
16. Spare parts.

1.25.2 Submittals

Submittals shall be made per the following requirements:

a. All submittals shall be as specified in Section 1.11.

b. Submit the following for approval:

1. Curriculum development document
2. Instructor’s manual
    i. Provide one copy for review
    ii. After acceptance (and before training) provide one copy and one camera ready original
3. Complete schedule of training activities. Include the following:
    i. Schedule of submittals
    ii. Schedule of classes
    iii. Coordinate with start-up and activities specified in Section 1.20
4. Training plan:
    i. Course outline

   ii. Time allocation for each training segment
   iii. Instructor qualifications
5. Presentation materials - Two reproducible copies
6. Manuals and class handouts:
   i. One reproducible copy for review
   ii. One copy for each student at least 5 working days before class.

1.25.3 Quality Assurance

The Contractor shall comply with the following:

a. Instructor:
   1. Submit qualifications for approval
   2. Minimum experience:
      i. 3 years actually operating and maintaining equipment
      ii. Academic or factory training
      iii. Combination of training and experience
   3. Engineer reserves the right to reject instructor’s lacking experience and education required to conduct the training
b. Pre-training conference:
   1. Schedule conference not less than 7 calendar days before training
   2. The Owner, the Engineer, the Contractor, training instructors, and other responsible parties to attend
   3. Submit an agenda 5 working days before conference. Include:
      i. Training schedule
      ii. Examination of training facilities
      iii. Problem identification and resolution.

1.25.4 Training Area

Training area to be provided by the Contractor:

a. Minimum requirements:
   1. Located outside of construction work area
   2. Air conditioned
   3. Seating for 15 students
   4. Tables suitable for students to write and lay out class materials
   5. All equipment required for audio/visual presentations
b. Owner may make existing training room available if not scheduled for use
   1. The Contractor shall coordinate availability
   2. Owner makes no guarantees that the Contractor will be able to use their facilities

1.25.5 Sequencing and Scheduling

The Contractor shall comply with the following items:

a. Conduct classroom training before in field training
b. Conduct hands-on training before system demonstration
c. Schedule training not less than 7 calendar days before desired training date
d. Training delays:
   1. The Contractor:
      i. Notify Engineer at least 3 days in advance of scheduled training
      ii. Failure to provide required notice shall make the Contractor responsible for costs incurred by the Owner for Owner's personnel
   2. The Owner/Engineer:
      i. May delay scheduled training by up to 5 calendar days for personnel time conflicts
      ii. Will notify the Contractor of delay at least 3 days in advance of scheduled training

1.25.6 Training Materials

The Contractor shall provide the following items:

1. Provide all materials and supplies (including consumables) necessary for training and demonstrations
2. Provide special tools required for training and demonstrations
3. Provide safety equipment required by instructors

1.26 Operation and Maintenance Data

This section outlines requirements for detailed information for the preparation, submission, and Engineer's review of operations and maintenance (O&M) data, as required by individual specification sections.

1.26.1 Definitions

Key terms used in this specification are defined as follows:

1. Preliminary data: Initial and subsequent submissions for Engineer's review
2. Final data: Engineer-accepted data, submitted as specified herein
3. Maintenance operation: As used on maintenance summary form is defined to mean any routine operation required to ensure satisfactory performance and longevity of equipment. Examples of typical maintenance operations are lubrication, belt tensioning, adjustment of pump packing glands, and routine adjustments

1.26.2 Sequencing and Scheduling

The Contractor shall comply with the following:

a. Equipment and system data:
   1. Preliminary data:
      i. Do not submit until shop drawing for equipment or system has been reviewed and approved by Engineer
      ii. Submit before shipment date
   2. Final data:

i. Submit instructional manual formatted data not less than 30 days before equipment or system field functional testing

ii. Submit compilation formatted and electronic media formatted data before substantial completion of project

b. Materials and finishes data:

1. Preliminary data: Submit at least 21 calendar days before request for final inspection
2. Final data: Submit within 10 days after final inspection

1.26.3 Data Format

The Contractor supplied data shall meet the following requirements:

a. Prepare preliminary data in the form of an instructional manual. Prepare final data on electronic media

b. Instructional manual format:

1. Binder: Commercial quality, permanent, four-ring or four-post binders with durable plastic cover
2. Size: A4, minimum
3. Cover: Identify manual with typed or printed title "OPERATION AND MAINTENANCE DATA" and list:
   i. Project title
   ii. Designate applicable system, equipment, material, or finish
   iii. Identity of separate structure as applicable
   iv. Identity of equipment number and Specification section
4. Title age:
   i. The Contractor name, address, and telephone number
   ii. Subcontractor, supplier, installer, or maintenance Contractor's name, address, and telephone number, as appropriate
      a) Identify area of responsibility of each
      b) Provide name and telephone number of local source of supply for parts and replacement
5. Table of contents:
   i. Neatly typewritten and arranged in systematic order with consecutive page numbers
   ii. Identify each product by product name and other identifying numbers or symbols as set forth in Contract documents
6. Paper: 9 kg. minimum, white for typed pages
7. Text: Manufacturer's printed data, or neatly typewritten
8. Four-hole punch data for binding and composition; arrange printing so that punched holes do not obliterate data
9. Material shall be suitable for reproduction, with quality equal to original. Photocopying of material will be acceptable, except for material containing photographs
10. Large format drawings that cannot be reduced to A3 shall be folded and inserted in heavy plastic folders attached into the binder

c. Data compilation format:

1. Compile all Engineer-accepted preliminary O&M data into a hard-copy, hardbound set
2. Each set shall consist of the following:
   i. Binder: Commercial quality, permanent, four-ring or four-post binders with durable plastic cover
   ii. Cover: Identify each volume with typed or printed title "OPERATION AND MAINTENANCE DATA, VOLUME NO. ___ OF ___", and list:
      a) Project title
      b) The Contractor's name, address, and telephone number
      c) If entire volume covers equipment or system provided by one supplier include the following:
         1) Identity of general subject matter covered in manual
         2) Identity of equipment number and specification section
         3) Provide each volume with title page and typed table of contents with consecutive page numbers. Place contents of entire set, identified by volume number, in each binder
   iii. Table of contents neatly typewritten, arranged in a systematic order:
      a) Include list of each product, indexed to content of each volume
      b) Designate system or equipment for which it is intended
      c) Identify each product by product name and other identifying numbers or symbols as set forth in Contract documents
   iv. Section dividers:
      a) Heavy, 80 pound cover weight, tabbed with numbered plastic index tabs
      b) Fly-leaf:
         1) For each separate product, or each piece of operating equipment, with typed description of product and major component parts of equipment
         2) List with each product:
            - Name, address, and telephone number of subcontractor
            - Supplier, installer, and maintenance Contractor, as appropriate
            - Identify area of responsibility of each
            - Provide local source of supply for parts and replacement
            - Identity of separate structure as applicable
3. Assemble and bind material, as much as possible, in same order as specified in the Contract documents

d. Electronic media format:
1. Portable document format (PDF):
   i. After all preliminary data has been found to be acceptable to Engineer, submit operation and maintenance data in PDF format on CD
   ii. Files to be exact duplicates of Engineer-accepted preliminary data. Arrange by specification number and name
   iii. Files to be fully functional and viewable in most recent version of Adobe Acrobat
2. Manufacturers' standard electronic format.

1.26.4 Submittals

Submittals for O&M data shall comply with the following requirements:

a. Informational:

1. Data outline: Submit two copies of a detailed outline of proposed organization and contents of final data before preparation of preliminary data

2. Preliminary data:

   i. Submit three copies for Engineer's review

   ii. If data meets conditions of the Contract:

      a) One copy will be returned to the Contractor

      b) One copy will be forwarded to the Owner

      c) One copy will be retained in Engineer's file

   iii. If data does not meet conditions of the Contract:

      a) All copies will be returned to the Contractor with Engineer's comments (on separate document) for revision

      b) Engineer's comments will be retained in Engineer's file

      c) Resubmit three copies revised in accordance with Engineer's comments.

3. Final data:

   i. Submit two hardcopies of each manual in format specified herein

   ii. Submit five copies of each CD of the electronic media format with printed labels identifying contents

   iii. Final electronic manual shall be organized in the same format as the hardcopy manual

1.26.5 Data for Equipment and Systems

Data for equipment and systems shall meet the requirements of the following articles under this section.

1.26.5.1 Content for Each Unit (or Common Units) and System

a. Product data:

1. Include only those sheets that are pertinent to specific product

2. Clearly annotate each sheet to:

   i. Identify specific product or part installed

   ii. Identify data applicable to installation

   iii. Delete references to inapplicable information

   iv. Function, normal operating characteristics, and limiting conditions

   v. Performance curves, Engineering data, nameplate data, and tests

   vi. Complete nomenclature and commercial number of replaceable parts

   vii. Original manufacturer's parts list, illustrations, detailed assembly drawings showing each part with part numbers and sequentially numbered parts list, and diagrams required for maintenance

   viii. Spare parts ordering instructions

ix. Where applicable, identify installed spares and other provisions for future work (e.g., reserved panel space, unused components, wiring, and terminals)

b. As-installed, colour-coded piping diagrams

c. Charts of valve tag numbers, with the location and function of each valve

d. Drawings: Supplement product data with drawings as necessary to clearly illustrate:

1. Format:
   i. Provide reinforced, punched, binder tab; bind in with text
   ii. Reduced to A4 size, or A3 size folded to A4 size
   iii. Where reduction is impractical, fold and place in A4 envelopes bound in text
   iv. Identify specification section and product on drawings and envelopes
2. Relations of component parts of equipment and systems
3. Control and flow diagrams
4. Coordinate drawings with project record documents to assure correct illustration of completed installation

e. Instructions and procedures: Within text, as required to supplement product data.

1. Format:
   i. Organize in consistent format under separate heading for each different procedure
   ii. Provide logical sequence of instructions for each procedure
   iii. Provide information sheet for Owner’s personnel, including:
      a) Proper procedures in event of failure
      b) Instances that might affect validity of guarantee or bond
      c) Installation Instructions: Including alignment, adjusting, calibrating, and checking
2. Operating procedures:
   i. Start-up, break-in, routine, and normal operating instructions
   ii. Test procedures and results of factory tests where required
   iii. Regulation, control, stopping, and emergency instructions
   iv. Description of operation sequence by control manufacturer
   v. Shutdown instructions for both short and extended duration
   vi. Summer and winter operating instructions, as applicable
   vii. Safety precautions
   viii. Special operating instructions
3. Maintenance and overhaul procedures:
   i. Routine maintenance
   ii. Guide to troubleshooting
   iii. Disassembly, removal, repair, reinstallation, and reassembly

f. Safety:

1. Separate safety section which identities specified safety hazards associated with maintenance of the equipment

2. As a minimum identity elements with stored energy (springs, compressed gas, large capacities etc.), confined space entries, tag out and lock out procedures

g. Guarantee and service agreements: In accordance with Section 1.24.2.

1.26.5.2 Content for Each Electric or Electronic Item or System

a. Description of unit and component parts:
   1. Function, normal operating characteristics, and limiting conditions
   2. Performance curves, Engineering data, nameplate data, and tests
   3. Complete nomenclature and commercial number of replaceable parts
   4. Interconnection wiring diagrams, including control and lighting systems
b. Circuit directories of panel boards:
   1. Electrical service
   2. Controls
   3. Communications
c. List of electrical relay settings, and control and alarm contact settings
d. Electrical interconnection wiring diagram, including control and lighting systems
e. As-installed control diagrams by control manufacturer
f. Operating procedures:
   1. Routine and normal operating instructions
   2. Sequences required
   3. Safety precautions
   4. Special operating instructions
g. Maintenance procedures:
   1. Routine maintenance
   2. Guide to troubleshooting
   3. Adjustment and checking
   4. List of relay settings, control and alarm contact settings
h. Manufacturer’s printed operating and maintenance instructions
i. List of original manufacturer’s spare parts, manufacturer’s current prices, and recommended quantities to be maintained in storage

1.26.5.3 Maintenance Summary:

a. Compile individual maintenance summary for each applicable equipment item, respective unit or system, and for components or sub-units.
b. Format:
   1. Each maintenance summary may take as many pages as required
   2. Use only A4 size paper
   3. Complete using typewriter or electronic printing
c. Include detailed lubrication instructions and diagrams showing points to be greased or oiled; recommend type, grade, and temperature range of lubricants and frequency of lubrication

d. Recommended spare parts:
   1. Data to be consistent with manufacturer's bill of materials/parts list furnished in O&M manuals
   2. Unit is the unit of measure for ordering the part
   3. Quantity is the number of units recommended
   4. Unit Cost is the current purchase price

1.26.5.4 Guideline Outline Form

Following outline is a guideline of the minimum required contents to be included in the O&M manuals:

a. Cover page: with name of project, date, language version (English), Contract number, and C's name
b. Table of contents: showing contents and sequential page numbering
   1. List of tables (if any)
   2. List of figures (if any)
   3. List of pictures (if any)
   4. List of sheets (if any)
   5. List of abbreviations (if any)
c. Introduction: showing the use of the manual and the appropriate electrical/mechanical equipment or system general description
d. Detailed description of the facility: General, Inlet and sedimentation chamber, trash racks, process facilities, storage reservoir, piping, valves, flow metering, instrumentation and control, etc.
e. Description of utilities and building services: general, high voltage power source, power distribution, potable water, seal water system, ventilation, etc.
f. Operation of the facility
g. Operation of utilities and building services: high voltage power source, power distribution, potable water, seal water system, ventilation, etc.
h. Maintenance: General, preventive maintenance system, corrective maintenance, housekeeping, maintenance stores, etc.
i. Safety: Personal, maintenance, safety hazards, commitment to safety, standard safety procedures, safety programs, etc.
j. Records and record keeping: General, operation records, maintenance records, and operation costs records, etc.
k. Personals: General, personal organization chart, job descriptions, etc.
l. References
m. Glossary of terms.

1.26.6 Data for Materials and Finishes

Data for materials and finishes shall comply with the following requirements:

a. Content for architectural products, applied materials, and finishes:
   1. Manufacturer's data, giving full information on products:
      i. Catalogue number, size, and composition

ii. Colour and texture designations

iii. Information required for reordering special-manufactured products

2. Instructions for care and maintenance:

i. Manufacturer's recommendation for types of cleaning agents and methods

ii. Cautions against cleaning agents and methods that are detrimental to product

iii. Recommended schedule for cleaning and maintenance

b. Content for moisture protection and weather exposed products:

1. Manufacturer's data, giving full information on products:

i. Applicable standards

ii. Chemical composition

iii. Details of installation

2. Instructions for inspection, maintenance, and repair.

1.26.7 Irrigation System and Landscaping

Irrigation and landscaping submittals shall comply with the following items:

a. Content for irrigation system:

1. Site plan marked to show system layout and locations of all isolation valves, control valves, controllers, etc.

2. P & ID type system drawing(s) that detail the system furnished and installed

3. Manufacturers' data sheets for each item installed in the system

b. Content for landscape:

1. Basic care instructions for each type of planting

2. Recommended watering program by irrigation circuit and controller for each season

c. Format: Format shall generally follow that for equipment and systems.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 2 - EARTHWORKS

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

CHAPTER 2: Earthworks

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LIST OF TABLES

2 EARTHWORKS

2.1 General

2.1.1 Description

This section describes the general provisions under which earthworks shall be performed:

1. Prior to the start of earthwork, the Contractor shall perform all control surveying in accordance with Section 1.2.6. And submit to the Engineer for review and approval. Limits of areas to be protected shall be surveyed and protective fenced installed. Excavation and backfill control staking shall be surveyed and placed.
2. Prior to start of earthwork, the Contractor shall take cross-sections of existing ground every 25 m jointly with the Engineer, in accordance with the requirements of Section 1.7 of Chapter 1, General Requirements, and as agreed to by the Engineer. Cross-sections shall have supplemental additional topographic information, including locations of all existing surface features in the plan to include structures, fences, utility risers and markers, utility chambers, drainage structures, areas of vegetation and trees, etc., all located to x and y coordinates and labelled with surface elevations, as per the Engineer's instructions.
3. Use all necessary precautionary and protective measures required to maintain existing utilities, services, and appurtenances that must be kept in operation. In particular, the Contractor shall take adequate measures to prevent undermining of utilities and services presently in service.
4. Earthwork shall be constructed to the lines, grades, elevations, slopes, and cross-sections indicated on the Contract plans.
5. All excavation and backfilling shall be performed in dry condition, sunless otherwise directed by the Engineer.
6. All excavation and backfill work, including the associated work performed in accordance with these specifications, Contract plans, and particular specifications, and as instructed or approved by the Engineer.
7. Contractor shall ensure the removal and diversion of underground and surface water from all excavations and finished surfaces.
8. Contractor to finish the work with final trimming and grading of all surfaces and removal of any remaining construction debris and waste materials

2.1.2 Reference Standards and Codes

Standards and codes for earthworks shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Construction Specifications;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
ASTM	American Society for Testing and Materials;
AD EHSMS RF	Abu Dhabi Environment, Health and Safety Management System Regulatory Framework Manual;

ADM EHS	Municipality of Abu Dhabi City - Guide Lines for Developing EHS Plan for Building and Construction Sector;
ADQCC (TR-516)	Abu Dhabi Road Structures Design Manual;
BS	British Standards;
BS EN	European Standards;
DOT-M-08	Environmental, Health and Safety Manual for Road Projects;
OSHA	Occupational Safety and Health Administration.

Table 2-1 and Table 2-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for earthworks. It also includes designations and titles.

Table 2-1: Designations and titles for AASHTO and ASTM standards that apply to earthworks

AASHTO Designation	ASTM Designation	Title
	ASTM E380 - 2010	*Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System).*
	ASTM D1452 - 09	*Standard Practice for Soil Exploration and Sampling by Auger Borings.*
	ASTM D2113 - 08	*Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.*
	ASTM D4647 / D4647M - 13	*Standard Test Methods for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*
	ASTM D4542 - 07	*Standard Test Method for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer.*
	ASTM D2974 - 07a	*Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.*
	ASTM D5333-03	*Standard Test Method for Measurement of Collapse Potential of Soils (Withdrawn 2012).*
AASHTO M 145		*Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.*
	ASTM D5731 - 08	*Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications.*
AASHTO T 176		*Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.*
AASHTO T 96		*Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
AASHTO T 27		*Sieve Analysis of Fine and Coarse Aggregate.*

AASHTO Designation	ASTM Designation	Title
AASHTO T 11		*Standard Method of Test for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.*
AASHTO M 288		*Standard Specification for Geotextile Specification for Highway Applications.*
	ASTM D5261 - 10	*Standard Test Method for Measuring Mass per Unit Area of Geotextiles.*
	ASTM D4632 - 08	*Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.*
	ASTM D6241 - 04(2009)	*Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.*
	ASTM D4533 - 11	*Standard Test Method for Trapezoid Tearing Strength of Geotextiles.*
	ASTM D4355 - 07	*Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.*
	ASTM D4751 - 04	*Standard Test Method for Determining Apparent Opening Size of a Geotextile.*
	ASTM D4491 - 99a(2009)	*Standard Test Methods for Water Permeability of Geotextiles by Permittivity.*
	ASTM D5199 - 12	*Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.*
AASHTO T 180		*Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop.*
AASHTO T 99		*Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop.*
AASHTO T238		*Standard Method of Test for Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth).*
AASHTO T239		*Standard Method of Test for Moisture Content of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth).*
AASHTO T 2		*Standard Method of Test for Sampling of Aggregates.*
AASHTO T86		*Investigations and Sampling Soils and Rock for Engineering Purposes.*
AASHTO T 87		*Standard Method of Test for Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.*
AASHTO T 88		*Standard Method of Test for Particle Size Analysis of Soils.*
AASHTO T 89		*Standard Method of Test for Determining the Liquid Limit of Soils.*

AASHTO Designation	ASTM Designation	Title
AASHTO T 90		*Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils.*
AASHTO T 93		*Standard Specification for Determining the Field Moisture Equivalent of Soils.*
AASHTO T 217		*Standard Method of Test for Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester.*
AASHTO T 100		*Standard Method of Test for Specific Gravity of Soils.*
AASHTO T 85		*Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate.*
AASHTO T 193		*Standard Method of Test for The California Bearing Ratio.*
AASHTO T 191		*Standard Method of Test for Density of Soil In-Place by the Sand-Cone Method.*
AASHTO T 204		*Standard Method of Test for Density of Soil In-Place by the Drive Cylinder Method.*
AASHTO T 205		*Standard Method of Test for Density of Soil In-Place by the Rubber-Balloon Method.*
	ASTM D4873 – 02 (2009)	*Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples*
	ASTM D4943 - 08	*Standard Test Method for Shrinkage Factors of Soils by the Wax Method.*

Table 2-2: Designations and titles for BS and BS EN standards that apply to earthworks

BS Designation	BS EN Designation	Title
BS 1377-4		*Methods of test for soils for civil engineering purposes - part 4: Compaction-related tests.*

2.1.3 Contractor's Responsibility

2.1.3.1 *Site Visit*

Contractor shall be deemed to have visited the site prior to submitting his Tender and to have made all necessary inspections and investigations per the requirements contained in Section 1.6.1 of Chapter 1, General Requirements of these Standard Specifications.

2.1.3.2 *Boreholes*

Contractor shall perform all work as required to auger or core drill boreholes or test borings when directed by the Engineer when unsuitable soils are encountered at the bottom of excavations or where directed by the Engineer within or immediately adjacent to the work area

The boreholes drilling, sampling and logging shall be carried out in full compliance with ADQCC Manual for Geotechnical Works (TR-509 Vol. 1 and 2).

Purpose of these boreholes shall be to determine the character, thickness and stratification of the subsurface material, the relative density and permeability of granular materials, coring of rock and such other data as may be required by the Engineer to determine the adequacy of the subsurface material.

a. Depth of Boreholes

Depth of such boreholes and the depth at which core samples shall be taken shall be as directed by the Engineer.

The depth of the boreholes shall be determined according to the type and characteristics of the subsurface soil. If no rock is encountered, boreholes shall be driven to a depth of 20 metres in predominantly gravelly-sandy-silty soils and to 30 metres in soft clay soils or soils with a low bearing capacity where piling may be required, all in accordance with the directions and to the satisfaction of the Engineer. If rock is encountered before reaching the above depths, the borehole shall penetrate at least 10 metres in the rock. If the thickness of the rock is less than 10 metres, the borehole shall be continued as specified above and/or as directed by the Engineer.

b. Drilling of Boreholes

Boreholes or test borings shall be advanced between sampling intervals by driving a steel casing to such depth below the ground surface. Casing diameter shall be as required to facilitate removal of the soil sampling or rock coring that is required.

Boreholes shall be augered or core drilled as directed by the Engineer. Augered boreholes shall comply with the requirements of ASTM D1452 and as specified herein. Core drilled boreholes shall comply with ASTM D2113 with double tube, swivel-type, M-design core barrels and as specified herein. Casing at boreholes shall be NX size, with outside diameter of 89 mm and inside diameter of 76.2 mm.

The boring shall be performed with continuous coring and the cores extracted shall be carefully kept in proper core boxes so that the lithology can be recorded as accurately as possible. A preliminary description of the core shall be made when it is extracted. Then these descriptions, together with technical operational details shall be entered in the daily log which shall be available for inspection by the Engineer at all times.

c. Borehole Equipment and Methods

Method and the equipment to be used for advancing the borehole shall be submitted by the Contractor to the Engineer for approval. Casing shall be driven without the use of wash water unless the Engineer specifically approves simultaneous washing and driving. Washing, spudding or drilling ahead of the casing will not be permitted.

Between the depth intervals at which sampling is accomplished as hereinafter specified, loose material within the casing shall be removed by the usual wash pipe method or other suitable means. No downward directed jets will be permitted. Casing shall remain in the hole until the Engineer authorizes its removal.

To prevent caving and mixing strata, casing or drilling mud material (bentonite) shall be used when boring through any stratus which is not sufficiently cohesive to stand firmly without it.

Use of drilling mud to stabilize a borehole will be permitted only if the Engineer deems it is not detrimental to pumping tests or groundwater observations.

d. In-Situ Testing and Sampling

Standard Penetration Tests (S.P.T.) is to be performed during the course of the boring at 1.0m intervals or at every change of stratum.

Pocket penetrometer and/or vane test measurements shall be performed on all suitable cohesive samples immediately after their sampling and before waxing.

Disturbed samples shall be taken from the top of each stratum from the material contained within the standard penetration tool after the S.P.T. has been carried out, and from the cutting shoe of the undisturbed sampler after the undisturbed samples have been taken. Each soil samples shall be stores in a container of glass, plastic or other approved material, fitted with an airtight cover and waxed immediately being taken from the boreholes. Each container shall be numbered and labelled in such a way that the sample can be easily be identified with the boreholes, the soil stratum, the depth from which it was taken and the date on which it was taken

Undisturbed samples should be taken in cohesive soils including mixed soils. Undisturbed samples shall be taken from the most significant beds using appropriate means. The internal diameter of the sampler shall be about 10cm and the useful length at least 50cm. The samplers shall be in good condition and therefore shall be no signs of oxidation on the inner walls or damage to the base.

After the samples have been taken the ends shall be coated with wax, after having removed the loose material. The containers shall then be sealed and clearly marked as specified for the disturbed samples. A careful description shall be made of the undisturbed samples in the laboratory when they are extracted from the container and before starting the required laboratory testing.

Samples and rock cores, immediately upon recovery, shall be placed in containers as approved by the Engineer, identified as specified herein and delivered to the Site Laboratory included under Section 1.19.7 of Chapter 1, General Requirement, of these Standard Specifications.

Each sample or rock core shall be identified and include the following information:

1. Location of borehole.
2. Date when sample was taken.
3. Boring number.
4. Surface elevation.
5. Name of driller.
6. Description and length of casing, if any.
7. Depth of bottom of boring.
8. Depth from which the sample or rock core was taken.

Testing of all samples and rock cores will be performed by the Engineer in the Site Laboratories. Contractor shall furnish the Engineer with all pertinent data as may be required relative to the sample so as to aid the Engineer in his testing program.

e. Water Levels

All water levels encountered in the boreholes shall be recorded and a check shall be made of the static level after boring has been completed.

f. Borehole Logs

Boreholes logs shall be supplied to the Engineer as soon as possible after the borings have been completed. They shall be in such a form as to indicate the location relative to any of the reference points, the description and thickness of each type of soil, the level of the lower contact of each stratum relative to the said level, the level of the water table if any, and the position and record number of every sample taken. The records are to be written in English and the descriptions of the layers have to be in accordance with the International Standards. Furthermore, the records shall include the results of standard penetration tests and of pocket penetrometer and/or vane tests and rock core descriptions (total core recovery, solid core recovery and rock quality designation).

The site investigation works shall not be regarded as complete until all boreholes logs have been submitted to the Engineer and approved by him.

g. Laboratory Tests

As a minimum, the following laboratory tests are to be carried out:

i. For disturbed samples:

- Grading and Atterberg Limits (LL and PL) on representative samples from each borehole as requested by the Engineer.

ii. For undisturbed samples:
- Grading by sieves and or by sedimentation, Atterberg Limits (LL and PL), Natural Moisture Content and Bulk Density on all samples.
- Consolidated undrained triaxial test (3 tests at different confining pressures on three 1-1/2" diameter specimens from each sample) on samples selected by the Engineer.
- Oedometer consolidation tests on samples selected by the Engineer.

iii. Unconfined compression tests on rock samples.

iv. Corrosion effect on concrete of water and soils.

The results of the tests shall be given to the Engineer on approved forms. All measurements shall be expressed in the decimal system.

The above laboratory tests provide a general guideline. Additional testing or elimination of some tests may be requested by the Engineer

h. Final Reports

On completion of all laboratory testing a final report in triplicate shall be submitted to the Engineer.

This final report shall include a generalized subsoil profile and all borehole logs, soil identification, in-situ and laboratory testing, observations and recommendations on the type of foundation and on safe bearing capacity of the foundation soils and where piles are advised recommendations on their safe bearing capacity.

2.2 Clearing and Grubbing

2.2.1 Description

This section describes clearing of the site, grubbing, and removal of topsoil necessary for construction of the work covered by the Contract, in accordance with these specifications.

2.2.2 Construction Requirements

No clearing and grubbing shall be performed unless approved by the Engineer. Contractor shall take all necessary precautions to prevent damage to structures and other private or public property.

Any unauthorised damage to, or interference with, private or public property, including trees, shall be repaired to the satisfaction of the Engineer and the owner, at the Contractor's sole expense.

2.2.2.1 *Areas to be Cleared, Grubbed, and Removed of Topsoil*

Areas to be cleared, grubbed, and removed of topsoil shall be in accordance with the particular specifications and Contract plans, or as directed by the Engineer. In general, clearing and grubbing shall be performed to 3 m outside the top of the fill slope and 3 m outside the top of the cut slope, to include the following areas:

1. To be excavated, including areas staked for slope treatment
2. Where utility, drainage, and subdrainage trenches shall be dug, unsuitable material removed, or structures built
3. Upon which embankments shall be placed
4. Wherever road, parking, and pedestrian pavement is to be placed

No trees that fall between the worksite and the limits of clearing and grubbing shall be removed or damaged without the written authorisation of the concerned authority. Contractor shall submit shop drawings, depicting the existing trees within the limits of the woks, clearly indicating those to be removed and those to be retained, for the Engineer's approval and as per the tree removal management plan as may be contained in the Contract Documents. Individual trees designated by the Engineer shall be left standing and uninjured.

Within built-up areas, clearing and grubbing shall be strictly limited to the extent of cut or fill as shown in the Contract plans or as directed by the Engineer. No private property such as buildings, crops, signs, fences, etc., shall be removed, relocated, or altered without the authorisation of the Engineer.

2.2.2.2 *Clearing*

Clearing shall consist of the removal of all trees (only as approved by the Engineer), bush, shrubs, other vegetation, rubbish, fences, and all other objectionable material, including the disposal of all material resulting from clearing and grubbing. Clearing shall also include the removal of all rocks and boulders that are exposed or lying on the surface.

2.2.2.3 *Grubbing*

In any roadway and paved area, all stumps and roots exceeding 50 mm in diameter shall be removed at least to the depth that is the larger of the following:

600 mm below the finished pavement level

100 mm below the ground level after removal of topsoil

3. 300 mm below the top of improved subgrade or formation level

All stumps and roots, including matted roots, shall be removed to a depth of at least 300 mm below the formation level — the top of the improved subgrade. Cavities resulting from the grubbing shall be backfilled with approved material and compacted to comply with the specifications for the relevant layer.

2.2.2.4 *Conservation of Existing Topsoil, Vegetation, and Cutting of Trees*

Where provided for in the Contract plans, certain designated areas of existing topsoil, vegetation, and trees encountered in the road reserve shall be carefully protected by the Contractor. Contractor shall provide temporary fencing around these areas and shall provide instruction to all personnel and equipment operators not to intrude within that fencing. Protective fencing shall meet the requirements of Section 1.21.2 of Chapter 1, General Requirements, of these Standard Specifications.

Where the Contract Plans or particular specifications include specific plants to be protected or removed and replanted, the Contractor shall include in its bid rates for clearing and grubbing full compensation for omitting or the careful removal and planting of the plants in a protected and fenced-off area. Additionally, on completion of the road, the Contractor shall provide for replanting of the plants in suitable positions in accordance with the Engineer’s instructions.

In cases where the Engineer has approved the cutting of trees, they shall be cut in sections from the top downwards. Branches of trees to be left standing shall be trimmed so as to leave a 7-m clearance above the carriageway and parking areas, and a 2.5-m clearance above pedestrian walkways. Unless otherwise approved by the Engineer, the Contractor shall engage an Owner approved subcontractor for the trimming, removal and replanting of the trees.

2.2.2.5 *Removal and Salvage of Topsoil*

Topsoil shall be removed to a depth as instructed by the Engineer within the areas requiring clearing and grubbing.

If not used immediately, the topsoil shall be transported and deposited in stockpiles or spoil banks provided by the Contractor at locations approved by the Engineer. Salvaged topsoil shall be reused for agricultural and landscape areas.

2.2.2.6 *Roadside Cleanup*

Roadside cleanup, as ordered by the Engineer, consists of work not otherwise provided for in the Contract. Such work may include:

1. Removing trees, snags, brush, other vegetation, upturned stumps, large rocks and boulders, debris, and other unsightly matter outside the areas staked for clearing or grubbing within project right-of-way
2. Trimming trees or brush
3. Filling holes and smoothing and contouring the ground
4. Shaping the ends of cuts and fills to fit adjacent terrain and to enhance the area's appearance
5. Obliterating abandoned roads and reshaping the areas to blend naturally with surroundings within the project right-of-way

Methods and equipment used in roadside cleanup shall be approved by the Engineer.

2.2.2.7 *Disposal of Material*

Material obtained from clearing, grubbing, and removal of topsoil shall be disposed of as approved by the Engineer. Materials to be disposed of shall generally be hauled to a waste site obtained and provided by the Contractor or placed in borrow pits or other suitable places and covered up with soil or gravel, with full coordination and approvals from the concerned authorities. Trees and brush to be removed may be chipped in place. Topsoil to be reused, shall be stockpiled.

Burning of material shall only be permitted by prior written approval of the Engineer. All statutory provisions with regards to environmental constraint and air pollution shall be carefully observed.

2.3 Removal of Structures and Obstructions

2.3.1 Description

This section describes the removal and disposal of structures that obtrude, encroach upon, or otherwise obstruct the work.

2.3.2 Construction Requirements

2.3.2.1 *General*

Contractor shall remove and dispose of all buildings, foundations, bridges, drainage structures, pavement, railings, barriers, fences and other obstructions within the limits of the work, except items designated to remain and utilities and obstructions to be removed under other provisions of the Contract.

All designated salvage material shall be removed, without damage, in sections or pieces that may be readily transported, and shall be stored by the Contractor or transported to the Owner warehouse by the Contractor, as directed by the Engineer.

Basements or cavities left by structure removal shall be filled to the level of the surrounding ground and shall be compacted in accordance with the relevant requirements in this specification.

Existing utilities running through or near existing structures shall be protected and/or relocated in accordance with the Contractor's coordination with the appropriate utility authority.

2.3.2.2 *Removal of Structures and Foundations*

Demolition, removal, and disposal of all buildings and structures designated for removal on the Contract plans or in the particular specifications shall be completed by the Contractor. Work shall include the removal and disposal of all excess debris and the removal of all other foundations, paving, concrete floor slabs, sidewalks, signs, sheds, garages, fences, and tanks, as well as any other miscellaneous work necessary to fully complete the removal of the buildings and appurtenances.

Discontinuance of all utility services that serve the building or structure shall be arranged by the Contractor, who shall also properly remove, disconnect, and plug all such services in accordance with the requirements of the respective utility agency.

Existing underground storage tanks on-site or within the buildings shall be removed and disposed of by the Contractor, who shall take all necessary precautions to remove any remaining fluids within the tanks. Any hazardous materials and petroleum products shall be handled and disposed of in accordance with Section 2.3.2.5. When removing foundations, the Contractor shall perform the following:

1. Remove foundations to a depth of at least 300 mm below finished ground elevation or subgrade elevation, whichever is lower.
2. Break up basement floors to promote drainage.
3. Fill basements or other cavities left by the removal of structures. Fill shall match the level of the surrounding ground. Fill within the area of the roadway embankment prism, under pedestrian pavement, or adjacent to other structures and utilities that require lateral or bearing support. Fill shall be compacted to meet the requirements of Section 2.5.3.1.

2.3.2.3 *Removal of Bridges, Culverts, and Drainage Structures*

Bridges, culverts, and other drainage structures shall not be removed until the Contractor has made satisfactory arrangements to accommodate traffic and the flow of water. Contractor shall not commence removal work before preparing and submittal and the Engineers approval of a Removal Method Statement which provides a detailed description of the Contractor's proposed removal methods, public and traffic safety accomodations, noise and dust controls, disposal methods and locations, and any other item as required by the Engineer.

Unless otherwise indicated, the existing substructures shall be removed 300 mm below the natural ground surface. Portions of existing structures within the limits of a new structure shall be removed to accommodate the construction of the proposed structure.

Work includes removal and disposal of underground obstructions, including walls; individual rocks; structures; abandoned drainage structures, pipe lines, and utilities; foundations; and other structures of steel or concrete.

Removal of existing utilities required to permit the orderly progression of work shall be accomplished in coordination with the appropriate agency. Contractor shall contact the proper agency or owner and arrange for its removal.

Bridges designated as salvaged material shall be dismantled without damage and match-marked. Structures designated to become the property of the Contractor shall be removed from the site.

Blasting or other operations necessary for removing existing structures or obstructions that may damage new construction shall be completed by the Contractor prior to placing new work. Use of explosives shall be governed by Section 2.4.2.4.

Where partial demolition of obstructions or structures is indicated, the Contractor shall remove the indicated structure with care and caution so as not to damage the remaining portions of the existing structure.

2.3.2.4 *Removal of Pavement, Barriers, Railings, Sidewalks, Kerbs, and Gutters*

Existing pavement shall be removed to the subgrade level at locations identified in the Contract plans or the particular specifications. Where existing pavement is removed along a section of pavement to remain, the Contractor shall saw-cut to neat lines along the break line in such a manner as to avoid damage to the pavement that is to remain. Any damage to pavement areas that is to remain shall be restored to the satisfaction of the Engineer and in accordance with Section 3.4.3.2 of Chapter 3, Pavement, of these Standard Specifications.

Existing asphalt pavement shall be broken up and stockpiled for reuse in aggregate-based coarse layers as stipulated in Section 3.2.2 of Chapter 3, Pavement, of these Standard Specifications.

After removal of pavements, the old roadbed shall be scarified or ploughed to mix the remaining road material thoroughly with earth and shall be graded and smoothed to a pleasing appearance to match and blend in with the existing contours and terrain.

Where barriers, railings, kerbs and gutters are to be removed adjacent to pavement to remain, the work shall be carried out without damaging the existing pavement. Haunching and foundations shall be included in the removal. Removed railings kerbs, sidewalks, gutters, and barriers shall be properly disposed of, and shall not be reused on the project.

2.3.2.5 *Disposal of Materials*

As much as practicable, waste concrete, asphalt, and masonry shall be broken into suitably sized pieces and incorporated in embankment slopes or basement fills. Any broken concrete or masonry and all other materials not considered suitable for use in construction or elsewhere shall be disposed of by the Contractor at approved locations. In no case shall any discarded materials be left adjacent to or within the site.

Engineer will approve the manner in which materials are disposed and their location, which shall not create an unpleasant or objectionable view. When the Contractor requires a disposal area outside of the jobsite, the Contractor shall obtain permission in writing from the appropriate agency and waste disposal operation, and file this information with the Engineer.

If the Contractor or Engineer finds any evidence that excavated or waste material has become contaminated with petroleum products or other hazardous materials, as determined by visual, olfactory, or other means, the potentially contaminated material shall be stockpiled separately, sampled, and analysed to determine disposal options.

2.4 Roadway Excavation

2.4.1 Description

Excavation consists of the following:

1. Roadway excavation consists of all materials excavated from within the right-of-way or easement areas, (including all material encountered regardless of its nature or characteristics) except sub-excavation described in 2 below and structure excavation described in 4 below.
2. Subexcavation consists of material excavated from below subgrade elevations in cut sections or from below the original ground line in embankment sections. Subexcavation does not include the work required in Section 2.2.2.5.
3. Borrow excavation includes the material used for embankment and other fill construction that is obtained from outside of the roadway prism.
4. Structural excavation consists of material excavated for purposes of structure construction.

Work described in this section, regardless of the nature or type of the materials encountered, includes excavating and grading the roadway, excavating in borrow pits (sites providing fill materials), excavating below-grade, excavating channels, excavating and grading non-load bearing areas outside of the traffic and pedestrian pavement areas, removing slide material, and disposing of all excavated material. These activities may be performed in making cuts, embankments, slopes, roadway ditches, approaches, parking areas, intersections, and pedestrian walkways, and in completing related work.

2.4.2 Construction Requirements

2.4.2.1 *Preparation for Roadway Excavation*

Cross-sections and topographic information shall be surveyed, plotted and submitted in accordance with Section 2.1, prior to the start of excavation and other earthwork.

Areas of vegetation and obstructions shall be cleared in accordance with Sections 2.2 and 2.3. Topsoil shall be conserved from roadway excavation and embankment foundation areas in accordance with Section 2.2.2.5.

At the end of each day's operations during the rainy season, the work area surface shall be shaped to drain to a uniform cross-section. All ruts and low spots that could hold water shall be eliminated.

2.4.2.2 *Control of Excavation*

All roadway excavation shall be finished to a reasonably smooth uniform surface, shall not vary by more than 15 mm above or below the grade established, and shall be in reasonably close conformance to the lines, dimensions, and cross-sections shown on the Contract plans or as established by the Engineer.

Instructions from the Engineer shall be obtained by the Contractor before starting the work in regards to the slope of excavation sides slopes and the depth to take cuttings, including the dimensions of any in-situ treatment of cuts that may be required below the formation level. Excavation in soils shall be trimmed and graded to a smooth finish to prevent initiation of slope erosion.

When excavating, the Contractor shall take proper care not to loosen any material outside of the specified cut line, whether by ripping, blasting, or by other means. Care shall also be taken not to undercut any slopes, and proper control shall be exercised by regular survey checking and by using batter poles at close intervals at all times.

All excavations made outside the specified cut line, or below the specified level, without the approval of the Engineer, shall be backfilled with approved material, compacted to the satisfaction of the Engineer, and re-trimmed; all at the Contractor's expense.

a. Direct Hauling

If it is practical, the Contractor shall haul roadway or borrow fill materials immediately from the excavation site to its final place on the roadbed. Payment for such work shall be made in accordance with the bill of quantities item for roadway excavation.

b. Delayed Excavation

If it is impractical to haul roadway or borrow fill material to its final place at once, the Contractor shall delay excavation until the placement is workable. No extra payment shall be made for delayed excavation.

c. Stockpiling

If delaying the excavation will hamper grading or force impractical movements of equipment, the Engineer may allow the Contractor to stockpile roadway or borrow fill materials. In this case, the Engineer will approve where and when the Contractor may excavate, stockpile, haul, and place the fill materials. No additional payment will be made for stockpiling roadway or borrow fill material.

2.4.2.3 *Dewatering*

a. Description and General Requirements

Dewatering operations shall comply with the following requirements, unless otherwise approved by the Engineer.

1. Contractor shall furnish, install, operate and maintain all equipment and appliances necessary to keep excavations free from water at all times during construction.

2. Contractor must also provide sufficient backup equipment (including pumps) in order to sustain the dewatering systems at all times
3. Water from other construction activities shall be prevented from entering an excavation by suitable means.
4. All water must be removed in a manner to avoid damage to property and minimise nuisance or menace to the public
5. Contractor shall be responsible for any structures subjected to hydrostatic pressure from ground water during construction
6. In general, all dewatering shall be performed by well-point systems, unless otherwise approved by the Engineer
7. Contractor shall ensure that the static water level will be drawn down to a depth sufficient to keep the bottom of the excavation dry (at least 300 mm below formation level)
8. No excavation shall be allowed in wet conditions and no pipelaying or concrete activities shall commence until the Contractor demonstrates that he can maintain the excavations in dry conditions, acceptable to the Engineer
9. Contractor must maintain dewatering at all times during construction so that no groundwater comes into contact with any reinforcement or unprotected concrete surfaces
10. All dewatering discharge shall have suitable sediment traps, filters or settling tanks to avoid discharge of any sands and sediments where discharging to an existing storm drain, ditch or area that has been declared a sensitive or protected area by the environmental agency or the Engineer
11. Failure to comply with the above shall entitle the Engineer to condemn the section of work affected and demand complete removal and replacement, at the Contractor's expense.

b. Qualified Personnel

Contractor must provide experienced, qualified personnel to perform the dewatering operations

If approved by the Engineer, the Contractor may furnish the services of an experienced, qualified and properly equipped dewatering Subcontractor to design and operate the dewatering and groundwater recharging systems required for the work.

c. Monitoring

Where required to do so by the Engineer, the Contractor shall establish a specified number of groundwater level monitoring stations at each site, which will be observed during the work. These shall be located as directed by the Engineer and consist of acceptable open tube piezometers

If required by the Engineer, settlement gauges shall be provided as designated by the Engineer, to monitor settlement existing structures and facilities

d. Construction Requirements

1. Well point systems: All well-point systems shall conform to the following requirements, unless otherwise approved by the Engineer:
    a. Well-point system shall be placed on both sides of a trench or completely around isolated excavations
    b. Maximum allowable drawdown for a single stage system shall be 4.0 meters
    c. Multi-stage well-point systems shall be used for excavations requiring a draw-down of more than 4 meters
    d. Well-points at all levels of multi-stage systems shall be installed on both sides of a trench or completely around isolated excavations
    e. Maximum spacing of well-points shall be 1.0 m

f. Well-points shall be placed by jetting methods

g. If necessary, auger boring shall be used in hard soils

h. Well-points set in bored holes shall be backfilled with coarse sand

i. All well-points shall have a suitable valve for "trimming" the system to obtain maximum draw-down

j. Vacuum assisted pumps of suitable size and quantity shall be used to maintain the system

2. Sump pumping: Sump pumps may not be used, unless approved by the Engineer. If approved, sump pumping shall comply with the following requirements:

   a. At least two sumps shall be placed in each excavation (preferably in opposite corners)

   b. For long trenches, sumps shall be placed on each side of the trench

   c. Each sump shall be provided with a separate pump, suction hose and discharge line

   d. Sumps shall be large enough to hold sufficient water for priming, pumping and maintaining the excavation floor in a relatively dry condition

   e. All sumps shall be fitted with a suitably sized cage for graded filter material

   f. Drains leading to the sump must be so arranged as to allow drainage of the entire excavation and given sufficient fall to prevent silting up, unless steps are taken to keep them cleared out

   g. Ditches shall be sufficiently wide to allow a water velocity low enough to prevent erosion

   h. Maximum water service elevation in the sump shall be at least 300mm below formation level

   i. Maximum draw down shall be 5-6 m

   j. For greater draw downs, use pumps at lower levels or use suspended submersible pumps

   k. If excavation faces become unstable, the sump shall be abandoned and other methods of dewatering shall be utilized

e. Maintenance of Existing Water Table Level

Dewatering systems shall be installed and operated so that the groundwater level outside the excavation is not reduced to the extent that would damage or endanger adjacent structures or property.

If necessary, a water injection recharging system shall be maintained to replenish the groundwater supply as required to maintain the water table, including pumps, piping, well-points, standby units, other required equipment and a source of water sufficient to meet the recharge requirements, should supply of water from dewatering operations be interrupted or become inadequate.

Contractor shall repair all damage or settlement to foundations, structures, existing facilities, or works due to failure of excavation protection, operations of dewatering or recharging system, or failure to maintain the existing ground water outside the dewatering area.

Contractor shall check discharge pipes at regular intervals, to ensure that the pumping system is functioning properly.

f. Disposal of Water

Water not injected back into the ground shall be disposed of lawfully without damage to new and existing facilities or adjoining properties.

No water shall be pumped into an existing or new drainage system, or to a environmentally sensitive area (as defined by the environmental authority or by the Engineer) unless discharge is equipped with a suitable sediment trap, filter or sedimentation tank, as approved by the Engineer.

Where necessary, the Contractor shall divert natural and artificial waterways encountered at the site, until the works have been completed.

Route of the dewatering discharge main shall be approved by the Engineer.

g. Removal of Dewatering Systems

No dewatering system shall be removed without the approval of the Engineer. Release of groundwater back to its static level shall be performed in a manner to prevent disturbance of natural foundation soils, compacted fill or backfill and to prevent flotation or movement of structures, pipelines and sewers.

Equipment shall only be removed when no longer required. Monitoring and settlement measurement systems shall be maintained in operation as required by the Engineer.

If approved by the Engineer, well-points and like items may be abandoned in place.

Drainage provisions:

1. Drainage ditches, diversions and temporary pipes shall be constructed as required to maintain proper drainage in the work areas
2. Drainage ditches shall be constructed with cross-sectional area and gradient at least equal to that of the intercepted watercourses or as approved by the Engineer
3. Berms shall be provided to prevent surface water from draining into excavations
4. Earth banks shall be suitably protected from erosion during excavation work.

2.4.2.4 *Rock Cuts*

Contractor shall excavate rock cuts to 150 mm below subgrade level within the roadbed limits, backfill to the subgrade with embankment materials that meet the requirements of Section 2.5.2.2 and compact the materials in accordance with Section 2.6.

Rock excavation using blasting shall meet the following requirements:

a. Rock Blasting

1. Description

Rock blasting consists of fracturing rock and constructing stable final rock-cut faces using controlled and production blasting techniques.

Controlled blasting uses explosives to form a shear plane in the rock along a specified back slope. Controlled blasting includes pre-splitting and cushion blasting.

Production blasting uses explosives to fracture rock.

Contractor shall be able to demonstrate suitable past experience and qualifications in the art of construction blasting. Otherwise, a qualified Subcontractor shall be used. Experience and qualifications, whether of the Contractor or a Subcontractor shall be submitted to the Engineer for review and acceptance. No blasting work shall be started until written approval of the Contractor’s qualifications and method statements have been approved by the Engineer.

2. Materials

Explosives and initiating devices less than one year old shall be used by the Contractor. These include, but are not limited to, dynamite and other high explosives, slurries, water gels, emulsions, blasting agents, initiating explosives, detonators, and detonating cord.

3. Construction Requirements

I. Regulations. Furnish copies or other proof of all applicable permits and licenses that comply with the requirements of the relevant government ministries. Upon Owner approval, the Contractor shall comply with any additional requirements.

II. Safety and health. Comply with the requirements of Section 1.16.7 of Chapter 1, General Requirements, and when required by the Engineer OSHA, Standard No. 1926, Subpart U.

III. Storage, security, and accountability. Provide proper buildings or magazines in suitable locations for storage of explosives, in a manner as approved by the Engineer. All storage shall be secure with locked access and guarded by security personnel 24 hours a day. Provide for a detailed method of controlling and inventorying of all explosive materials, as approved by the Engineer. All unused explosive materials shall be disposed of in a manner approved by the Engineer and the approving governmental Owner.

IV. Blaster-in-charge. Designate, in writing, a blaster-in-charge, and submit evidence that the blaster-in-charge has specific and related experience, as well as a valid blaster's license issued by a recognized licensing body for the type of blasting required.

V. Blasting plans. Blasting plans are for quality control and record-keeping purposes, and are to be signed by the blaster-in-charge. Review and acceptance of blasting plans does not relieve the Contractor of the responsibility for using existing drilling and blasting technology, and for obtaining the required results. Do not deliver explosives to the project until the general blasting plan is accepted.

- General blasting plan. Submit a general blasting plan for acceptance before drilling operations begin, which includes, at a minimum, the following safety and procedural details:
  - Working procedures and safety precautions for storing, transporting, handling, and detonating explosives
  - Proposed product selection for both dry and wet holes and furnished manufacturer's material safety data sheets for all explosives, primers, initiators, and other blasting devices
  - Typical plan and section views for both production and controlled blasting, including maximum length of the shot, burden, hole spacing, hole inclination, hole depth, hole diameter, subdrill depth, and powder factor
  - Proposed initiation and delay methods and times
  - Proposed format for providing all the required information for the site-specific blasting plans
  - Site-specific blasting plans. After the general blasting plan is accepted, the Contractor shall submit site-specific blasting plans for acceptance before drilling operations begin. The plan shall include the following information:
  - Site drawings showing a scaled map of the blast area and cross-sectional views that indicate beginning and ending stations; free-face locations; hole spacing, diameter, depth, burden, and inclination; and subdrill depth. Include any significant joints or bedding planes within the blast zone and incorporate this geology into the blast design.
  - Where blasting may affect nearby structures or utilities, the Contractor shall provide the method of monitoring and controlling blast vibrations.
  - Provide a loading pattern diagram showing the location and amount of each type of explosive to be used in the holes, including primer and initiators and the location, type, and depth of stemming, column heights, and overall powder factor for each type of loading.

- Provide a delay and initiation diagram showing the delay pattern, sequence, and delay times.
- Preblast condition survey and vibration monitoring and control. When blasting near buildings, structures, or utilities that may be subject to damage from ground or air-blast vibrations, the Contractor shall provide a blast vibration specialist with at least five consecutive years of experience in vibration monitoring for at least three projects. Fourteen days before blasting, the Contractor shall submit to the Engineer the name and qualifications of the blast vibration specialist including the following information:
- Project names, locations, and services performed
- Name and phone number of an owner or agency contact who can verify the experience of the specialist
- Relevant qualifications and licences

Before blasting, the Contractor shall arrange for a pre-blast condition survey of nearby buildings, structures, or utilities that may be at risk from blasting damage, and shall use a survey method acceptable to its insurance company. Damage resulting from blasting is the Contractor’s responsibility. All pre-blast condition survey records shall be made available to the Engineer and the Contractor shall notify the Engineer and occupants of nearby buildings at least 24 hours before blasting.

Vibrations shall be controlled by a blast vibration specialist using properly designed delay sequences and allowable charge weights per delay when blasting near buildings, structures, or utilities that may be subject to damage from blast-induced vibrations. Trial blasts shall be conducted to measure vibration levels and base allowable charge weights per delay. Test blasts shall be conducted with blast plan modifications that limit ground and air-blast vibrations to a level that will not cause damage to nearby buildings, structures, or utilities, as determined by the blast vibration specialist.

When vibration damage to buildings, structures, or utilities is possible, the blast vibration specialist shall monitor each blast with approved seismographs and air-blast monitoring equipment located at acceptable locations. Seismographs capable of recording particle velocity for three mutually perpendicular components of vibration shall be used. The blast vibration specialist shall interpret the seismograph and air-blast records to ensure that the data is effectively used in the control of blasting operations.

VI. Test Blasting. Before full-scale drilling and blasting, the Contractor shall drill, blast, and excavate one or more test sections as proposed in the blasting plan. Test blasts may be made away from or at the final slope line.

For the cushion, or trim, method of controlled blasting, the Contractor shall space blast holes no more than 1.5 m apart for the initial test blast. For the pre-splitting method of controlled blasting, the Contractor shall space blast holes no more than 750 mm apart for the initial test blast. Spacing shall be adjusted as approved. Contractor shall use the approved spacing in the full-scale blasting or subsequent test blasts.

A test blast is unacceptable when it results in fragmentation beyond the final rock face, fly rock, excessive vibration, air blast, over break, damage to the final rock face, or overhang. When a test blast is unacceptable, the Contractor shall revise the blasting plan and make an additional test blast.

VII. Blasting.

a. General. Drill and blast according to the blasting plan.

Before drilling, the Contractor shall remove overburdened soil and loose rock along the top of the excavation for at least 10 m beyond the hole drilling limits, or to the end of the cut.

All holes shall be capped to prevent unwanted backfill. Place a stake next to each hole that numbers each hole and displays the total depth drilled.

Use the types of explosives and blasting accessories necessary to obtain the required results. A bottom charge may be larger than the line charges if no over break results.

After blasting, the hole shall be free of obstructions for its entire depth. Charges shall be placed without caving the blast hole walls. The upper portion of all blast holes shall be stemmed with dry sand or other granular material passing the 9.5-mm sieve. Do not stem the hole with drill cuttings.

Following a blast, the Contractor shall stop work in the entire blast area and check for misfires before allowing workers to excavate the rock.

Workers shall remove or stabilise all cut face rock that is loose, hanging, or potentially dangerous. They shall scale by hand or machine methods, as approved by the Engineer. Minor irregularities or surface variations shall be left in place, if they do not create a hazard. Drill the next lift only after the cleanup and stabilisation work is complete.

If blasting operations trigger fracturing of the final rock face, the Contractor shall repair or stabilise it in an approved manner at no cost to the Owner. Repairs or stabilisation may include removal, rock bolting, rock dowels, or other techniques.

When any of the following occur, the Contractor shall halt blasting operations to perform additional test blasts:

- Slopes are unstable
- Slopes exceed tolerances or overhangs are created
- Back slope damage occurs
- Safety of the public is jeopardized
- Property or natural features are endangered
- Fly rock is generated
- Excessive ground or air-blast vibrations occur in an area where damage to buildings, structures, or utilities is possible

b. Drill logs. Drill logs submitted by the Contractor shall include the following:

- A blast plan map showing designated hole numbers
- Individual hole logs completed and signed by the driller that show total depth drilled; depths and descriptions of significant conditions encountered during drilling that may affect loading, such as water or voids; and the date drilled

c. Controlled blasting. When test blasts indicate the need for controlled blasting, the Contractor shall use controlled blasting methods to form the final rock cut faces when the rock height is more than 3 m above ditch grade and the staked slope has a ratio of 2:1 or steeper.

Controlled blasting includes only those holes drilled on the row furthest from the free-face and that are drilled on the design slope.

Down-hole angles or fan drill blast holes shall be used for pioneering the tops of rock cuts or preparing a working platform for controlled blasting. Use the diameter of the blast hole and spacing established for controlled blasting during the test blasts.

Drill controlled blast holes no larger than 100 mm in diameter along the final rock face line; within 75 mm of the proposed surface location; and at least 10 m beyond the production holes to be detonated or to the end of the cut.

Drilling equipment with mechanical or electrical-mechanical devices that accurately control the angle the drill enters the rock shall be used. Select a lift height and conduct drilling operations so the blast hole spacing and down-hole alignment does not vary more than 225 mm from the proposed spacing and alignment. When more than 5 percent of the holes exceed the variance, reduce the lift height and modify the drilling operations until the blast holes are within the allowable variance. The maximum lift height is 15 m.

A 600 mm offset is allowed for a working bench at the bottom of each lift for drilling the next lower controlled blasting hole pattern. Adjust the drill inclination angle or the initial drill collar location so the required ditch cross-section is obtained when the bench is used.

Drilling 500 mm below the ditch bottom is allowed for removing the toe.

Do not use bulk ammonium nitrate and fuel oil for controlled blasting.

Pre-splitting delays the nearest production blast row at least 25 milliseconds after blasting the presplit line. Pre-split a minimum of 10 m ahead of the production blasting zone.

Cushion, or trim, blasting can delay the cushion blast row from 25 milliseconds to 75 milliseconds after blasting the nearest production row.

d. Production blasting. Drill the row of production blast holes closest to the controlled blast line parallel and no closer than 2 m to the controlled blast line. Do not drill production blast holes lower than the bottom of the controlled blast holes.

   Detonate production holes on a delay sequence toward a free-face.

VIII. After blast reports.

Within three days after a blast and before the next blast, the Contractor shall submit an after-blast report that includes the following:

a. Results of the blast and whether or not blasting objectives were met. If blasting objectives were not met, the Contractor shall submit proposed changes to future site-specific blasting plans that shall produce acceptable results and proposed repair or stabilisation plans for unstable or blast-damaged back slopes.
b. Blasting logs that include the following:
   i. All actual dimensions of the shot, including blast hole depths, hole diameter, burden, spacing, subdrilling, stemming, powder loads, and timing
   ii. A drawing or sketch showing the direction of the face, or faces, and the physical shot layout
   iii. If a seismograph was used, the Contractor shall provide the following:
      (1) Identification of instrument used
      (2) Name of qualified observer and interpreter
      (3) Distance and direction of recording station from blast area
      (4) Type of ground recording station and material on which the instrument is sitting
      (5) Maximum particle velocity in each direction
      (6) A dated and signed copy of the seismograph readings
      (7) Post-blast condition survey
      (8) Results of air-blast monitoring
      (9) Results of the post-blast condition survey

2.4.2.5 *Subexcavation*

Unsuitable material, including soft, muck, or vegetative material, shall be excavated by the Contractor to the limits designated by the Engineer. Cross-sections shall be taken in accordance with Section 2.1. Prevent unsuitable material from becoming mixed with the backfill. Unsuitable material shall be disposed of in accordance with Section 2.4.2.7 Sub-excavated limits shall be backfilled with suitable load bearing material in accordance with Section 2.5.3.

When water fills an area after the removal of unsuitable materials, the Contractor shall drain the site so that any backfill may be compacted. If drainage is not possible, the Contractor shall use free drainage material which can be hydraulically compacted for backfilling in water. Backfill method and materials shall be approved by the Engineer, and shall be carried out on the Contractor's expense.

2.4.2.6 *Slope Treatment*

Earth slopes shall be finished to reasonably smooth surfaces and shall be free of all debris and loose material. All shattered or loosened material shall be removed from rock cut slopes.

Tops of all roadway cut slopes, except solid rock cuts, shall be rounded in accordance with the Contract plans.

Surfaces of earth slopes shall be left in a uniform and smooth condition, trimmed, and graded to no more than ±50 mm of the neat lines shown on the Contract plans. Where the slopes of earth excavations are to be covered with topsoil or other agricultural planting soil, the excavated surface shall be caterpillar tread-walked in a vertical direction, or similar measure, to roughen the surface and help hold the upper topsoil layers.

If a layer of earth covers a rock cut, the slope shall be rounded above the rock as if it were an earth slope. All work required to complete slope treatment, including excavation, haul, and slope rounding, shall be included in the unit price for roadway excavation.

2.4.2.7 *Disposal of Unsuitable or Excess Material*

Unsuitable or excess material shall be disposed of off-site at disposal sites furnished by the Contractor and approved by the Engineer. Waste material shall be shaped and compacted in its final location.

If the Contractor or Engineer finds any evidence of petroleum or other hazardous products contamination of any excavated material by visual, olfactory, or other means, the potentially contaminated material shall be stockpiled separately and sampled and analysed to determine disposal options.

Material that is excavated and deemed unsuitable or as excess material shall be placed in a covered transport and hauled to the disposal site. Excavated material shall not spill, overflow, or release during transport to the disposal site.

Soil that is designated for landfill disposal and contains free water shall be stabilised using lime, cement, or fly ash, where required by the disposal facility.

Soil shall not be transported off-site in containers with water draining from the container.

2.4.2.8 *Wasting Material*

If the Contractor wastes excavated material needed for the embankment or other fill, it shall be replaced at no expense to the Owner with material the Engineer approves.

2.4.2.9 *Roadway Ditch and Pond Excavation*

a. Description

This work consists of excavating permanent open ditches and ponds to the required lines, grades, and cross-sections as shown on the Contract plans. It also includes disposing of all excavated material regardless of its nature or type; unless excavated material is approved as borrow material.

b. Construction requirements

Before excavating any open ditch or pond, the Contractor shall clear and grub the area in accordance with Section 2.2.

Where the excavated ditch or pond material is approved for use as embankment material in accordance with the requirements of Section 2.5.2.2, the material shall be used to build dikes or berms as shown on the plans. Dikes and berms shall be constructed in accordance with the requirements for roadway embankment compaction in Section 2.5.3.

Excess excavated material may be disposed of by dressing or spreading above the back slopes of ditches and outside of dikes and berms, as approved by the Engineer. Otherwise, the Contractor shall dispose of excess excavation material in accordance with Section 2.4.2.7.

At each transition from cut to fill, the Contractor shall divert any roadway ditch away from the embankment in natural ground. Ditches shall never permit water to flow into or upon embankment material.

2.4.2.10 *Borrow Excavation*

All suitable roadway excavation shall be used by the Contractor in embankment construction, and borrow excavation shall not be used when it results in excess roadway fill material.

Borrow sources shall be preapproved by the concerned authorities and the Engineer. Approval shall be based on the Contractor’s submittal of location, sample testing, estimation of quantities, written approval of the borrow source owner and/or regulating authority, and restoration of borrow source upon completion as shown on the shop drawings. For borrow sources to be accepted, the material shall meet the requirements for the applicable load-bearing or non-load-bearing material requirements in Section 2.5.2.

Develop and restore borrow sources in accordance with the Engineer-approved methods. Do not excavate beyond the established limits. When applicable, the Contractor shall shape the borrow source to permit accurate measurements when excavation is complete. Borrow sources shall be left in a manner that is pleasing to the eye, with excavated slopes and surfaces left in a smooth and uniform shape at geotechnical stable angles. No extra payment will be made for restoration and final grading of the borrow source.

2.4.2.11 *Structural Excavation*

a. General

Contractor shall include all operations necessary to excavate, as required for the construction of the structures, and as indicated on the Contract plans.

This work shall consist of the necessary excavation for construction of minor structures including storm drain and utility structures and wall items as otherwise specified in these general specifications. Contractor will not be paid for excavation of any minor structures or portions of minor structures that are constructed within the volume of the roadway embankment excavation or fill prism. This work shall include necessary dewatering, sheeting, bracing, construction of cribs and cofferdams, furnishing materials, and the subsequent removal of cribs and cofferdams.

Excavation to remove and replace unsuitable material encountered below the structure foundation elevation shall meet the requirements of Section 2.4.2.5. Depending on conditions, the Engineer may require the use of alternative materials as replacement fill for sufficient foundation strength. This may include one of the following materials:

1. Load-bearing embankment material meeting the requirements of Section 2.5.2.2
2. Structural backfill material meeting the requirements of Section 2.5.2.4
3. Pervious backfill material meeting the requirements of Section 2.5.2.5
4. Controlled density fill meeting the requirements of Section 4.3.10.3 of Chapter 4, Concrete Works, of these Standards Specification.

b. Excavation Support

All excavations measuring 1.5 m or more in depth, trench or otherwise, shall be laid back to a stable slope or supported. Excavation support systems are subject to the approval of the Engineer. Prior to commencing any structure excavation work 1.5 m or more in depth, the Contractor shall design and submit detailed shop drawings of the structure excavation support systems and proposed methods to the Engineer. These submissions shall show support member materials, sizes, spacing, and Engineering calculations to validate the design of the above, including the maximum theoretical deflections of the support members.

Support systems shall be designed in such a manner that no sheeting, struts, or any other support members extend through surfaces exposed in the finished construction, and no shoring or bracing is placed under permanent structures.

Engineering calculations shall be in English and shall show lateral earth pressures for the full excavation depths; forces at various stages of support during installation, removal, and concrete placement; anticipated equipment loads; surcharge loads of any description; and the maximum design loads carried by various members of the support system and strut pre-load forces.

In the event the proposed structure excavation support system includes tieback anchors, the Contractor's submittal drawings shall show the profile of the soil in which each anchor is to be installed, the design load for the full depth of excavation, the maximum design and proof loads, surcharge loads of any description, equipment loads, forces at various stages of support during installation and removal, and the criteria proposed for deformations under proof loads.

Where a proposed system of tieback anchors projects beyond the vertical projection of the Contract limit lines indicated on the Contract plans onto the adjoining property, the Contractor shall obtain the permission of the owner in writing, and submit such permission to the Engineer at the time the shop drawings of the support system are submitted.

c. Excavation Limits

So that cross-sectional elevations and measurements may be taken of the undisturbed ground, the Contractor shall notify the Engineer sufficiently in advance of any structure excavation. Natural ground adjacent to the structure shall not be disturbed without the Engineer’s permission.

Structures shall be excavated to the lines and grades or elevations indicated on the Contract plans, or as described in the bill of quantities. Excavations shall be of sufficient size to permit the placing of structures or structure footings of the full width and length indicated.

Unless otherwise specified, the excavation limits for structural excavation shall be from the bottom level (formation level) of the roadway excavation which falls within the roadway excavation width.

Boulders, rocks, and any other objectionable material encountered during excavation shall be removed.

After each excavation is completed, the Contractor shall notify the Engineer. No footing, bedding material, or structure shall be placed until the Engineer has approved the depth of excavation and the character of the material on which the foundations shall bear.

d. Disposal of Excavated Materials

All excavated material at structures shall be loaded and hauled away to an approved disposal area in accordance with Section 2.4.2.7, unless the excavated materials are approved by the Engineer for use as borrow material meeting the applicable requirements of Section 2.5.2.

2.4.2.12 *Manual Excavation*

a. General

All manual or hand excavation and other required work to locate existing utilities or services within the limits of the Contract or at off-site locations shall be performed by the Contractor in accordance with the requirements of these general specifications and as directed by the Engineer.

Existing utilities and services to be located by manual excavation shall include, but not be limited to, all water mains and electric lines, both power and lighting; telephone; and others that may be encountered under the Contract or at off-site locations.

b. **Coordination with Utility Departments**

Purpose of manual excavation is to determine the existence and location, including depth, size, shape, composition, and condition, of all existing utilities and services. Immediately after uncovering existing utilities, the Contractor shall coordinate with the respective utility departments and agencies to obtain their assistance, if necessary, for the accurate identification of each uncovered utility line.

Information obtained during this process shall be recorded and shown on working or shop drawings that the Contractor shall submit to the Engineer and the relevant utility agencies. Utility agencies shall require this information to finalise relocation or protection plans.

c. **Procedure**

Before commencing manual excavation, the Contractor shall obtain the Engineer's approval and obtain specific work permits from respective utility agencies for manual excavation in close proximity to important utility lines such as, but not limited to, 11 kV, 33 kV circuits, 132 kV circuits, water transmission and distribution main lines, and telephone and gas lines.

Contractor shall furnish the Engineer with copies of all work permits, field notes, and shop drawings with the details of all utilities and services located by manual excavation, as recorded by the Contractor.

Width of manually excavated trenches shall be such that a workman can excavate safely and efficiently to a depth determined as reasonable by the Engineer in consideration of existing utilities information.

Manual excavations shall be carried out in the presence of the Engineer, taking all precautions to prevent damages to services, properties, and persons. Any damage resulting from the negligence of the Contractor shall be repaired at the Contractor's expense. This is in addition to any indemnities stipulated in these specifications dealing with public utilities and safety.

Contractor shall provide all tools, labour, equipment, and accessories required to complete the manual excavation. Further, the Contractor shall provide all the materials, labour, and equipment necessary to protect the existing utilities, as well as any shoring, sheeting, dewatering, and any other means required for protection during manual excavation.

All materials removed shall be disposed of by the Contractor in accordance with Section 2.4.2.7, unless the excavated materials are approved by the Engineer as material meeting the applicable requirements of Section 2.5.2.

All manually excavated trenches within traffic and pedestrian pavement areas, other structure foundation areas, and where necessary for adjacent structure or utility lateral and vertical bearing support shall be backfilled with load-bearing embankment material in accordance with the requirements of Article c of Section 2.5.3.1. Trenches within non-load-bearing areas shall be backfilled in accordance with Section 2.5.3.3.

Contractor shall place and compact material with care so as not to damage existing utilities.

2.4.2.13 *Unclassified Excavation*

Unclassified excavation shall include any and all materials encountered during the construction of the Work. This classification shall not apply to any material, which has been classified and bid upon under any of the foregoing classifications, "Borrow Excavation", "Rock Cut", "Structure Excavation" or "Manual Excavation".

2.5 Embankments and Backfill

2.5.1 Description

Embankment and backfill requirements shall apply to the construction of roadway embankments, including the widening of embankment sections and the preparation of the areas upon which embankment material is to be placed; the construction of dikes and berms; the placing and compacting of material where unsuitable material has been removed; backfill for structures and the placing of non-load-bearing, topsoil and sweet sand materials in landscaping areas; and other areas not under roadway and pedestrian pavements.

Before the start of construction, the Contractor shall submit plans showing the proposed method of work, the selection of materials, the method of compaction, and any other matter that may affect the construction of the embankment or sequence of operations.

2.5.2 Materials

2.5.2.1 *Unsuitable Material*

Unsuitable material includes but not limited to

- Topsoil,
- Organic soils,
- Vegetative material,
- Trash,
- Contaminated soil,
- Soluble material such as gypsum and salt, very fine sand, non-cohesive silt, organic clay and highly dispersive soils.

Dispersivity potential of soil shall be determined by test ASTM D4647. Any material classified other than ND1 or ND2 (non dispersive) will be considered as unsuitable.

Materials with soluble substances more than 3% (by test method ASTM D4542) and organic content more than 5% (by test method ASTM D2974) by weight of dry material are all considered as unsuitable and shall not be used for construction of embankment.

Collapsible soils are also considered as unsuitable material and shall be treated before construction of embankment. Collapse index is determined according to ASTM D5333.

2.5.2.2 *Embankment Material (Load-Bearing)*

Load-bearing embankment material shall consist of suitable material taken from the roadway excavation or the borrow source. Load-bearing embankment material shall consist of granular material free of excess moisture and other unsuitable material conforming to the following:

1. Maximum particle size: not to exceed one-third of placement layer thickness
2. Materials shall be classified according to AASHTO M 145. In general, suitable materials shall meet soil classification: A-1, A-3, or A-2-4.
3. Material that can be compacted to 95 percent of the maximum density as required in Article b of Section 2.5.3.4
4. Material shall have a maximum plasticity index of 6 and a soaked CBR after 4 days soaking is not less than 20% when compacted to 95% of MDD.

Suitability tests including material gradation, plasticity and CBR tests shall be done in accordance with Table 2-12. All suitability testing will be done with one test each per 1000 m^3 of embankment material.

Embankment material placed adjacent to bridge abutments, retaining and wing walls, and other minor structures, as shown on the Contract plans or as directed by the Engineer, shall be classified as structure backfill and shall conform to the requirements in Section 2.5.2.4, except for drainage layer backfills when shown on the Contract plans, which shall conform to the requirements of Section 2.5.2.5 for pervious backfill.

2.5.2.3 *Rock Fill Material*

Rock fill material shall be made of strong, hard, durable, and clean pieces of sound rock, having the following requirements:

1. Point load strength index (I_{s50}) (per ASTM D5731) greater than 1 mPa
2. Maximum wet/dry strength variation of 35 %
3. Maximum and minimum dimensions are determined based on the application, however the maximum dimension for embankment construction shall be 600 mm.

Rock fill material borrow source(s) shall be pre-identified and submitted with samples and test results meeting the above requirements for review and approval by the Engineer prior to delivery of the material to the site.

Typically, rock fill material excavated from within the roadway excavation prism will be incorporated within the embankment fill, if meeting the requirements as specified herein. Otherwise it will be disposed of by the Contractor at the sites and locations as approved by the Engineer.

2.5.2.4 *Structural Backfill*

Structural backfill shall be a uniform mixture of gravel and/or stone fragments with sand, silt and clay, conforming to the following requirements:

1. A maximum particle size of 53 mm
2. Material gradation meeting the requirements in Table 2-3
3. Liquid limit: 25 maximum
4. Uniformity coefficient: >10
5. Plasticity index: 4 maximum
6. Sand equivalent (AASHTO T 176): 25 Minimum
7. Loss by abrasion (AASHTO T 96): 40 Maximum
8. Material that can be compacted to 95 percent of the maximum density as required in Article b of Section 2.5.3.4 with a maximum dry density: minimum 20 kN/m^3
9. Minimum soaked CBR (remoulded sample after 4-days soaking, AASHTO T193: 60% minimum at 95% compaction

Material gradation, liquid limit and plasticity tests shall be done in accordance with Table 2-12. All suitability testing will be done with three tests each per 1000 m3 of select material except for gradation testing which shall be one test per 1000 m^3.

Table 2-3: Structural backfill gradation

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
53 mm	100
37.5 mm	75-100

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
25.0 mm	55 -85
19.0 mm	50 - 80
9.5 mm	40 - 70
4.75 mm	30 - 60
2.0 mm	20 - 50
425 µm	10 - 30
75 µm	5 - 15

2.5.2.5 *Pervious Backfill*

Pervious backfill material shall be clean, hard, durable sand, gravel or crushed stone free from organic material, clay balls or other deleterious substances conforming to the gradation requirements in Table 2-4 Pervious backfill material used as a drainage layer against soil retaining structures (such as bridge abutments and cut or fill retaining walls) shall meet the gradation requirements of Table 2-5

Table 2-4: Pervious backfill gradation

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
53 mm	100
37.5 mm	95 - 100
19 mm	50 to 100
9.5 mm	15 - 55
2.36 mm	0 - 5
75 µm	0 - 3

Table 2-5 Pervious backfill material for use as drainage layer against soil retaining structures such as bridge abutments and retaining walls

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
75 mm	100
53 mm	90 - 100
37.5 mm	35 - 70
25.0 mm	0 - 15

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
12.5 mm	0 - 5

2.5.2.6 *Material for Free-Draining Blankets*

Material for free draining blankets, used for constructing vertical drains or as a base layer for embankments constructed over soft foundations, shall consist of either a clean processed aggregate material meeting the gradation requirements of Table 2-6 or natural dune sand obtained from a clean, uniformly open graded and non-contaminated source.

Table 2-6: Gradation for free-draining blanket material

Sieve size	Percent by mass passing designated sieve (AASHTO T 27 and T 11)
75 mm	100
19 mm	95 - 100
4.75 mm	50 - 100
1.18 mm	20 - 85
0.3 mm	3 -30
0.15 mm	0 - 7
0.075 mm	0 - 3

2.5.2.7 *Non-Load-Bearing Material*

Non-load-bearing material shall include topsoil and sweet sand material in accordance with the requirements of Article a of Section 2.5.2.7

Non-load-bearing material shall also consist of roadway excavation or other borrow material approved by the Engineer and deemed suitable for use as fill material for raising existing areas not located under roadway pavements, roadway embankments, pedestrian pavements, or other structures, and to grades shown on the Contract plans. This material may also fill low-lying natural areas to grades suitable for placing upper topsoil or sweet sand courses within landscaped areas, in accordance with the Contract plans or as directed by the Engineer.

Material shall be reasonably free from salts, refuse, roots, heavy or stiff clay, stones or rocks larger than 30 mm in size, sticks, brush, litter, or other deleterious materials or substances.

a. **Topsoil and Sweet Sand Material**

Topsoil shall consist of the material excavated and stockpiled in accordance with Section 2.2.2.5.

Sweet sand shall consist of borrow material supplied from sources approved by the Engineer, which has been analysed by the Contractor as being suitable for agricultural purposes. Sweet sand shall be obtained from well-drained inland dunes and shall be reasonably free from salts, refuse, roots, heavy or stiff clay, stones or rocks larger than 30 mm in size, noxious seeds, sticks, brush, litter, debris, or other deleterious materials or substances.

Topsoil and sweet sand borrow material destined for placement on the surface of vegetated landscape areas and existing soil surfaces to remain in place within project constructed vegetated landscape areas shall be tested and amended, as necessary, to comply with the requirements of planting soil described in Section 13.1.2.1 of Chapter 13, Landscaping and Irrigation of these Standard Specifications.

2.5.2.8 *Prefabricated Vertical Drains*

Prefabricated vertical drains (PVD) for embankment foundation water pressure relief shall consist of a continuous plastic drainage core wrapped in a non-woven geotextile material, as approved by the Engineer.

PVDs shall be of newly manufactured materials from an approved manufacturer, and shall comply with the requirements as indicated in Table 2-7. For each type of drain to be used, the manufactured PVD to be used on site shall be subjected to all the tests in the table. The types of PVD to be used at site shall be approved by the Engineer.

Geotextile shall be capable of resisting all bending, puncturing and tensioning subjected during installation and design life of the drain. Core shall be made of continuous plastic material fabricated to facilitate drainage along the axis of the vertical drain. Core shall be a profiled strip with or without perforation or a profiled mat with an open or closed structure.

Contractor shall indicate the proposed source of the materials prior to delivery to site. Contractor shall also submit samples and manufacturer's certificates to verify the physical, mechanical and hydraulic properties of the drain to be used for the Engineer's approval.

Prior to installation and at the discretion of the Engineer, an individual test sample shall be cut from at least one roll selected at random to represent each batch or every 100,000 meters, whichever is less. Individual sample shall be not less than 3 m in length and shall be full width. Samples shall be tested for the properties listed in the following table. Should any individual sample randomly selected fail to meet the specification, then that roll shall be rejected and two additional samples taken at random from two other rolls. If either of these two additional samples fail, then the entire batch of vertical drains represented by the samples will be rejected by the Engineer.

Table 2-7: Vertical filter drain properties

Properties	Required value	Test designation
Drain properties		
Width (mm)	100 ± 2	
Thickness (mm)	3 to 4	
Discharge capacity for straight drain at hydraulic gradient i = 0.1 and 250 kPa* (m^3/s)	≥ $50x10^{-6}$	ASTM D4716
Discharge capacity for buckled drain at hydraulic gradient I = 0.1 and 150 kPa* (m^3/s)	≥ 15 $x10^{-6}$	ASTM D4716
Tensile strength (kN)	1.5 @ 10 % strain	ASTM D4595
Elongation at break (%)	≥ 2	
Elongation at 0.5 kN (%)	≤ 10	ASTM D4362
Geotextile (Class 1 as per AASHTO M 288)		
Grab tensile strength (N)	> 950	ASTM D4632

Properties	Required value	Test designation
Elongation at break	>70 %	ASTM D4632
Trapezoidal tear strength (N)	375	ASTM D4533
Puncture resistance (N)	> 2000	ASTM D6241
Burst strength (kN/m^2)	> 900	ASTM D3786
Permeability at 100 mm head (m/s)	≥ $1x10^{-4}$	ASTM D4491
Permitivity (s^{-1})	> 0.4	ASTM D4491
Apparent pore size, O_{90} (micron)**	> 80	ASTM D4751
Fabric Weight (g/m^2)	180	Manufacturer

*If (drain depth + 2 x fill height) > 25 m but < 50 m, pressure shall be 500 kPa for straight drain and 350 kPa for buckled drain.

**Alternatively, O_{95} shall be < 90 micron

Drains shall be free of defects, rips, holes, or flaws. During shipment and storage, drains shall be wrapped in a heavy-duty protective covering, and the storage area shall protect the drain material from sunlight, mud, dirt, dust, debris, and detrimental substances.

2.5.2.9 *Construction Geotextile*

Geotextile fabrics shall consist only of long-chain polymeric fibers or yarns formed into a non-woven, needle-punched stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95% by weight of the material shall be polypropylene, polyolefin or polyesters. These materials shall be free from defects or tears. Materials shall also be free of any treatment or coating that might adversely alter its hydraulic or physical properties after installation.

Thread used for sewing geotextile shall consist of high-strength polypropylene, polyester, or polyamide. Nylon threads shall not be allowed. Thread used to sew permanent erosion-control geotextile, and to sew geotextile seams in exposed faces of temporary or permanent geotextile retaining walls, shall also be resistant to ultraviolet (UV) radiation. Thread shall be of contrasting colour to that of the geotextile itself.

Geotextile shall meet the application requirements of AASHTO M 288 and the specific requirements included in Table 2-8 through Table 2-12, in accordance with its intended use.

All geotextiles used in construction which are to receive an overlying layer of rock fill such as, but not limited to, pervious backfill, rip rap, boulders or other similar covering material shall be protected from damage due to the rock fill by placement of 50 mm thick layer of natural screened sand with a nominal size between 3 mm and 5 mm, as approved by the Engineer.

Contractor shall submit the following information regarding each geotextile material’s proposed use to the Engineer:

1. Manufacturer’s name and current address
2. Full product name
3. Geotextile structure, including fiber or yarn type
4. Geotextile polymer types

5. Proposed Geotextile uses
6. Certified test results for minimum average roll values

Table 2-8: Geotextile for underground drainage

Geotextile property	ASTM test method	Geotextile property requirements
		Non-woven
Fabric weight	D5261	180 g/m^2 minimum
Grab tensile strength, in machine and x-machine direction	D4632	700 N minimum
Grab failure strain, in machine and x-machine direction	D4632	≥ 50 percent
Puncture resistance	D6241	1375 N minimum
Tear strength, in machine and x-machine direction	D4533	250 N minimum
UV radiation stability	D4355	50 percent strength retained minimum, after 500 hours in a xenon arc device

Table 2-9: Geotextile for underground drainage-opening size properties

Geotextile property	ASTM test method	Geotextile property requirements		
		Percent *in situ* Soil Passing 0.075 mm		
		<15	15 to 50	>50
AOS	D4751	≤ 425 µm	≤ 212 µm standard sieve	≤ 150 µm
Water permittivity	D4491	0.5 sec^{-1} minimum	0.2 sec^{-1} minimum	0.1 sec^{-1} minimum

Table 2-10: Geotextile for separation or soil stabilization

Geotextile property	ASTM test method	Geotextile property requirements	
		Separation	Soil stabilization
Weight	D5261	180 g/m^2 minimum	200 g/m^2 minimum
Thickness	D5199	1.7 mm minimum	1.7 mm minimum
AOS	D4751	Standard sieve 212 µm max.	Standard sieve 212 µm max.
Water permittivity	D4491	0.02 sec^{-1} minimum	0.05 sec^{-1} minimum

Geotextile property	ASTM test method	Geotextile property requirements	
		Separation	Soil stabilization
Grab tensile strength, in machine and x-machine direction	D4632	1,400 N minimum	1,500 N minimum
Grab failure strain, in machine and x-machine direction	D4632	< 50 percent	< 50 percent
Puncture resistance	D6241	2,750 N minimum	2,800 N minimum
Tear strength, in machine and x-machine direction	D4533	500 N minimum	600 N minimum
UV radiation stability	D4355	50 percent strength retained minimum, after 500 hours in xenon arc device	

Table 2-11: Geotextile properties for retaining walls and reinforced slopes

Geotextile property	ASTM test method	Geotextile property requirements
Weight	D5261	180 g/m^2 minimum
Thickness	D5199	1.7 mm minimum
AOS	D4751	Standard sieve 212 µm max.
Water permittivity	D4491	0.02 sec^{-1} minimum
Grab tensile strength, in machine and x-machine direction	D4632	1,200 N minimum
Grab failure strain, in machine and x-machine direction	D4632	< 50 percent
Seam breaking strength	D4632	1,000 N minimum
Puncture resistance	D6241	2,200 N minimum
Tear strength, in machine and x-machine direction	D4533	400 N minimum
UV radiation stability	D4355	70 percent for polypropylene and polyethylene, and 50 percent strength retained minimum for polyester, after 500 hours in a xenon arc device

2.5.2.10 *Surface Protection*

The material for Surface Protection on the slopes in cut and fill shall be only A-1-a, A-1-b material according to AASHTO M 145 with C.B.R. not less than 30% when compacted to 95% M.D.D. The material for Surface Protection shall also have in the respect a Plasticity Index of 4 minimum and 9 maximum when determined according to AASHTO Designation T 90 and a Limit Liquid not exceeding 35 when determined according to AASHTO Designation T 89

The material for surface protection shall be laid, compacted to an averaged density of 98% with no single value below 96%.

2.5.2.11 *Water*

Use of sea water or brackish water shall be permitted for roadway embankment earthwork except for non-load-bearing topsoil and sweet sand filling. Also, except for water used for compaction of backfill around metal pipe culverts and for subgrade and layers above, or in contact with or adjacent to a reinforced concrete element or structure backfill, which shall be from a source approved by the Engineer conforming to the requirements specified for concrete mixes as per Section 4.3.8 of Chapter 4, Concrete Works, of these Standard Specifications.

2.5.3 Construction Requirements

Embankment and backfill construction consists of the placement and compaction of fill materials. This work includes the following:

1. Preparing the foundation for embankment
2. Benching for side-hill embankments
3. Constructing roadway embankments
4. Constructing dikes, ramps, mounds, and berms
5. Backfilling subexcavated areas, holes, pits, and other depressions
6. Backfilling around structures, walls, and abutments
7. Backfilling of manual excavation trenches
8. Filling areas outside of the pavement prism with non-load-bearing material, topsoil, and sweet sand

All fills shall be constructed to a reasonably smooth and uniform surface and shall not vary by more than 25 mm above or below the grade established and in reasonably close conformity to the lines, dimensions, and cross-sections shown on the Contract plans.

At the end of each day's operations, when rain is expected, the Contractor shall shape to drain and lightly compact the fill surface to a uniform cross-section. Contractor shall eliminate all ruts and low spots that could hold water.

2.5.3.1 *Embankment Construction*

a. **Preparing Foundation for Embankment Construction**

Preparation of foundations for embankment construction shall be done as shown on the Contract plans, as may be required in the Particular Specifications and as approved by the Engineer. Preparation of embankment foundation plans shall be included in the Contractors method statement as required in Section 1.15 of Chapter 1, General Requirements, of these Standard Specifications. Construction of earthwork, and in particular construction of embankments shall not begin until this method statement is approved.

Preparing foundations for embankment construction includes the following:

1. All embankments shall be cleared and grubbed in accordance with Sections 2.2 and 2.3.

2. Embankments less than 1 m high over natural ground: Completely break up the cleared ground surface to a minimum depth of 150 mm by ploughing or scarifying. Compact the ground surface according to Article b of Section 2.5.3.4
3. Embankments less than 500 mm high over an existing asphalt, concrete, or gravel road surface: Scarify gravel roads to a minimum depth of 150 mm. Pulverize asphalt and concrete roads to 200 mm below the pavement. Reduce all particles to a maximum size of 150 mm and produce a uniform material. Compact the surface according to Article b of Section 2.5.3.4
4. If stabilization of soft foundations is not otherwise shown on the Contract plans or required in the Particular Specifications, where embankments cross ground not capable of supporting construction equipment, the Contractor shall dump successive loads of embankment material by type and gradation, as approved or directed by the Engineer, in a uniformly distributed layer to construct the lower portion of the embankment on his expense. This layer shall not require compaction to a controlled density unless otherwise directed by the Engineer.

   Additional support may be provided by installing sand filter blankets or geotextile/geogrid layers under this layer, if directed by the Engineer. Geotextile fabric shall be used to separate the fine material from the coarse material layers, meeting the material requirements of Section 2.5.2.9.
5. For embankments on existing slopes, including hillsides or widened existing embankments steeper than a ratio of 1:3, the Contractor shall cut horizontal benches in the existing slope to a sufficient width to accommodate placement and compaction operations and equipment. Slope shall be benched as the embankment is placed and compacted in layers. Each bench shall begin at the intersection of the original ground and the vertical cut of the previous bench.
6. Prior to the start of embankment construction, the Contractor shall construct a trial embankment section using the methodology, materials and equipment that he intends to utilize for the work. Trial will be observed and tested for compliance by the Engineer, and if satisfactory the Contractor shall proceed with embankment construction. A separate trial section shall be constructed for each instance where the materials, material source, equipment or methodology changes. Size and location of the trial embankment area shall be as approved by the Engineer.
7. When required in the Contract plans, particular specifications or included in the Bills of Quantities, foundation preparation may include installation of prefabricated vertical drains (PVD). PVDs shall be installed at the locations, spacing and to the depths as shown on the Contract plans or required in the Particular Specifications and as may be modified by the Engineer, in accordance with Section 2.5.3.5.

b. **Rock Embankment Construction**

Rock embankment construction is defined where the embankment material consists of 25 percent or more by volume of rock particles sized between 100 and 300 mm in diameter. Rock fill material shall meet the applicable requirements of Section 2.5.2.3, unless otherwise approved by the Engineer.

Rock fill material shall be placed in horizontal layers not exceeding 300 mm in compacted thickness. Oversized boulders or rock fragments shall be incorporated into the 300 mm layer by reducing their size. Individual boulders up to a maximum of a 600 mm in diameter can be distributed within the embankment so as to prevent nesting and to fill in voids between the layers with finer material. Rock layers with smaller rocks and blinding material shall be placed to fill these voids. Each layer shall also be compacted according to Article a of Section 2.5.3.4 before placing the next layer.

Where structural pilings are to be placed in embankment locations and for embankment adjacent to structures, the Contractor shall limit the maximum particle size to 100 mm.

The top 300 mm of the embankment with embankment material Type A-1 according to AASHTO M 145 and Section 2.5.2.2.

c. **Earth Embankment Construction**

Embankments shall be placed in successive layers parallel to the final road surface, and the construction of wedge-shaped layers shall be restricted to the bottom layers of embankments where this may be unavoidable because of cross fall, the tapering out of embankments, or the super elevation of the final road surface.

Materials shall be placed at optimum moisture content. Dry material shall be watered and mixed as necessary to obtain uniform moisture content within the optimum compaction range. Material shall be placed in uniform horizontal layers not exceeding 200 mm in depth before compaction (up to 300 mm maximum thick layers where trial compaction tests show the material is suitable and consistently meets the compaction requirements uniformly through the layer as otherwise specified, and if approved by the Engineer). Material layer shall be compacted in accordance with Article b of Section 2.5.3.4.

Placement of borrow materials or fills at points inaccessible to normal compaction equipment shall be made in horizontal layers of loose material not exceeding 100 mm in depth and thoroughly compacted by the use of mechanical tampers to the minimum compaction requirements included in Article b of Section 2.5.3.4.

2.5.3.2 *Structural Backfill*

This work consists of backfilling against and around walls, abutments, and structures.

Backfill material shall meet the requirements of Section 2.5.2.4. Where pervious material is required as a drainage layer backfilled adjacent to walls and abutments, it shall meet the requirements of Section 2.5.2.5. Geotextile fabric used as a filter layer between drainage layers and finer backfill materials shall meet the requirements of Section 2.5.2.9 and Table 2-11

All structural backfill that will be under roadway or pedestrian pavement, within the roadway embankment prism, or where lateral and vertical bearing support is required for adjacent structures and utilities shall be compacted to at least 95 percent of the maximum dry density, as determined by the tests described in Article c of Section 2.5.3.4.

To prevent the distortion or displacement of structures, in particular walls and abutments, the Contractor shall place backfill evenly around all sides and parts of the structure.

For bridge abutments, the Contractor shall not backfill prior to placing the superstructure. After the superstructure is in place, the use of small compactors may be required to compact the backfill around the structure. Embankments and backfill behind the abutments shall be brought up in layers and compacted concurrently. Differences in backfill height against each abutment shall not exceed 0.6 m, unless approved by the Engineer.

2.5.3.3 *Non-Load-Bearing Fill Placement*

When placing non-load-bearing, topsoil, or sweet sand material outside the staked roadway prism, the Contractor shall place and grade in layers that shall not exceed a thickness of 300 mm to the levels and grades as shown on the Contract plans, or as required by the Engineer. Specific compaction is not required other than what occurs during placement and natural consolidation. Equipment traffic and resultant compacting of non-load-bearing material placement in vegetated landscape areas shall be minimized.

2.5.3.4 *Compacting Embankments*

a. **Compacting rock embankments**

Adjust the moisture content of the material to a moisture content suitable for compaction by determining the maximum density and optimum moisture content for the materials passing the 4.76 mm sieve per Article c of Section 2.5.3.4c. Compact each layer of material full width with one of the following:

1. Four roller passes of a 45-metric-ton compression-type roller

2. Four roller passes of a vibratory roller having a minimum dynamic force of a 180-kilonewton impact per vibration and a minimum frequency of 16 hertz
3. Eight roller passes of a 20-metric-ton compression-type roller
4. Eight roller passes of a vibratory roller having a minimum dynamic force of a 130-kilonewton impact per vibration and a minimum frequency of 16 hertz

b. Compacting Earth Embankments

Materials shall be classified according to AASHTO M 145. For material classified A-1 or A-2-4, the Contractor shall determine the maximum density according to AASHTO T 180, Method D. For other material classifications, the Contractor shall determine the optimum moisture content and maximum density according to AASHTO T 99, Method C.

Moisture content of the material shall be adjusted to the optimum.

Material placed in all embankment layers shall conform to the requirements of Article c of Section 2.5.3.1 and not more than 150mm in compacted thickness and shall be placed and compacted to at least 95 percent (average of minimum 5 compaction tests) with no single value less than 93 percent of the maximum density. Determine the in situ density and moisture content according to AASHTO T 238 and T 239 standards.

Prior to the placement of any materials, the Contractor shall construct trial compaction tests as directed by the Engineer. The material used in the trials shall be the proposed embankment material and the compaction equipment to be used shall be that specified and acceptable to the Engineer.

The objective of these trials is to determine the relationship between the number of compaction equipment passes and density for the proposed materials.

c. Compaction and Moisture Control Tests

Embankment construction shall be tested using the procedures listed in Table 2-12.

Table 2-12: Embankment material and compaction tests

Test	AASHTO* designation
Testing of materials:	
Sampling	T 2, T 86
Sample preparation	T 87
Sieve analysis	T 27, T 88
Liquid limit	T 89
Plastic limit and plasticity index	T 90
Moisture content	T 93, T 217
Moisture – density relationship	T 180
Sand equivalent	T 176
Specific gravity	T 100, T 85
California bearing ratio (CBR)	T 193
Classification	M 145
Testing degree of compaction:	
Sampling	T 86
Density-in-place, including sand cone method	T 191

Test	AASHTO* designation
Density-in-place, including drive cylinder method	T 204
Density-in-place, including rubber balloon method	T 205

*American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

2.5.3.5 *Prefabricated Vertical Drains*

When shown in the plans or included in the Bills of Quantities, the Contractor shall furnish and install prefabricated vertical drains (PVD). Installation shall be in accordance with the details shown in the Contract plans, as may be described in the particular specifications, and as recommended by the prefabricated vertical drain manufacturer.

Prior to installation of the PVDs, the Contractor shall submit details of the sequence and method of installation to the Engineer. At a minimum, this submittal shall contain the dimensions and length of mandrel, a detailed description of the proposed methods for overcoming obstructions, and the proposed methods for splicing drains.

Equipment, methods, and materials shall be demonstrated to produce a satisfactory installation in accordance with these specifications. For this purpose, the Contractor shall be required to install trial drains at different locations within the work area.

PVDs shall be constructed prior to embankment construction.

Prior to installation of vertical drains, a sand drainage blanket shall be placed on the ground surface for use as a working platform. This platform shall have a minimum depth of 60 cm and shall consist of un-compacted material meeting the requirements of Section 2.5.2.6. Vertical drains shall be installed with equipment that disturbs subsoil minimally. A mandrel or sleeve shall be advanced through the subsoil using vibratory, constant load, or constant rate of advance methods. Mandrels shall have a maximum cross-sectional area of 90 cm^2; shall protect the prefabricated drain material from tears, cuts, and abrasions during installation; and shall be provided with an anchor plate or rod. An anchor plate or rod shall provide sufficient strength to prevent the soil from entering the bottom during installation, and shall anchor the bottom of the drain at the required depth when the mandrel is removed. Falling weight impact hammers or jetting shall not be used within the compressible subsoil to be drained.

Prefabricated drains shall be installed vertically from the working surface to the required elevations and in a sequence that shall not require equipment to travel over previously installed drains. Contractor shall provide the Engineer with a suitable means of verifying the plumbness of the equipment and determining the depth of the drain at any time. The equipment shall not deviate more than 6.35 mm per metre from the vertical.

Splices or connections in the PVD material shall be performed in a professional manner to ensure continuity of the PVD material. PVD shall be cut to leave at least 150 mm protruding above the working platform at each drain location.

Where obstructions are encountered and cannot be penetrated, the Contractor shall abandon the hole. A maximum of two attempts shall be made to install a new drain within 45 cm of the obstructed hole. Drains that otherwise deviate from the drawing location by more than 150 mm, or that are damaged or improperly installed, shall be rejected.

While installing the drains, the Contractor shall consider and coordinate with any geotechnical instrumentation and existing utility locations. Special care shall be taken when installing drains near instrumentation and existing utilities already in place. Replacement or repair of instrumentation or utilities damaged by the Contractor shall be the responsibility of the Contractor.

2.5.3.6 *End Caps and Draw Lines for Ducts, Conduits, Pipe Sleeves and Culverts*

The Contractor shall furnish and install end caps for vacant ducts, conduits and pipe sleeves before backfilling to prevent any intrusion of backfill material into the ends of such ducts, conduits and pipe sleeves.

Open ends of vacant pipe culverts and concrete box culverts shall be closed with bulkheads. The bulkheads shall be constructed with suitable concrete blocks or bricks and mortar and as approved by the Engineer.

End caps shall be of the type and material as manufactured for respective types of ducts, conduits and pipe sleeves and as approved by the Engineer.

Prior to the installation of end caps and bulkheads as specified herein, the Contractor shall furnish and install draw lines in all vacant ducts, conduits, pipe sleeves and culverts longer than ten metres (10 M). The draw lines are intended to facilitate future installation of utility cables and pipes. Draw lines shall consist of 6 mm dia. nylon rope as approved by the Engineer. The draw lines shall be secured with a temporary fastener inside both ends of the ducts, conduits, pipe sleeves or culverts as approved by the Engineer.

2.6 Subgrade Preparation

Before placing any paving, the Contractor shall bring the subgrade to the required line, grade, and cross-section. Subgrade shall be compacted in accordance with Sections 2.6.1 and 2.6.2. A compacted area shall be wide enough to allow paving machines to operate without visible distortion of surfacing material.

Until the pavement is placed, the Contractor shall maintain the subgrade in the required condition.

2.6.1 Traffic Pavement

Top 300 mm of the roadway embankments at the subgrade level shall be constructed in two layers of 150 mm each, of embankment material meeting the requirements of Section 2.5.2.2, and shall have a minimum density in percent of the maximum dry density of 95% with a minimum CBR of 30%.

Where traffic pavement is placed on existing ground or on existing subgrade, the existing material shall be scarified and re-compacted in accordance with Article a of Section 2.5.3.1 Clause 2, where it shall have a minimum CBR of 10 % when compacted to 90% of MDD and a minimum CBR of 30% at a compaction of 95% of MDD. If the CBR of the existing material is less than 10, then the top 300 mm depth shall be removed and replaced with load bearing material compacted to a minimum density of 95%, with a CBR of 30.

2.6.2 Pedestrian Pavement

Top 150 mm of roadway embankments under pedestrian pavement at the subgrade level shall be compacted to a minimum density in percent of maximum dry density of 95% with a CBR of 25. An additional working layer of aggregate material may be placed on top of the compacted embankment material where shown on the Contract plans or approved by the Engineer.

Where pedestrian pavement is placed on existing ground or on existing subgrade, the existing material shall be scarified and recompacted in accordance with Article a of Section 2.5.3.1 Clause 2.

2.7 Geotextile Installation

2.7.1 Description

Contractor shall furnish and place construction geotextile fabric, in accordance with the details shown in the Contract plans.

2.7.2 Materials

Geotextile materials shall meet the requirements of Section 2.5.2.9.

Geotextile roll identification, storage, and handling shall conform to ASTM D 4873. During periods of shipment and storage, the geotextile shall be stored off the ground. Geotextile shall be covered at all times during shipment and storage to keep it fully protected from UV radiation, including sunlight; site construction damage; precipitation; chemicals consisting of strong acids or strong bases; flames, including welding sparks; temperatures in excess of 71^{o} C; and any other environmental condition that may damage the physical property values of the geotextile.

2.7.3 Construction Requirements

Areas to be covered by the geotextile shall be graded to a smooth, uniform condition free from ruts, potholes, and protruding objects such as rocks or sticks. Geotextile shall be spread immediately ahead of the covering operation and shall not be left exposed to sunlight during installation for a total of more than 7 calendar days.

Geotextile shall be laid smooth without excessive wrinkles. Under no circumstances shall the geotextile be dragged through mud or over sharp objects that could damage it.

Soil piles, or the manufacturer's recommended method, shall be used as needed to hold the geotextile in place until the specified cover material is placed.

Cover material shall be placed on the geotextile and the minimum initial lift thickness required shall be between the equipment tires or tracks and the geotextile at all times. Construction vehicles shall be limited in size and weight to reduce rutting in the initial lift above the geotextile to not greater than 70 mm deep to prevent overstressing. Turning of vehicles on the first lift above the geotextile shall not be permitted.

When placed as a measure to help stabilize soft foundations, the lift thickness covering the geotextile shall be 300 mm to 600 mm thick. By routing loaded haul equipment over its entire width, the Contractor shall compact the first layer. No vibratory compaction shall be allowed on the first lift.

Should the geotextile be torn, punctured, or the overlaps or sewn joints disturbed (as evidenced by visible geotextile damage, subgrade pumping, intrusion, or roadbed distortion) the backfill around the damaged or displaced area shall be removed and the damaged area repaired or replaced by the Contractor. Repair shall consist of a patch of the same type of geotextile placed over the damaged area. Patch shall overlap the existing geotextile from the edge of any part of the damaged area by the minimum required overlap for the application.

If geotextile seams are to be sewn in the field or at the factory, the seams shall consist of one row of stitching, unless the geotextile where the seam is to be sewn does not have a selvedge edge. If a selvedge edge is not present, the seams shall consist of two parallel rows of stitching. Two rows of stitching shall be 25 mm apart with a tolerance of ±10 mm and shall not cross except for restitching. Seam, stitch type, and the equipment used to perform the stitching shall be as recommended by the manufacturer of the geotextile and as approved by the Engineer.

Seams shall be sewn in such a manner that the seam can be inspected readily by the Engineer or a representative. Seam strength may be tested and shall meet the requirements stated in Table 2-10 for seam breaking strength.

2.7.3.1 *Subsurface Drainage and Soakaways*

Trench walls shall be smooth and stable. Geotextile shall be placed in a manner that ensures direct contact between the soil and the geotextile (i.e., no voids, folds, or wrinkles).

Geotextile shall either overlap a minimum of 300 mm at all longitudinal and transverse joints or the geotextile joints shall be sewn. Where the trench width is less than 300 mm, the minimum overlap shall be the trench width.

An area drain is defined as a geotextile layer placed over or under a horizontal to moderately sloping layer of drainage aggregate. For area drains, the geotextile shall be overlapped a minimum of 600 mm at all longitudinal and transverse joints, or the geotextile joints shall be sewn. Minimum initial lift thickness over the geotextile in the area drain shall be 300 mm. In all cases, the upstream geotextile sheet shall overlap the next downstream sheet.

2.7.3.2 *Permanent Erosion Control and Ditch Lining*

Geotextile fabric used as a filter material under or behind erosion control work, such as gravel or rock surface stabilisation, loose and grouted riprap and rock, gabions, ditch linings, energy dissipaters, and outlet protection pads, shall either be overlapped a minimum of 600 mm at all longitudinal and transverse joints, or the geotextile joints shall be sewn, unless otherwise shown on the Contract plans. If overlapped, the geotextile shall be placed so that the upstream strip of the sheet shall overlap the next downstream strip.

Placement of protective aggregate bedding over the top of the geotextile shall be performed where shown on the Contract plans and as stipulated in Section 2.7.3.

When placed on slopes, each geotextile strip shall overlap the next downhill strip. Placement of aggregate, riprap, or other cover material on the geotextile fabric shall start at the toe of the slope and proceed upwards. Geotextile fabric shall be keyed at the top and the toe of the slope as shown in the Contract plans. Geotextile fabric shall be secured to the slope, but shall be secured loosely enough so that the geotextile shall not tear when the riprap or other cover material is placed on the sheet. Geotextile fabric shall not be keyed at the top of the slope until the riprap or other cover material is in place to the top of the slope.

All voids in the riprap or other cover material that allow the geotextile to be visible shall be backfilled with coarse aggregate of 75 mm maximum size so that the geotextile is completely covered, as designated by the Engineer. When an aggregate cushion between the geotextile fabric and the riprap, or other cover material, is required, it shall have a minimum thickness of 150 mm, unless otherwise shown in the Contract plans.

Grading of slopes after placement of the riprap, or other cover material, shall not be allowed if grading results in stone movement directly on the geotextile. Under no circumstances shall stones with a weight of more than 50 kg be allowed to roll down slope. Stones shall not be dropped from a height greater than 1 m above the geotextile surface if an aggregate cushion is present, or 300 mm if a cushion is not present. Lower drop heights may be required if geotextile damage from the stones is evident and determined by the Engineer. If the geotextile fabric is placed on slopes steeper than a ratio of 2:1, the stones shall be placed on the slope without free fall. Trial area to be prepared for survivability check.

2.8 Trimming and Cleanup

2.8.1 Description

This work consists of dressing and trimming all roadways improved under the Contract. This work extends to excavated cut slopes, compacted fill slopes, ditches, ponds, berms, and non-load-bearing fill areas.

2.8.2 Construction Requirements

Contractor shall perform the following:

1. Trim cut and fill slopes, ditches, and other fill slopes to produce smooth surfaces and uniform cross-sections that conform to the grades shown on the Contract plans or set by the Engineer.
2. Open and clean all channels, ditches, and gutters to ensure proper drainage.
3. Dress the back slope of any ditch and pond berm and borrow source that shall remain adjacent to the roadway. Round off the top of the back slope and distribute the material evenly along its base.

4. Grade and smooth to uniform slopes and to the grades shown on the Contract plans or set by the Engineer. Also, grade and smooth any natural areas within the roadway corridor that are not otherwise designated not to be disturbed and protected as required by the Engineer.
5. Remove and dispose of all weeds, brush, refuse, and debris that lie within the roadway corridor.
6. Remove from shoulders all loose rocks and gravel.
7. Distribute evenly along the embankment slope any material not needed to bring the embankment fill slope to the required cross-section.

Contractor shall not perform the following:

1. Use heavy equipment, such as tractors, graders, etc., to trim the embankment surface of an existing or new bituminous surface.
2. Drag, push, or scrape any material across completed surfacing or pavement.

When the Contract requires the Contractor to rebuild part of a roadway, only the rebuilt areas shall be trimmed and cleaned up. If the Contractor's work obstructs ditches or side roads, they shall be cleared and the debris disposed of as the Engineer directs.

Trimming and cleanup work will be inspected by the Engineer, and final acceptance is subject to the Contractor's approval.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 3 - PAVEMENT

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 3: Pavement

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3 PAVEMENT

This work shall consist of furnishing, placing, spreading, and compacting pavements for new construction and rehabilitation works including asphaltic and Portland cement types in accordance with these specifications and conforming to the lines, grades, and dimensions shown in the Contract documents.

3.1 Reference Standards and Codes

Standards and codes shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
ASTM	American Society for Testing and Materials;
BSI	British Standards Institution;
BS EN	European Standards;
AIM	Asphalt Institute Manual;
AI MS-2	Mix Design Methods for Asphalt Concrete and Other Hot Mixes;
ITE	Institute of Traffic Engineers;
ITE	Equipment and Material Standards of the Institute of Transportation Engineers, 2001.

Table 3-1 and Table 3-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for pavement works. It also includes designations and titles.

Table 3-1: Designations and titles for AASHTO and ASTM standards that apply to pavement works

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO T96		*Standard method of test for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine.*
	ASTM D75 / 75M - 09	*Standard practice for sampling aggregates.*
	ASTM C131 - 06	*Standard test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine.*
	ASTM C535 – 12	*Standard test method for resistance to degradation of large-size coarse aggregate by abrasion and impact in the los Angeles machine.*
	ASTM C88-05	*Standard test method for soundness of aggregates by use of sodium sulfate or magnesium sulfate.*
	ASTM D2419 - 09	*Standard test method for sand equivalent value of soils and fine aggregate.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
	ASTM D4318-10	*Standard test methods for liquid limit, plastic limit, and plasticity index of soils.*
	ASTM D1883-07e2	*Standard test method for CBR (California bearing ratio) of laboratory-compacted soils.*
	ASTM C128-12	*Standard test method for density, relative density (specific gravity), and absorption of fine aggregate.*
	ASTM C127-12	*Standard test method for density, relative density (specific gravity), and absorption of coarse aggregate.*
	ASTM D1559-89	*Test method for resistance of plastic flow of bituminous mixtures using Marshall apparatus (withdrawn 1998).*
	ASTM C25 - 11	*Standard test methods for chemical analysis of limestone, quicklime, and hydrated lime.*
	ASTM C50 / C50M - 12	*Standard practice for sampling, sample preparation, packaging, and marking of lime and limestone products.*
	ASTM C51 - 11	*Standard terminology relating to lime and limestone (as used by the industry).*
	ASTM D244 -09	*Standard test methods and practices for emulsified asphalts.*
	ASTM D1075-11	*Standard test method for effect of water on compressive strength of compacted bituminous mixtures.*
	ASTM D2172 / D2172M - 11	*Standard test methods for quantitative extraction of bitumen from bituminous paving mixtures.*
AASHTO M 208	ASTM D2397	*Standard Specification for Cationic Emulsified Asphalt*
	ASTM D6307 - 10	*Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method.*
	ASTM D3387 - 11	*Standard test method for compaction and shear properties of bituminous mixtures by means of the U.S. Corps of Engineers gyratory testing machine (GTM).*
	ASTM D3142 / D3142M - 11	*Standard test method for specific gravity, API gravity or density of cutback asphalts by hydrometer method.*
	ASTM D6927 - 06	*Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures.*
	ASTM D6926 - 10	*Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
	ASTM D5821 – 01 (2006)	*Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.*
	ASTM D4791 - 10	*Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.*
	ASTM D3042 - 09	*Standard Test Method for Insoluble Residue in Carbonate Aggregates.*
	ASTM C1077 - 13	*Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation.*
	ASTM C295 / C295M - 12	*Standard Guide for Petrographic Examination of Aggregates for Concrete.*
	ASTM C33 / C33M - 11a	*Standard Specification for Concrete Aggregates.*
	ASTM C186 - 05	*Standard Test Method for Heat of Hydration of Hydraulic Cement.*
	ASTM C114 - 11b	*Standard Test Methods for Chemical Analysis of Hydraulic Cement.*
	ASTM C1240 - 12	*Standard Specification for Silica Fume Used in Cementitious Mixtures.*
	ASTM D1751 – 04 (2008)	*Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).*
	ASTM C494 / C494M - 11	*Standard Specification for Chemical Admixtures for Concrete.*
	ASTM C881 / C881M - 10	*Standard Specification for Epoxy Resin Base Bonding Systems for Concrete.*
	ASTM C1260 - 07	*Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar Bar Method).*
	ASTM C136 - 06	*Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.*
AASHTO T 176-08		*Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.*
AASHTO T2		*Standard method of test for sampling of aggregates.*
AASHTO M 145		*Standard specification for classification of soils and soil-aggregate mixtures for highway construction purposes.*
AASHTO T 104		*Standard method of test for soundness of aggregate by use of sodium sulfate or magnesium sulfate.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO T 89-10		*Determining the Liquid Limit of Soils*
AASHTO T 90		*Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils.*
AASHTO T 100		*Standard Method of Test for Specific Gravity of Soils.*
AASHTO T 85		*Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate.*
AASHTO T 180		*Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop.*
AASHTO T 193		*Standard Method of Test for The California Bearing Ratio.*
AASHTO. T 96-02		*Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
AASHTO T112-00 (2008)	ASTM C142-97	*Standard method of test for clay lumps and friable particles in aggregate.*
AASHTO T 191		*Standard Method of Test for Density of Soil In-Place by the Sand-Cone Method.*
AASHTO T 11		*Standard Method of Test for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.*
AASHTO T 27-06		*Sieve Analysis of Fine and Coarse Aggregates.*
AASHTO M 85		*Standard specification for Portland cement.*
AASHTO T 22-10		*Compressive Strength of Cylindrical Concrete Specimens.*
AASHTO T 205		*Standard Method of Test for Density of Soil In-Place by the Rubber-Balloon Method.*
AASHTO T 165		*Standard method of test for effect of water on compressive strength of compacted bituminous mixtures.*
AASHTO M 17	ASTM D242	*Standard specification for mineral filler for bituminous paving.*
AASHTO M 20		*Standard specification for penetration-graded asphalt cement.*
AASHTO M 33-99		*Preformed Expansion Joint Filler for Concrete (Bituminous Type).*
AASHTO M 82		*Standard specification for cutback asphalt (medium-curing type).*
AASHTO M 140		*Standard specification for emulsified asphalt.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO M 208		*Standard specification for cationic emulsified asphalt.*
AASHTO M 226		*Standard specification for viscosity-graded asphalt cement.*
AASHTO M 320		*Standard specification for performance-graded asphalt binder.*
AASHTO M 323		*Standard specification for superpave volumetric mix design.*
AASHTO MP2		*Standard specification for superpave volumetric mix design.*
AASHTO MP 19		*Standard Specification for performance-graded asphalt binder using multiple stress creep recover (MSCR) test.*
AASHTO R 12		*Standard Specifications for bituminous mixture design using the Marshall and Hveem procedures.*
AASHTO R 35		*Standard practice for superpave volumetric design for hot mix asphalt (HMA).*
AASHTO PP 28		*Standard specification for superpave volumetric design for hot mix asphalt (HMA).*
AASHTO T 2		*Standard Method of Test for Sampling of Aggregates.*
AASHTO T 11-05		*Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.*
AASHTO T 30		*Standard specification for mechanical analysis of extracted aggregate.*
AASHTO T 96-02		*Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
AASHTO T 99		*Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop.*
AASHTO T 104-99		*Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.*
AASHTO T 164		*Standard method of test for quantitative extraction of asphalt binder from hot mix asphalt (HMA).*
AASHTO T 168		*Standard method of test for sampling bituminous paving mixtures.*
AASHTO T 219		*Standard method of test for testing lime for chemical constituents and particle sizes.*
AASHTO T 230		*Standard method for determining the degree of pavement compaction of a bituminous-aggregate mixture.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO T 245		*Standard method of test for resistance to plastic flow of bituminous mixtures using Marshall apparatus.*
AASHTO T 308		*Standard method of test for determining the asphalt binder content of hot-mix asphalt (HMA) by the ignition method.*
AASHTO T 304-11		*Standard Method of Test for Uncompacted Void Content of Fine Aggregate.*
AASHTO M 303		*Standard Specification for Lime for Asphalt Mixtures.*
AASHTO R 14-88 (2007)	ASTM D4552-92 (2004)	*Standard Recommended Practice for Classifying Hot-Mix Recycling Agents.*
AASHTO TP 61		*Standard Method of Test for Determining the Percentage of Fracture in Coarse Aggregate.*
AASHTO T 85-10		*Specific Gravity and Absorption of Coarse Aggregate.*
AASHTO T 84-10	ASTM C 128-07a)	*Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate.*
	ASTM C150 / C150M - 11	*Standard Specification for Portland Cement.*
AASHTO M 140		*Standard Specification for Emulsified Asphalt.*
AASHTO T 19M/T 19-00 (2004)		*Standard Method of Test for Bulk Density ("Unit Weight") and Voids in Aggregate.*
AASHTO T 182		*Standard Method of Test for Coating and Stripping of Bitumen-Aggregate Mixtures.*
AASHTO T 210-10		*Aggregate Durability Index.*
AASHTO T 112		*Standard Method of Test for Clay Lumps and Friable Particles in Aggregate.*
AASHTO M 195-06		*Lightweight Aggregates for Structural Concrete.*
AASHTO T 27		*Sieve Analysis of Fine and Coarse Aggregate.*
AASHTO T 89		*Standard Method of Test for Determining the Liquid Limit of Soils.*
AASHTO M 43-05		*Sizes of Aggregate for Road and Bridge Construction.*
AASHTO M 254		*Standard Specification for Corrosion-Resistant Coated Dowel Bars.*
AASHTO M 284M/M 284-09		*Epoxy-Coated Reinforcing Bars: Materials and Coating Requirements.*

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO T 97		*Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).*
AASHTO PP 50		*Standard Practice for Operating Inertial Profilers and Evaluating Pavement Profiles.*
AASHTO PP 51		*Standard Practice for Pavement Ride Quality When Measured Using Inertial Profiling Systems.*
AASHTO PP 52		*Standard Practice for Developing a Quality Assurance Plan for Hot-Mix Asphalt (HMA).*
	ASTM C618 - 08a	*Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.*
	ASTM A615 / A615M - 09b	*Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement.*
ASHTO M 31M/M 31 - 10		*Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.*
AASHTO M 42M/M42	ASTM A996 / A996M - 09b	*Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement*

Table 3-2: Designations and titles for BS and BS EN standards that apply to pavement works

BS Designation	BS EN Designation	Title
BS 1377-2:1990		*Methods of test for soils for civil engineering purposes. Classification tests.*
BS 1377-3:1990		*Methods of test for soils for civil engineering purposes. Chemical and electro-chemical tests.*
BS 812-110:1990		*Testing aggregates. Methods for determination of aggregate crushing value (ACV).*
BS 812-105-105.1:1985		*Testing aggregates. Methods for determination of particle shape. Flakiness index.*
BS 1377-4: 1990		*Methods of test for soils for civil engineering purposes. Compaction-related tests.*
BS 1377-9:1990		*Methods for test for soils for civil engineering purposes. In-situ test.*
	BS EN 1744-1+A1	*Tests for chemical properties of aggregates. Chemical analysis.*
BS 812-117:1988		*Testing aggregates. Method for determination of water-soluble chloride salts.*
	BS EN - 12620:2002+A1:2008	*Aggregates for concrete.*

3.2 Subbase and Bases

3.2.1 Granular Subbase Course

3.2.1.1Description

Granular subbase shall consist of furnishing, spreading, and compacting subbase in accordance with the details shown on Contract plans and these specifications or as established by the Engineer.

3.2.1.2 Materials

Granular subbase material shall consist of hard, durable natural, screened gravel or crushed stone, and shall be free from clay balls or other deleterious substances. Granular subbase type I shall be used under footpath and type II under roads. Granular subbase shall be well graded and lie within the grading envelope shown in Table 3-3 when tested in accordance with **AASHTO T27**

Table 3-3: Granular subbase gradation

Sieve size	Percentage passing	
	Type I (Under Footpath)	**Type II (Under Roads)**
50 mm	100	100
37.5 mm	85 – 100	85-100
25.4 mm	72 – 96	70-90
19.0 mm	62 – 92	62-82
9.5 mm	40 - 82	40-70
4.75 mm	25 - 70	25-55
0.6 mm	8 - 32	8-28
0.075 mm	0 - 10	0-10

a. Sampling and Testing

One sample every 1000 m^3 of **Type II and One sample every 2000 m^3 of Type I** , or part of as directed by the Engineer shall be tested for grading, plasticity index, maximum dry density, CBR and loss by abrasion. Three in-situ density tests shall be made every unit of granular subbase laid (one unit being 300 m^2) or as directed by the Engineer.

Materials shall meet the minimum requirements per the testing standards listed in Table 3-4. Materials that do not comply with the requirements of these specifications will be rejected and removed immediately from the site unless otherwise instructed by the Engineer. No rejected materials, the defects of which have been corrected, shall be used until approval has been given by the Engineer.

Table 3-4: Granular subbase test requirements

Test	Standard	Limit
Sampling	AASHTO - T2	Min. One sample every 1,000 m^3
Los Angeles Abrasion	AASHTO-T96	30 % max.
Soundness (Magnesium Sulphate Solution - 5 cycles)	AASHTO-T-104	15% max.
Liquid Limit	AASHTO-T-89	35 % max.

Test	Standard	Limit
Plasticity Index	AASHTO-T-90	6 max.
Compaction Test (Dry Density / Moisture Content test)	AASHTO-T-180 D	2.00 Mg/m^3 min
Particle size sieve analysis of fine and coarse aggregate	AASHTO T27	Table 3-3
C.B.R. at 98 % of Maximum dry density (96 hour soaked)	AASHTO-193	45% min Type I 60% min Type II
Field Density	AASHTO T191	Avg.100% min. at MDD **for Type II** **Avg.98% min. at MDD for Type I**
Linear Shrinkage	BS 1377: Part 2 Method 6.5	3 % max.
Sulphate Content (Acid soluble)	BS EN 1744-1	0.5 % max.
Chloride Content (Acid soluble)	AASHTO T260	1 % max.
Sand Equivalent	AASHTO - T176	25% Min. for footpath 35% Min. for Roads
Organic matter content	AASHTO T267	0.2% Max.

b. Material Sources

Contractor shall notify the Engineer of the sources of materials for the Engineer's approval prior to delivery of materials to the site. Where the source of material does not meet specified requirements, the Contractor shall furnish material from other sources. Delivery of materials produced from commercial manufacturing processes shall be accompanied by the manufacturer's certification and test report showing the materials comply with the specification requirements.

c. Storage and Handling of Materials

Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes. Stockpiles shall be kept flat and the formation of high cone-shaped piles will not be permitted. When conveyor belts are used for stockpiling aggregates, the Engineer may require the use of baffle-chutes or perforated chimneys. When trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. The use of tractors or loaders to push material deposited at one location to another location in the stockpile will not be allowed during the construction of the stockpile and their use shall be limited to levelling the deposited material only.

3.2.1.3 Construction Requirements

Pavement subbase material shall be delivered to the roadbed as a uniform mixture and shall be spread in layers or windrows. Segregation shall be avoided and the subbase shall be free from pockets of coarse or fine materials.

Each pavement subbase layer shall be spread by finisher and/or grader or other approved mechanical methods, watered, shaped to a compacted thickness not exceeding 150 mm and compacted to the required grade and cross section.

Compaction procedure and plant shall be to the satisfaction of the Engineer. At the time of compaction, the moisture content of the laid material shall not vary by more than $\pm$ 2 % from the optimum moisture content.

Granular subbase shall be compacted to an average of 100% with no single value less than minimum value of 98% **for Type II, and an average of 98% with no single value less than minimum value of 96% for Type I.** Surface on completion of compaction shall be well closed, free from movement under compaction plant and free from ridges cracks or loose material. Finished surfaces of the road subbase shall not vary at any point more than 10 mm above or below the grade shown on the Contract plans or established by the Engineer. Pavement subbase shall be maintained in a condition satisfactory to receive any subsequent base or surfacing material. Subbase which does not conform to the above requirements shall be reshaped or reworked, watered and thoroughly recompacted to conform to the specified requirements.

3.2.2 Aggregate Base Course

3.2.2.1 Description

Aggregate base course shall consist of crushed mineral aggregates natural mineral aggregates, or a combination of crushed and natural mineral aggregates of the gradation and thickness specified in these specifications and shown on the Contract plans. Contractor shall furnish, place and compact aggregate base course for approach slabs for paved roadways, service roads and parking areas complying with the lines, grades, thicknesses and typical sections shown on the Contract plans, as specified herein or as directed by the Engineer.

3.2.2.2 Materials

Natural aggregate base course shall consist of coarse and fine mineral aggregates which have been screened and blended to the various gradations specified herein and constructed to the thickness as indicated on the Contract plans.

Crushed aggregate base course shall consist of crushed coarse aggregate and crushed or natural fine aggregate screened and blended in accordance with the gradation specified herein and constructed to the thicknesses as indicated on the Contract plans.

Materials for base courses shall comply with the requirements as specified herein and shall be as approved by the Engineer. Contractor shall submit samples of all materials to the Engineer for approval prior to furnishing and placing any materials.

One sample every 1000 m^3, or part of as directed by the Engineer shall be tested for grading, plasticity index, maximum dry density, CBR and loss by abrasion. Three in-situ density test shall be made every unit of aggregate base course laid (one unit being 300 m^3) or as directed by the Engineer.

Material samples shall meet the minimum requirements per testing standards shown in Table 3-5.

Materials that do not comply with the requirements of these specifications will be rejected and removed immediately from the site unless otherwise instructed by the Engineer. No rejected materials, the defects of which have been corrected, shall be used until approval has been given by the Engineer.

Table 3-5: Aggregate base course test requirements

Test	Standard	Limits
Sampling	AASHTO - T2	Min. One sample every 1,000 m^3
Classification	AASHTO - M 145	A-1-a
Los Angeles Abrasion	AASHTO - T96	30 Max.

Test	Standard	Limits
Soundness (Sodium)	AASHTO - T104	12% Max.
Soundness (Magnesium)	AASHTO - T104	15% Max.
Sand Equivalent	AASHTO - T176	40% Mini.
Liquid Limit	AASHTO - T89	35% Max.
Plasticity Index	AASHTO - T90	6.0% Max.
Sulphate Content (Acid soluble)	BS EN 1744-1	0.50% Max.
Chloride Content (Acid soluble)	AASHTO T260	1.0% Max.
Flakiness Index	BS EN 933-3	35% Max.
Elongation	ASTM D4791	35% Max.
Specific Gravity	AASHTO-T100 & T85	2.20 Min.
Max Dry Density	AASHTO - T180D	2.10 gr/cc Min.
C.B.R. at 98% of M.D.D.	AASHTO - T193	**70**% min.

a. Fine Aggregates

Fine aggregate (passing the 4.75 mm sieve) shall consist of natural sand and/or crushed sand and shall be of such gradation that when combined with other required aggregate fractions in proper proportions, the resultant mixture will meet the gradation specified in Sub-article c of Article 3.2.2.2.

Fine aggregate shall be clean and free from organic matter, clay and other extraneous or detrimental materials.

Portion of fine aggregates passing the 75 µm sieve shall not exceed 2/3 of the portion passing the 425 µm sieve.

Material passing the 425 µm sieve shall have a maximum liquid limit of 35 and the plasticity index shall not exceed 6.

When the source of fine aggregates does not meet the above requirements, the Contractor may, with the Engineer's approval, add additional fine aggregate and/or filler to correct the gradation or to change the characteristics of the material passing the 425 µm sieve so as to meet the specifications. Such additional material shall be added in a manner which ensures a completely homogeneous gradation as approved by the Engineer.

b. Coarse Aggregate

Coarse aggregate (retained on the 4.75 mm sieve) shall consist of crushed stone, crushed gravel or natural gravel and shall be of such gradation that when combined with other required aggregate fractions in proper proportion, the resultant mixture will meet the gradation specified in Sub-article c of Article 3.2.2.2.

When crushed aggregate is required, not less than 50 % by weight of the particles retained on the 4.75 mm sieve shall have at least one fractured face. Flakiness Index of the crushed aggregate shall not exceed 35 %.

Percentage of wear of coarse aggregate shall not exceed 30% maximum when tested for resistance to abrasion (AASHTO T-96).

Course aggregate shall be hard and durable and free from organic matter, clay and other extraneous or detrimental materials.

Coarse aggregate shall have a maximum sodium sulphate soundness loss of 12 % and magnesium sulphate soundness loss of 15 %.

c. Aggregate Gradation

Combined gradation including fine and coarse aggregates shall conform to the gradation of Type (A) or (B) or (C) in Table 3-6.

Table 3-6: Aggregate base course gradation

	Percent passing by weight		
Sieve size	**Gradation A**	**Gradation B**	**Gradation C**
50.8 mm		-	100
41.75 mm		100	75-100
25.4 mm	100	70-100	55-85
19.05 mm	70-100	60-90	50-80
9.53 mm	50-80	45-75	40-70
4.75 mm	35-65	30-60	30-60
2.00 mm	25-50	20-50	20-50
425 µm	15-30	10-30	10-30
75 µm	5-15	5-15	5-15

Note:

The final gradation of aggregate subcase and base course shall be subject to the following tolerances during construction:

Passing 25mm sieve and larger ± 6%

Passing sieves 4.75mm (No. 4) to 19mm (No. 3/4”) ± 5%

Passing sieves 425µm (No. 40) to 2mm (No. 10) ± 4%

Passing 75µm (No. 200) ± 2%

The gradation of materials to be used in the aggregate base courses as shown in Table 3-6 indicates the limits within which the material could be accepted. The continuous smooth gradation of materials used shall be kept within the specified gradation limits and gap grading shall be avoided. Selection of one of the gradations shown in the table shall be as shown on the Contract plans and approved by the Engineer. Unless otherwise specified, Gradation B shall be used.

d. Material Sources

Contractor shall notify the Engineer of the sources of materials for the Engineer’s approval prior to delivery of materials to the site. Where the source of material does not meet specified requirements, the Contractor shall furnish material from other sources. Delivery of materials produced from commercial manufacturing processes shall be accompanied by the manufacturer's certification and test report showing the materials comply with the specification requirements.

e. Storage and Handling of Materials

Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes. Stockpiles shall be kept flat and the formation of high cone-shaped piles will not be permitted. When conveyor belts are used for stockpiling aggregates, the Engineer may require the use of baffle-chutes or perforated chimneys. When trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. The use of tractors or loaders to push material deposited at one location to another location in the stockpile will not be allowed during the construction of the stockpile and their use shall be limited to levelling the deposited material only.

3.2.2.3 Construction Requirements

a. Equipment

1. Spreaders: Spreaders / pavers shall be self-propelled and shall be capable of spreading the base materials in one operation so as to make it ready for compaction with minimum shaping. Spreader shall be provided with a screed that strikes off and distributes the material to the required width and level. Width of each spread shall not be less than a traffic lane wide. Screed shall be adjustable to the required cross-section. Screed action includes any practical motion that produces a finished surface texture of uniform appearance.
2. Travel mixers: Travel mixers shall be of a type which is capable of mixing to the full depth of the layer thickness being processed, by picking up the material, mixing, agitating or otherwise blending into a homogeneous mass which complies with the required general gradation and other specifications. Mixers shall be equipped with an accurate depth control device to avoid the disturbance of previously accepted layers. After mixing, the material shall be deposited by the mixer in its final position so that prior to compaction no spotting, picking-up or otherwise shifting the material will be required. Mixers may be equipped with pressure spray bars which can supply a uniform distribution of metered water during the mixing process.
3. Central mixers: A central mixing plant shall be either of an approved drum or pugmill type with a moisture control system so that the material may be spread without further mixing or processing.

b. Surface Preparation

Prior to commencing the construction of the base courses, the Contractor shall make sure that the subbase complies with the specifications and that the surface thereof complies with the levels and slopes shown in the longitudinal and cross-section Contract plans. In all cases the approval of the Engineer must be obtained before commencing spreading of material for the base courses.

c. Screening and Mixture of the Materials

Screening shall be required for the materials used in aggregate base courses. Screens shall be of the size and number required to remove oversize aggregate and, if necessary, to separate the materials into two or more fractions so that they may be combined to meet the required gradation. When conveyor belt samples from the end of the screening and/or crushing-screening operation yield a product consistently within the specified gradation, no further mixing shall be required and the material may be loaded and hauled directly to the stockpile. In the event the material is stockpiled, it shall be stockpiled so as to prevent segregation.

Mixing of material shall be achieved through the use of the central mixing plant or travel mixer specified in sub-article a) of Article 3.2.2.3.

Where separate size materials are to be blended to meet the gradation, such blending shall be as directed by the Engineer and shall be accomplished prior to delivery to the roadway. Mixing of separate materials on the roadway by motor grader will not be permitted by the Engineer.

d. Compaction Trials

Prior to the commencement of aggregate base course operations, the Contractor shall construct trial length, not less than 30m. Material used in the trials shall be that approved for use as aggregate base course and the equipment used shall be that accepted as the Contractor's approved detailed list of resources.

Aim of this trial is to determine the adequacy of the Contractor's equipment, the loose thickness measurements necessary to result in the specified compacted layer thickness, the field moisture content, and the relationship between the number of compactions passes and the resulting density of the material.

Contractor may proceed with aggregate base course work only after the method and procedures established in the compaction trial have been approved by the Engineer

Method statement shall indicate the width of the pavers, number of pavers, compacting plant and equipment, number of passes by rollers .

e. Spreading and Compaction

After carrying out the screening and mixing of aggregate material, samples of the approved material shall be taken in order to determine the optimum moisture content.

Material shall then be spread on the prepared surface by mechanical paver / spreader in layers not more than 150 mm compacted thickness to achieve the total thickness as shown on the Contract plans. After spreading and before compaction the gradation shall be checked by the engineer for its compliance with specifications.

Care shall be taken in spreading and compacting the aggregate base not to damage the geotextile fabric, if provided. It is required to use 50 mm thick crushed sand on top of the geotextile to protect the geotextile during spreading the subsequent aggregate layer.

Existing moisture content of materials constituting the base courses shall be determined. If the existing moisture content is less than the optimum moisture content, the necessary amount of water must be added to obtain the optimum moisture content allowing for the quantity which may be lost by evaporation in the process of raking, levelling and compacting. Layer shall be compacted when the moisture content therein is within ± 2 % of the optimum moisture content and uniform in all parts of the section and depths within the layer thickness.

Compaction shall start immediately thereafter, by means of pneumatic and steel rollers or vibratory rollers and in accordance with the Engineer’s approval or instructions.

Compaction shall start with rollers from extreme sides proceeding gradually toward the road axis. Rolling shall continue until a relative density of not less than 100% of the maximum dry density has been obtained as determined by the moisture-density relationship test, AASHTO T-180. CBR of the base material shall not be less than 70% @ 98% MDD.

f. Multi-layers

During the operations of mixing, spreading, compacting and levelling of base course material, care shall be taken so that layers already compacted under the layer being executed are not affected, or that the finished subgrade or subbase surface is also not affected. This requirement shall be given special attention in places where equipment makes turns in going back and forth and any such damage resulting in mixing the various layers constituting the different subgrade, subbase and base courses shall be carefully made good by the Contractor at his expense and to the satisfaction of the Engineer.

If more than one base course is required for reaching the required thickness described in the specifications, each such course shall be constructed as specified herein.

Where the finished total compacted thickness exceeds 150 mm, each layer shall be executed in composite layers not exceeding 150 mm in thickness after compaction unless otherwise approved by the Engineer.

g. Protection of Surface

Contractor shall protect the base course so that it shall be maintained sound during work progress, after its completion and prior to receiving the bituminous layers or prior to laying the surface overlay thereon. Any damage caused to the layer if exposed to traffic or natural conditions resulting in damage to its surface should be made good to the satisfaction of the Engineer.

Base courses shall not be rolled when the underlying material is soft or yielding or when the rolling causes a wave-like motion in this course.

When the rolling develops irregularities, the irregular surface shall be loosened, then refilled with the same kind of material as used in constructing the course and again rolled according to specifications. Along places inaccessible to rollers, the base course material shall be tamped thoroughly with mechanical tampers.

Work on the base course will not be permitted during rainy weather.

Hauling equipment may be routed over completed portions of the base courses provided no damage results and provided that such equipment is routed over the full width of the course to avoid rutting or uneven compaction.

Engineer has the right to stop all hauling over completed or partially completed base courses when in his opinion such hauling is causing damage.

h. Acceptance of Aggregate Base Courses

Prior to the application of any prime coat or any other paving course, the aggregate base course shall have been tested and accepted by the Engineer. The following shall be adhered to in accepting completed aggregate base courses:

1. Requirements for compaction: the degree of compaction testing values should have an average of 100% with no single value less than minimum value of 98%. Wherever the degree of compaction is found to be less than the 98% specified, the area of base course involved shall be satisfactorily corrected so that the minimum specified density is achieved.
2. Requirements for gradation: Wherever the gradation is found to be outside the limits specified, the area of base course involved shall be scarified, removed or otherwise reworked as directed by the Engineer to provide a material within the specified limits.
3. Thickness requirements: The total constructed thickness of aggregate base course used for new construction, reconstruction or widening of roadways shall not vary more than 8 mm from the total thickness indicated on the Contract plans.

   In the event the constructed thickness of the aggregate base course is 8 mm more than the total thickness indicated on the Contract plans, the area involved shall be corrected as directed by the Engineer by removing excess material in an approved manner to provide the required thickness.

   In the event the constructed thickness of the aggregate base course is 8 mm less than the total thickness indicated on the Contract plans, the Contractor shall provide additional material in the next course (base course or wearing course). In no case shall the deficiency of the base course exceed 12mm.

   Aggregate base course shall be constructed to the grade level as indicated on the Contract plans, as specified and as approved by the Engineer.

   In no case shall the total sum thickness of the aggregate subbase course, aggregate base course and asphalt pavements be less than the total sum thickness of all courses as indicated on the Contract plans.
4. Requirements for evenness of surface and grade level: Final surfaces of the base course shall be tested by means of a 5 m long straight edge; and no rises or depressions in excess of 10 mm shall appear on the surface; otherwise such areas shall be stripped, corrected and re-compacted to comply with all specification requirements and as approved by the Engineer. Further, the finished surface of the base course shall be constructed to within 12 mm of the grade levels indicated on the Contract plans.

3.2.3 Wet mix Macadam

3.2.3.1 Description

Item of work consist of furnishing and placing one or more layers of wet mix macadam, including additives if required, on a prepared surface in accordance with these specifications and in conformity with the lines, grades, thicknesses and typical cross-sections shown on the Contract plans or established by the Engineer.

3.2.3.2 Materials

All aggregates for Wet Mix Macadam shall consist of crushed gravel, crushed rock or stone fragments obtained by crushing gravel that has first been screened in such a manner that no less than 90 % of the material to be crushed is retained on a 4.75 mm sieve.

Amount of crushing shall be regulated so that at least 100 %, by weight, of the pieces retained on the 4.75 mm sieve have at least 1 fractured face.

All aggregates for wet mix macadam shall conform to the requirements of Table 3-7.

Table 3-7: Physical requirements of aggregate for wet mix macadam

Loss of sodium sulphate soundness test (AASHTO T 104)	10 % maximum
Loss of magnesium sulfate soundness test (AASHTO T 104)	12 % maximum
Loss of abrasion test (AASHTO T 96)	30 % maximum
Thin and elongated pieces, by weight (B.S. 812)	5 % maximum
Friable particles (AASHTO T 112)	0.25 % maximum

Material for wet mix macadam shall conform to the requirements in Table 3-8.

Table 3-8: Material requirements for wet mix macadam

Standard sieve size	Percentage passing by weight
50 mm	100
37.5 mm	95 – 100
19.0 mm	60 – 80
9.5 mm	40 – 60
4.75 mm	25 – 40
2.36 mm	15 – 30
600 µm	8 – 22
75 µm	0 – 8
Liquid limit (AASHTO T 89)	25 maximum
Plasticity index (AASHTO T 90)	4 maximum
Sand equivalent (AASTHO T 176)	45 minimum
Maximum dry density (AASTHO T 180)	2.20 gr./cc
CBR on remolded sample after 4 days soaking at 98 % MDD (AASHTO - T193	80% Minimum

a. Minimum Test Requirements

One sample every 1,000 m^3 shall be tested for grading, soundness, loss by abrasion, maximum dry density, plasticity index, sand equivalent, and CBR. One in-situ density test shall be taken every 300 m^2 of laid wet mix macadam.

3.2.3.3 Construction Requirements

a. Subgrade Preparation

Unless other subgrade preparation is indicated on the Contract plans or as a pay item in the bills of quantities, the Contractor shall, prior to the delivery of materials for the wet mix macadam, prepare the roadbed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper cross slope is obtained. However, in the process of shaping an existing roadbed, the originally compacted crust or top portion of the roadbed shall be disturbed as little as possible.

When completed and ready for wet mix macadam construction, the roadbed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

b. Compaction Trials

If directed by the Engineer, prior to the commencement of wet mix macadam operations, the Contractor shall construct trial lengths, not to exceed 1 km. Material used in the trials shall be that approved for use as wet mix macadam and the equipment used shall be that accepted as the Contractor’s approved detailed list of resources.

Aim of these trials is to determine the adequacy of the Contractor’s equipment, the loose thickness measurements necessary to result in the specified compacted layer thickness, the field moisture content, and the relationship between the number of compaction passes and the resulting density of the material.

Contractor may proceed with wet mix macadam work only after the method and procedures established in the compaction trial have been approved by the Engineer.

c. Method of Construction

Wet mix macadam shall be combined into a uniform mixture and water added only in a central mixing plant before final placement of the material. Mixing and watering by windrows will not be permitted. When binder is to be added, it shall be combined with the wet mix macadam by thoroughly mixing the binder and wet mix macadam in the central mixing plant.

Moisture added to the aggregates shall be that required, as designated by the Engineer, to obtain the specified density thereby preparing an aggregate completely ready for compaction after spreading on the roadbed. In no case will wetting of aggregates in stockpiles or trucks be permitted.

Wet mix macadam shall be delivered to the roadbed as a uniform mixture and shall be placed on the existing roadway, prepared subbase, or prepared subgrade, as the case may be, in a uniform layer or layers not exceeding 150 mm in compacted thickness. Spreading shall be done by means of approved self-propelled stone box spreader, distributing the material to the required width and loose thickness. When the required thickness is greater than 150 mm, the materials shall be spread in layers of equal thickness but no less than 100 mm.

Material shall be so handled, as to avoid segregation. If an aggregate spreader causes segregation in the material, or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, such spreader shall be removed and replaced by another box spreader. No “skin” patching will be permitted.

No hauling or placement of material will be permitted when, in the judgment of the Engineer, the weather or road conditions are such that hauling operations will cause cutting or rutting of the road surface or cause contamination of the wet mix macadam.

Immediately after placing, the wet mix macadam shall be compacted. Material shall be compacted to an average density of 100 % of MDD as determined according to AASHTO T 180 with no single value below 98 %. The field determination of density shall be made in accordance with AASHTO T 191. Percentage of density shall be adjusted to compensate for the weight and volume of aggregate larger than the aggregate used in the compaction control test where applicable.

Rolling shall be continued until the entire thickness of each layer is thoroughly and uniformly compacted to the density specified. Final rolling of the compacted wet mix macadam shall be done with a self-propelled roller. Rolling shall be accompanied by sufficient blading in a manner approved by the Engineer, to ensure a smooth surface, free from ruts or ridges and having the proper section and cross slope. When additional water is required, it shall be added in the amount and manner approved by the Engineer. Each layer of wet mix macadam shall be completely compacted by the Contractor and approved by the Engineer prior to the delivery of the materials for a succeeding layer.

Surface of the finished wet mix macadam will be tested with 5 m straight-edge by the Engineer at selected locations. Variation of the surface from the testing edge of the straight-edge between any 2 contacts with the surface shall at no point exceed 6 mm when placed on or parallel to the centerline or 6 mm when placed perpendicular to the centerline of the roadway. Wet mix macadam shall be compacted to the thickness and cross section as shown on the Contract plans and shall not vary by more than 5 mm from the required elevation. All humps and depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing the defective work or by adding new material, as directed by the Engineer.

If the material for the wet mix macadam is laid and compacted in more than 1 layer, the Contractor shall plan and coordinate the work in such a manner that the previously placed and compacted layers be allowed ample time for drying and the development of sufficient stability, before vehicles hauling materials for the succeeding layers or other heavy equipment are permitted on the wet mix macadam. Prior to placing the succeeding layers of materials, the top of the under-layer shall be made sufficiently moist to insure bond between the layers. Edges and edge slopes of the wet mix macadam shall be bladed or otherwise dressed to conform to the lines and dimensions shown on the Contract plans and present straight, neat and workmanlike lines and slopes as free of loose material as practicable.

Contractor shall also plan the work and handle the various operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If the Contractor delays placing of succeeding layers of wet mix macadam material to the extent that additional water must be applied to prevent raveling or excessive dripping, the application of such water shall be at the Contractor's expense and not be considered as the basis for a Claim for additional compensation. Water shall be applied at such times and in such quantities as directed by the Engineer. If after the wet mix macadam is compacted, any areas are above or below the proper grade and true elevations, such areas shall be loosened and after having had additional materials added or excess material removed, as the case may require, shall be reconstructed as described herein. If after the wet mix macadam is compacted any areas fail to meet the specified density and gradation requirements, such areas shall be loosened or removed as directed by the Engineer and reconstructed as described herein.

Following the construction of the wet mix macadam, the compacted layer shall be maintained by the Contractor at his expense. Contractor shall blade, broom, and otherwise maintains the wet mix macadam, keeping it free from raveling and other defects until such time as the bituminous prime or other surface is applied. Water shall be applied at such times and in such quantities as directed by the Engineer.

Engineer shall determine when the surface of the wet mix macadam is in the proper condition to permit the bituminous prime and/or surfacing to be applied. If the Contractor chooses not to apply the bituminous prime and/or surfacing at that time, he must continue to maintain the surface of the wet mix macadam, including the application of necessary water, at his expense until such time as the bituminous prime coat and/or surfacing is applied. Any additional expense incurred by the Contractor because of his failure to apply the bituminous prime coat and/or surfacing when so permitted by the Engineer will not be considered as the basis for a Claim for additional compensation.

3.2.4 Cement stabilized Subbase/Base

3.2.4.1 Description

Cement stabilized subbase/base shall consist of material aggregate uniformly mixed with cement and water, placed and compacted in one single layer on a prepared granular subbase in conformity with the Contract plans and this specifications or as established by the Engineer. Thickness and width of the cement stabilized subbase/ base layer shall be as shown on the Contract plans.

3.2.4.2 Materials

a. Mineral Aggregates

Mineral aggregates shall be either naturally occurring granular material or crushed stone or gravel or combination thereof and shall conform to requirements in Table 3-9.

Table 3-9: Aggregates for cement stabilized subbase/base

Test	Limits
Sampling ASTM D75	--
Liquid limit BS 1377- 2 : Test 4.5	25 % max.
Linear shrinkage (BS 1377-2 Method 6.5)	3 % max.
Plasticity index (BS 1377- 2 Test 5.4)	4 max.
Aggregate crushing value (BS 812-110:1990)	25 % max.
Water absorption (ASTM C128 / C127)	2.0 % max.
Flakiness index (BS 812-105-105.1)	30 max.
Elongation index (BS 812-105-105.2)	30 max.
Los Angeles abrasion loss (ASTM C-131 or C-535)	30 % max.
Soundness loss (ASTM C88) 5 cycles (magnesium sulfate)	12 % max
Organic Matter Content (BS 1377-3 Method 3)	0.2 % max.
Chloride Content (Acid Soluble) BS 812-117	1% max.
Sulfate Content (Acid Soluble) BS EN 1744-1	0.5% max.
Sand equivalent (ASTM D 2419).	45 min.

All of the combined aggregates retained on the Standard AASHTO 5 mm sieve shall have not more than 5 % of flat elongated pieces and, when tested in accordance with AASHTO T-11 and AASHTO T-27 shall conform to the grading limits (i.e. all in aggregate grading without cement) in Table 3-10.

Table 3-10: Combined aggregates grading limits

Sieve Size	Percent Passing
53 mm	100
37.5 mm	85 – 100
20 mm	65 – 90

Sieve Size	Percent Passing
10 mm	40 – 75
5 mm	25 – 45
2.36 mm	15 – 30
0.600 mm	8 – 18
0.075 mm	0 – 6

Coarse aggregate shall consist of crushed rock only, each particle shall have a minimum of two crushed face. Fine aggregate shall be crushed rock or naturally occurring material.

At least one sample from each stock pile every 1000 m^3 shall be taken for abrasion, sand equivalent, plasticity index and grading.

b. Cement

Cement shall be sulfate resisting and shall conform to the latest standard requirements of AASHTO M 85 for Type V. One 2 kg sample for quality test shall be taken from each 1,700 bags or equivalent.

c. Water

Water shall be clean and free from oil, alkali, vegetable matter, salt. Water shall be in sufficient supply for mixing and curing. 4-litre sample shall be obtained prior to use from each source and at least once a week during the production for quality.

d. Job Mix

At least 30 days prior to the date the Contractor intends to begin construction of the cement stabilized upper subbase, and after receiving approval of the aggregates from the Engineer and after the delivery on site of the cement specified for this work, the Contractor shall make written request for the approved job-mix formula from the Engineer. Job-mix formula will be prepared by the Contractor, and will be tested by the Engineer.

1. Mix Design

Job-mix formula shall combine the mineral aggregates with cement and water in such proportions as to produce a mixture conforming to the following requirements:

i. Trial dry mix design shall be done so as to achieve the grading requirement as specified above and to achieve maximum density (per ASTM D1557) from the coarse and fine aggregate combination (without cement), by different trials. Modified proctor test shall be done in 150 mm diameter mould to achieve maximum dry density (MDD) and optimum moisture content (OMC).

ii. 4 % cement by weight of total dry mix shall be added to the finalized gradation with maximum density.

iii. Final checking of the gradation shall be conducted after the addition of the cement. All in aggregate gradation shall be within design tolerance limit and the specification requirement.

iv. Cement (4% of total dry mix) plus varied amount of water (increment of +/- 1.0 % of OMC) shall be added to final 3 trial design mixes after accounting for water absorption by aggregates to ascertain the design optimum moisture content for workable laboratory mix. Mixing of the design mixes shall be done in a mixer of adequate capacity to make at least 9 unconfined compressive strength (UCS) samples (ASTM D1633). Mixing time for the trial mixes shall be 2 minutes in the mixer.

v. Consistency (workability) of the trial design mixes produced in laboratory shall be judged and recorded after every 30 minutes of mixing the cement and water. Design OMC shall be decided based on consistency observed after 60 minutes.

vi. UCS sample shall be prepared in a clean oiled/no sticky mould to avoid any damage to the UCS sample. Casting of the UCS sample shall be done immediately after 60 minutes for all the three trial design mixes in three layers and 56 uniformly distributed blows per layers. Adequate care shall be taken to make the top surface of the UCS sample free of irregularity. After casting, the UCS samples shall be kept in moist covered (with wet cloth) for 24 hours at 16 to 27 degree centigrade. After 24 hours the sample shall be taken out of the mould carefully and shall be put in water bath for curing for 3-day, 7 days and 28 day total duration at 16 to 27 degree centigrade.

2. Test Method

Following laboratory test procedure shall be carried out for satisfactory results. Sample shall be taken out of water bath one hour before the testing time. UCS sample shall be wiped around with damp cloth to make it saturated surface dry (SSD). UCS specimens prepared and cured as above shall be subjected to compressive strength tests in accordance with AASHTO T 22 (ASTM C39). A plywood/packing shall be kept on top and bottom of the sample for uniform application of loading. An approved calibrated universal testing machine (UTM) of adequate capacity shall be used to apply the loading. Maximum loading to failure shall be recorded and reported as failure load. Failure pattern shall be recorded and calculation of the unconfined compressive strength shall be done by dividing the failure load to the average plan area of the sample. The density and strength shall be as in Table 3-11.

Table 3-11: Minimum density and strength requirements

MDD as per BS 1377-4 test 3.7	2.1 mg/m^3 min.
Unconfined compression test at 7 days	6.0 ± 1 MPa

Strengths shall be obtained on the average of at least three specimens and individual test results moving more than 15 % from the average shall be discarded.

3. Tolerances

All production mixture shall conform to the job-mix approved by the Engineer, within ranges of tolerances as follows:

Aggregate passing 4.75 mm sieve or larger	+/- 5 %
Aggregate passing 2.00 mm sieve or larger	+/- 2 %
Cement	+/- 0.2 %
Water	+/- 1 %
Unconfined compressive strength	+/- 20 %

Each day the Engineer will take as many samples of the materials and mixtures as he considers necessary for checking the required characteristics of the mixtures.

At least one set of 6 specimens shall be prepared during the placing operations, every 500 linear metres of furnished mixture to check the required strengths of the mixture.

When unsatisfactory results or changed conditions make it necessary, the Engineer may require that a new job-mix be prepared.

Should a change in material be encountered or should a change in a source of material be made, a new job-mix formula shall be submitted and approved before the mixture containing the new material is delivered. Job materials will be rejected if they are found not to have the characteristics required by the established job-mix formula.

Sampling and testing shall be performed by the Contractor at his expense, under the observation of the Engineer.

Proportion required for the cement stabilized subbase/ base shall be obtained by tests on the mixture prepared in accordance with the selected job-mix formula and on samples taken at the spreading plant equipment during the works.

e. Plant and Equipment

Plant and equipment shall be according to the type and number outline in the Contractor's detailed programme of works, as approved by the Engineer. All equipment, tools, machinery and plants must be maintained in a satisfactory working condition.

3.2.4.3 Construction Requirements

Mixing of the aggregate, cement and water shall be accomplished by the plant-mixed method only.

a. Preparation of Granular Subbase

Top surface of granular subbase ready to receive cement stabilized upper subbase, (immediately prior to spreading) shall conform to the compaction and elevation tolerance otherwise specified, and shall be free of loose or extraneous material.

In hot weather, the top surface of granular subbase shall be moistened before spreading of the cement stabilized upper subbase, in order to prevent evaporation.

b. General Requirements of Plant Mixed Method

Aggregates and cement shall be proportioned and mixed in accordance with the following:

Plant-mixed cement stabilized subbase/ base shall be mixed at a central mixing plant by either batch type mixing using revolving blade or rotary drum mixers or by continuous type mixing as approved of the Contractor. Aggregates and cement may be proportioned either by weight or by volume. Plant shall be calibrated to produce the design mix proportion to the satisfaction of Engineer.

In all plants, the water shall be proportioned by weight or volume and there shall be means by which the Engineer may readily verify the amount of water per batch or the rate of flow for continuous mixing. Time of the addition of water or the points at which it is introduced into the mixer shall be as approved by the Engineer.

Moisture content of the completed mixture shall be at least the optimum moisture content plus or minus one percentage point at the point of delivery to the paving work site.

In all the plants, cement shall be added in such a manner that it is uniformly distributed throughout the aggregates during the mixing operation.

Safe and convenient facilities shall be provided for sampling cement in the supply line to the weight hopper or pugmill.

Charge in a batch mixer, or the rate of feed to continuous mixer, shall not exceed that which will permit complete mixing of all the material. Dead areas in the mixer, in which the material does not move or is not sufficiently agitated, shall be corrected.

Cement content of the completed mixture of cement stabilized upper subbase, after it has been spread on the granular subbase and prior to initial compaction, shall meet the specified requirements when sampled and tested.

Cement feeder and the aggregate feeders shall be equipped with devices by which the rate of feed can be determined while the plant is in full operation.

c. Spreading Cement Stabilized Subbase/Base

Immediately prior to depositing plant-mixed cement stabilized subbase/base the area to be covered shall be moistened and kept moist, but not excessively wet.

Mixed materials shall be spread in widths of not less than 2 lanes, either by one spreader or by several spreaders operating in staggered position across the granular subbase, unless otherwise directed by the Engineer.

If less than 2 lanes are to be spread, not more than 2 hours shall elapse between the time of placing the material in adjacent lanes to result in a 2-lane width. However, if traffic conditions preclude placement of cement stabilised subbase/base in adjacent lanes within hours, the Engineer may authorize such longer time as may be necessary.

Longitudinal construction joints shall fall within +/-300 mm of lane lines.

Cement stabilized subbase/base placed on areas inaccessible to mechanical spreading equipment may be spread in one layer by methods approved by the Engineer. After spreading, the material shall be thoroughly compacted to the required line grades, and cross section by means of pneumatic tampers or with other compacting equipment which consistently obtains the degree of compaction required.

In addition, spreading of cement stabilized subbase/base shall conform to the directions of the Engineer.

Use of motor graders will not be permitted during the spreading and compacting operating. Motor graders may be used to trim the edges and surface of the cement stabilized subbase/base after compaction in order to finish the subbase within the tolerances specified.

Mixture shall be spread in one operation with a self-propelled mechanical spreader ready for compaction without further shaping. Equipment not propelled by the unloading vehicle will be considered self-propelled. Spreader shall be provided with a screed that strikes off and distributes the material to the full width being spread and to the surface tolerances specified. Screed shall be adjustable to produce the required cross section. Screed action includes any cutting, crowding, or other practical motion that produces a finished surface texture of uniform appearance.

d. Compacting

Compacting equipment shall produce the required compaction within the operation time limit. Cement stabilized subbase/base shall be spread and compacted in only one layer according to the provisions specified herein. Initial compaction shall follow the spreading operating immediately and shall have at least one complete full coverage of the stabilised material.

When the finished surface after initial compaction is outside the tolerance specified hereinafter, all high spots shall be trimmed off to within the specified tolerances. Filling of low areas by drifting or hauling of trimmed material is prohibited.

Excess material may be placed as aggregate for shoulder construction or when directed by the Engineer.

Excess material may also be used at other locations in the work, provided said excess material complies with applicable specification requirements or shall be otherwise disposed of as permitted by the Engineer.

Following such trimming, the finished surface shall be thoroughly compacted so that the entire layer of cement stabilized subbase/base conforms to the compaction requirements hereinafter specified. Final compaction shall be accomplished in such a manner that no loose material remains on the surface and all tear marks are eliminated.

Relative compaction of cement stabilized subbase/base shall not be less than 98 % of the reference design maximum dry density for the specified mixture.

Areas of the finished cement stabilized subbase/base which are of less thickness than as stated above shall be removed and replaced with fresh mixture which complies with the requirements of these specifications, all at the expense of the Contractor.

Surface shall be kept moist at all times for at least 7days or until such time as directed by the Engineer.

e. Operation Time Requirements

Not more than 2 hours shall elapse between the time water is added to the aggregate and cement, and the time of completion of initial compaction prior to trimming. Not more than 2½ hours shall elapse between the time water is added to the aggregate and cement and the time completion of final compaction after trimming.

f. Construction Joints

At the end of each day's work and when cement stabilized subbase/base operations are delayed or stopped for more than 2 hours a construction joint shall be made in thoroughly compacted material, normal to the centre line of the roadbed, with a vertical face. Additional mixture shall not be placed until the construction joint has been approved by the Engineer.

Where cement stabilized subbase/base has been finally compacted more than one hour, longitudinal joints shall be constructed by cutting vertically into the existing edge. Material cut away may be disposed of as specified for excess material. Face of the cut joints shall be moistened in advance of placing the adjacent layer.

g. Curing

Completed cement stabilized subbase/base shall be covered with wet hessian cloth and watered so as to keep moist at all time for at least 7 days or for the duration as directed by Engineer. Hessian cloth shall be applied on the same day that final compaction is performed and as soon after said compaction as is practicable.

No equipment or traffic will be permitted on the completed cement stabilized subbase/base during the first 7 days unless otherwise permitted by the Engineer.

h. Surface Tolerances

At final compaction the finished surface of the cement stabilized upper subbase shall be uniform and shall not deviate at any point more than 6 mm from the bottom of 3 m straightedge laid in any direction.

Top of the layer shall not vary from the required elevation by more than 6 mm. All bumps and depressions exceeding the specified tolerance shall be corrected by removing the defective work and replacing it with new material as directed by the Engineer, all at the expense of the Contractor.

i. Thickness Requirements

Thickness of the completed cement stabilized subbase/base shall not vary more than 10 mm from the thickness shown on the Contract plans. Sufficient measurements of thickness shall be taken before and after compacting to establish the relationship between the thickness of the un-compacted material and the completed work. Thickness shall be controlled first by measurements taken of the un-compacted material. When the measurements indicate that an area will not be within the allowable tolerance for the completed work, the un-compacted area shall be corrected while the material is still in workable condition.

Immediately after final compaction the thickness shall be measured at one or more points in each 300 m of the laid lane width of stabilised subbase/base layer. Measurement shall be made by means of test holes or other approved methods. Points for measurement shall be selected by the Engineer at random locations within each 300 m sections of the laid lane width in such a manner as to avoid any regular pattern. Various points on the cross section shall be covered.

Whenever a measurement indicates a variation from the thickness shown on the Contract plans of more than the allowable tolerance, additional measurements shall be taken at intervals of approximately 50 m until the measurements indicate the thickness is within the allowable tolerance. Any area not within the allowable tolerance shall be corrected by removing the defective work and replacing it with new material as directed by the Engineer all at the expense of the Contractor. Cutting of test holes and refilling with materials properly compacted shall be done by the Contractor as observed and approved by the Engineer.

j. Compaction Control and Testing

Compaction of the cement stabilized subbase/base shall be controlled as the work progresses by means of field density tests.

Field density tests shall be carried out immediately after compaction and before hardening of the material in accordance with AASHTO T 191 or AASHTO T 205 or as directed by the Engineer. Frequency of testing shall be 1 test every 100 lin. m of laid lane width. Field density of the compacted cement stabilized subbase/base shall not be less than 98% of the reference design maximum dry density.

k. Weather Limitation

Cement stabilized subbase/base shall not be mixed or placed when the atmospheric temperature is over 30º C or when the weather is rainy.

Temperature requirements may be waived but only when so directed by the Engineer. When temperature is higher than 30º C, particular care shall be exercised in order to minimize water evaporation from the mixture.

In this case a test section shall be executed at the high temperature foreseen during the working period in order to evaluate the water content necessary to compensate evaporation and to establish actual setting time.

According to such test section the Engineer may order pre-moistening of aggregates before cement mixing and watering of the granular subbase finished surface level.

However particular attention shall be paid to prevent shrinkage due to excess of water. Contractor shall perform all tests required by the Engineer on said section at his own expenses.

Engineer will give approval of the test section not before 7 days from the completion of curing.

l. Trial Lengths for Cement Stabilized Upper Subbase

Prior to the commencement of the cement stabilized subbase/base operations, the Contractor shall construct trial lengths (not to exceed 250 m) to demonstrate adequacy plant and equipment and competence in performance of entire operation of production and laying and compliance to the specifications.

Design mix used in the trials shall be those approved for use as cement stabilized subbase/base and the equipment used shall be that according to the Contractor's approved detailed programme of work. Trial lengths shall not form part of the permanent works but may be permitted in the construction of temporary detours of sufficient length.

Contractor may proceed with the cement stabilized subbase/base work only after the methods and procedures established in the compaction trials have been approved by the Engineer.

3.2.5 Asphalt Treated Base

3.2.5.1 Description

Asphalt treated subbase and base courses shall be composed of mineral aggregates, mineral filler and bitumen combined in an asphalt mixing plant. Several mineral aggregates may be sized and combined in such proportions that the resulting blend is well-graded and is within the specified gradation requirements. Incorporation of mineral filler and/or other ingredients shall be in such amounts as found appropriate to meet the required criteria and test limits specified and as instructed by the Engineer.

Contractor shall furnish, place and compact a course of bituminous stabilized granular material composed of mineral aggregates, mineral filler and bitumen combined in an asphalt mixing plant.

Placement of the course shall be in compliance with the lines, grades, thicknesses and typical sections indicated on the Contract plans, as specified herein or as directed by the Engineer.

3.2.5.2 Materials

Unless otherwise indicated on the Contract plans, specified in the particular specifications, or directed by the Engineer, all sand asphalt base shall comply with the requirements of asphalt treated Type B as specified in Sub-article a of Article 3.2.5.2.

Materials used in asphalt treated subbase and base courses shall meet the requirements of the following sub paragraphs of paragraph 4 of sub-article b of Article 3.3.2.5:

- Fine Aggregate
- Coarse Aggregate
- Commercial Mineral Filler
- Asphalt Binder
- Hydrated Lime

a. Types of Asphalt Treated Subbase and Base Courses

Types of asphalt treated shall be as designated on the Contract plans or in the bills of quantities and shall comply with the compositions as described below and as shown in Table 3-12.

1. Asphalt treated type A shall consist of natural or crushed mineral, aggregate, hydrated lime, commercial mineral filler and bitumen combined to meet the specification requirements, and shall be constructed to the thickness as indicated on the Contract plans. A minimum of 1.5 % hydrated lime by weight of total mineral aggregates shall be added in accordance with Sub-article a of Article 3.3.3.1.
2. Asphalt treated type B shall consist of crushed coarse aggregate, natural and/or crushed fine aggregate, hydrated lime, commercial mineral filler and bitumen combined as otherwise specified and shall be constructed to the thickness as indicated on the Contract plans. A minimum of 1.5 % hydrated lime by weight of total mineral aggregate shall be added in accordance with Sub-article a of Article 3.3.3.1. Fine aggregate portion shall consist of a minimum of 25 % crushed sand.
3. Asphalt treated type C shall consist of natural or crushed mineral aggregates, commercial mineral filler and bitumen combined to meet the requirements as otherwise specified and shall be constructed to the thickness shown on the Contract plans.

Commercial mineral filler shall be used in all types of Asphalt treated mixes as necessary to meet gradation and design criteria.

Minimum quantity of hydrated lime specified for type A and type B asphalt treated shall be increased as necessary to meet design criteria.

b. Design Criteria

Laboratory test specimens of the asphalt treated mix shall be prepared and tested in accordance with the procedures set forth for the Marshall method of mix design. Mix designs shall be checked and approved by the Engineer prior to use.

Test requirements and criteria for asphalt treated mixes prepared as otherwise specified and as indicated in Table 3-12.

Table 3-12: Asphalt treated mixes composition including hydrated lime & commercial mineral filler as required

Standard sieve size	Percent passing by weight		
	Type A	Type B	Type C
25.0 mm	100		100
19.0 mm	95-100		95-100
9.5 mm	85-100	100	85-100
4.75 mm	-	85-100	-
2.36 mm	58-100	70-85	58-100
600 µm	22-74	38-56	22-74
300 µm	10-50	27-43	10-50
75 µm	4-12	4-12	4-12
Asphalt Binder percent by weight of total mineral aggregate	5.0 - 8.0	5.0 - 8.0	5.0 - 8.0

Table 3-13: Design criteria for asphalt treated

Test	Type A Min. - Max.	Type B Min. - Max.	Type C Min. - Max.
Marshall specimens (ASTM D1559)			
Number of compaction blows, each end of specimen	50	50	50
Stability, kg	200	175	150
Flow, 0.25 mm	8 - 20	8 - 20	8 - 20
Air voids, %	3 - 18	3 - 18	3 - 18
Immersion compression specimens (AASHTO T165)			
Index of retained strength	50	60	No requirement

c. Job mix Formula and Allowable Tolerances

All the provisions of Paragraph 2 of Sub-article b of Article 3.3.2.5 shall apply, except as specified below for the maximum permissible ranges of tolerances:

- Passing sieves 4.75 mm and larger ± 5.0 %
- Passing sieves 2.36 mm, 600 µm and 300 µm ± 7.0 %
- Passing sieve 75 µm ± 2.0 %
- Asphalt Binder ± 0.4 %

d. Sampling and Testing of Asphalt Treated

Sampling and testing of asphalt treated shall be in accordance with the procedures set forth in Paragraph 3 of Sub- article b of Article 3.3.2.5.

3.2.5.3 Construction Requirements

Contractor shall comply with all of the provisions of Section 3.3.3 with respect to asphalt treated, subject to the following modifications and additions:

1. Preparation and handling of mineral aggregates: Moisture content of the heated and dried aggregate shall not exceed 1.0 %. If the Engineer so requires, the angle of the drier shall be reduced to such a position as to hold material in the drier for a longer period of time for optimum condition of heating and drying.
2. Proportioning and mixing: Heated ingredients shall be combined in such a manner as to produce a mixture which when emptied from the mixer shall have a temperature of between 107° C and 149° C. Temperature of the aggregate immediately prior to mixing shall be within ± 7.0°C of the temperature of the Asphalt Binder and the temperature of the aggregate and asphalt prior to mixing shall be approximately that of the completed mix as defined in the job mix formula approved by the Engineer. Mix temperature shall be within the allowable tolerance set out in the job mix formula when emptied from the mixer but in no case shall exceed 149° C. Filler shall be proportioned into the mixer with the aggregate in the quantities specified in the job mix formula, all as approved by the Engineer.
3. Delivery of the mix: Mix shall be delivered to the job site at a temperature between 80° C and 149° C and shall in all cases comply with the temperature and with the permissible variation thereof set out in the job mix formula for mix temperature on delivery to the job site.
4. Spreading of the mix: Asphalt treated subbase and base courses shall be laid in maximum 50 mm layers. Thinner layers shall be used if excessive shoving, etc., occurs. Any additional layers shall be placed as soon as practicable after the first layer has been executed to the required grade, line, cross-section and density; finished, rolled and cooled; and after the tack coat, if required, has been applied in accordance with requirements of these specifications.
5. Compaction of the mix: Mix temperature shall not be allowed to drop below 74° C prior to initial breakdown rolling. Tapered edges against which no additional layer is to be placed, shall be carefully rolled along the entire length of the edges.

a. Testing and Acceptance of Asphalt Treated Subbase and Base Courses

All of the provisions of Paragraph 3 of Sub-article b of Article 3.3.2.5 shall be applicable to asphalt treated subject to the modifications and additions included herein.

1. Requirements for compaction of asphalt treated: Minimum degree of compaction for asphalt treated mixes shall be 95 % of the laboratory Marshall specimen prepared in accordance with the job mix formula.
2. Thickness requirements:
    i. Total constructed thickness of asphalt treated subbase or base course used for new construction, reconstruction or roadway widening shall not vary more than 8 mm from the total thickness shown on the Contract plans.
    ii. In the event the constructed thickness of the asphalt treated subbase or base course is 8 mm more than the total thickness shown on the Contract plans, the area shall be corrected as directed by the Engineer by removing the excess material in an approved manner to provide the required thickness.
    iii. In the event the constructed thickness of the asphalt treated subbase or base course is 8 mm less than the total thickness indicated on the Contract plans, the Contractor shall provide additional material in the next course (base course or wearing course). In no case shall the deficiency of the subbase or base course exceed 25 mm.
    iv. Asphalt treated subbase or base course shall be constructed to the grade level as shown on the Contract plans, as specified and as approved by the Engineer.

v. In no case shall the total sum thickness of the subbase course, base course and wearing course be less than the total sum thickness of all courses as indicated on the Contract plans.

3. Requirements for evenness of surface and grade level: Final surfaces of the subbase or base courses shall be tested by means of a 5 m long straight edge; and no rises or depressions in excess of 10 mm shall appear on the surface; otherwise such areas shall be stripped, corrected and recompacted to comply with all specification requirements and as approved by the Engineer. Further, the finished surface of the subbase or base course shall be constructed to within 12 mm of the grade levels shown on the Contract plans.

b. Equipment Used for Asphalt Treated Subbase and Base Courses

Provisions of 3.3.3.1, of shall be adhered to, subject to the following modifications and additions:

1. Screens for asphalt mixing plants: Asphalt mixing plant shall be equipped with screens suitable for screening the aggregate into sizes such that they may be recombined into a gradation meeting the requirements of the job mix formula. However, if the nature of the aggregate, in the opinion of the Engineer, is such that no screening is required by reason of its satisfactory natural gradation, then the plant may be equipped with a scalping screen of a size suitable to remove oversize aggregates and other deleterious material.
2. Rollers: Rolling equipment shall consist of steel-wheeled rollers and pneumatic-tired rollers as specified in Sub-article c of Article 3.3.3.1. A minimum of three rollers shall be required at all times: one self-propelled pneumatic-tired and two steel-wheeled rollers. As many additional rollers shall be used as necessary to provide the specified density and surface characteristics in any orderly, efficient and continuous manner. Tandem steel-wheeled rollers shall be of such weight that, under working conditions, will develop contact pressure adequate to obtain the required density.
3. Unacceptable equipment: Engineer will have the right to stop the use of any equipment or plant which he deems to be inferior to the quality required and to instruct the removal of such equipment and to have it replaced by suitable equipment or to alter the method of operation at any time. Contractor shall immediately comply with such instructions without being entitled to any indemnities or extensions as a result of such instructions. Contractor shall not be allowed to use any equipment or plant before obtaining the approval of the Engineer, and the Contractor shall undertake to follow sound technical methods of operation and to engage skilled and trained operators, mechanics and labor to carry out the works. Engineer will have the right to expel any operators, mechanics or labor and to instruct suitable replacement thereof at any time he deems such action is necessary.

3.2.6 Lime Stabilized Subbase/Base

3.2.6.1 Description

Lime stabilized subbase/base shall consist of material aggregate uniformly mixed with lime and water, placed and compacted in one single layer on a prepared granular subbase in conformity with the Contract plans and this specifications or as established by the Engineer. Thickness and width of the lime stabilized subbase/ base layer shall be as shown on the Contract plans.

3.2.6.2 Materials

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer of the proposed material sources and of changes to material sources. Obtain verification from the Engineer that the specification requirements are met before using the sources. The Engineer may sample and test project materials at any time before compaction.

a. Lime

Furnish lime that meets the requirements of AASHTO M 216 for hydrated lime, or AASHTO T 27 and AASHTO T 219 for quicklime. When furnishing quicklime, provide it in bulk.

b. Aggregate Material

Furnish aggregate material that meets the requirements “granular base or subbase course” for the type and grade shown on the plans, before the addition of lime. At least one sample from each stock pile every 1000 m3 shall be taken for abrasion, sand equivalent, plasticity index and grading

c. Water

Water shall be clean and free from oil, alkali, vegetable matter, salt. Water shall be in sufficient supply for mixing and curing. 4-litre sample shall be obtained prior to use from each source and at least once a week during the production for quality.

d. Asphalt emulsion

When asphalt emulsion is permitted for curing purposes, furnish materials that meet the requirements Bituminous Prime Coat, as shown on the plans or as directed.

e. Job Mix

At least 30 days prior to the date the Contractor intends to begin construction of the lime stabilized base/subbase, and after receiving approval of the aggregates from the Engineer and after the delivery on site of the lime specified for this work, the Contractor shall make written request for the approved job-mix formula from the Engineer. Job-mix formula will be prepared by the Contractor, and will be tested by the Engineer.

1. Mix Design

The steps for lime stabilization mix design are:

- Add the appropriate target percentages of lime (generally starting with 1 percent by weight of the entire mixture and increasing in 1 percent increments to 4 percent),
- Determine moisture density relationships for each aggregate-lime blend following either AASHTO T-99 or AASHTO T-180.
- Determine CBR (AASHTO T193) of the lime-aggregate blends following curing for 7-days at 40°C. CBR of the blind material shall not be less than 60% @ 98% MDD.

f. Storage and Handling of Materials

Store quicklime and dry hydrated lime in closed, weatherproof containers.

3.2.6.3 Equipment

Equipment shall be according to the type and number outline in the Contractor’s detailed programme of works, as approved by the Engineer. All equipment, tools, and machinery must be maintained in a satisfactory working condition.

If the lime will be Road mixed, pulverization equipment should be used. Otherwise mixing plant and spreader equipment are used for plant mixed.

a. Pulverization Equipment

Provide pulverization equipment that:

- cuts and pulverizes material uniformly to the proper depth with cutters that plane to a uniform surface over the entire width of the cut,
- provides a visible indication of the depth of cut at all times, and

- Uniformly mixes the materials.

b. Mixing Plant

Provide a stationary pugmill that uniformly mixes lime, water, and base material in the specified proportions. Obtain approval before providing weigh-batch or continuous mixers. Equip plants with automatic proportioning and metering devices.

c. Spreader Equipment

When shown on the plans, provide equipment that will spread the lime-treated mixture in a uniform layer in 1 pass. When shown on the plans, equip spreaders with electronic grade controls.

3.2.6.4 Construction

Construct each layer uniformly, free of loose or segregated areas, and with the required density and moisture content. Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans or as directed.

a. Preparation of Subgrade

Top surface of subgrade ready to receive lime stabilized subbase, (immediately prior to spreading) shall conform to the compaction and elevation tolerance otherwise specified, and shall be free of loose or extraneous material.

In hot weather, the top surface of subgrade shall be moistened before spreading of the lime stabilized subbase, in order to prevent evaporation.

b. Site Mixed

1. Pulverization

Pulverize or scarify existing material after shaping so that 100% passes a 37.5 mm sieve. If the material cannot be uniformly processed to the required depth in a single pass, excavate and windrow the material to expose a secondary grade to achieve processing to plan depth.

2. Application of Lime

Uniformly apply lime using dry or slurry placement as shown on the plans or as directed. Add lime at the percentage determined “Mix Design.” Apply lime only on an area where mixing can be completed during the same working day.

Minimize dust and scattering of lime by wind. Do not apply lime when wind conditions, in the opinion of the Engineer, cause blowing lime to become dangerous to traffic or objectionable to adjacent property owners. When pebble grade quicklime is placed dry, mix the material and lime thoroughly at the time of lime application. Use of quicklime can be dangerous. Inform users of the recommended precautions for handling and storage.

Before applying lime, bring the prepared roadway to approximately optimum moisture content. Distribute the required quantity of hydrated lime or pebble grade quicklime with approved equipment. Only hydrated lime may be distributed by bag. Do not use a motor grader to spread hydrated lime.

3. Mixing

Begin mixing within 6 hours of application of lime. Hydrated lime exposed to the open air for 6 hours or more between application and mixing will not be acceptable.

Thoroughly mix the material and lime using approved equipment. Allow the mixture to mellow for 1 to 4 days, as directed. When pebble grade quicklime is used, allow the mixture to mellow for 2 to 4 days, as directed. Sprinkle the treated materials during the mixing and mellowing operation, as directed, to achieve adequate hydration and proper moisture content. After mellowing, resume mixing until a homogeneous, friable mixture is obtained.

c. Plant Mixed

a. Mixing

Thoroughly mix materials in the proportions designated on the mix design, in a plant that meets the requirements “Mixing Plant.” Mix at optimum moisture content, unless otherwise directed, until a homogeneous mixture is obtained.

b. Placing

Place lime-treated base on a subgrade or subbase prepared in accordance with details shown on the plans. Bring the prepared roadway to the moisture content directed. Haul lime-treated base to the roadway in clean trucks and begin placement immediately. Spread and shape in a uniform layer with an approved spreader. Construct individual layers to the thickness shown on the plans, the same day as delivered, unless otherwise approved. Do not place lifts exceeding a compacted depth of 20 cm. Correct or replace segregated areas as directed.

d. Compaction

Compact the mixture using density control, unless otherwise shown on the plans. Multiple lifts are permitted when shown on the plans or approved. Bring each layer to the moisture content directed. Determine the moisture content of the mixture at the beginning and during compaction.

Begin rolling longitudinally at the sides and proceed toward the center, overlapping on successive trips by at least one-half the width of the roller unit. Operate rollers at a speed between 3 and 10 KMPH, as directed.

Rework, recompact, and refinish material that fails to meet or that loses required moisture, density, stability, or finish before the next course is placed or the project is accepted.

e. Reworking a Section

When a section is reworked within 72 hours after completion of compaction, rework the section to provide the required density. When a section is reworked more than 72 hr. after completion of compaction, add additional lime at 25% of the percentage determined “Mix Design.” Reworking includes loosening, adding material or removing unacceptable material if necessary, mixing as directed, compacting, and finishing. When density control is specified, determine a new maximum density of the reworked material and compact.

f. Construction joints

Construct vertical joints between segmented areas of lime-treated base. The vertical face may be created by using a header or by cutting back the face to approximately vertical. Place successive base courses using the same methods as the first course. Offset construction joints by at least 15 cm.

g. Curing

Cure for 5 days with wet hessian cloth and watered so as to keep moist at all time or by applying an asphalt emulsion at a rate of 0.2 to 0.50 kg/m2 as directed. Maintain moisture during curing.

No equipment or traffic will be permitted on the completed cement stabilized subbase/base during the first 7 days unless otherwise permitted by the Engineer

h. Surface Tolerances

At final compaction the finished surface of the lime stabilized base/subbase shall be uniform and shall not deviate at any point more than 6 mm from the bottom of 3 m straightedge laid in any direction.

Top of the layer shall not vary from the required elevation by more than 6 mm. All bumps and depressions exceeding the specified tolerance shall be corrected by removing the defective work and replacing it with new material as directed by the Engineer, all at the expense of the Contractor.

i. Thickness Requirement

Thickness of the completed lime treated subbase/base shall not vary more than 10 mm from the thickness shown on the Contract plans. Sufficient measurements of thickness shall be taken before and after compacting to establish the relationship between the thickness of the un-compacted material and the completed work. Thickness shall be controlled first by measurements taken of the un-compacted material. When the measurements indicate that an area will not be within the allowable tolerance for the completed work, the un-compacted area shall be corrected while the material is still in workable condition.

Immediately after final compaction the thickness shall be measured at one or more points in each 300 m of the laid lane width of stabilized subbase/base layer. Measurement shall be made by means of test holes or other approved methods. Points for measurement shall be selected by the Engineer at random locations within each 300 m sections of the laid lane width in such a manner as to avoid any regular pattern. Various points on the cross section shall be covered.

Whenever a measurement indicates a variation from the thickness shown on the Contract plans of more than the allowable tolerance, additional measurements shall be taken at intervals of approximately 50 m until the measurements indicate the thickness is within the allowable tolerance. Any area not within the allowable tolerance shall be corrected by removing the defective work and replacing it with new material as directed by the Engineer all at the expense of the Contractor. Cutting of test holes and refilling with materials properly compacted shall be done by the Contractor as observed and approved by the Engineer.

j. Compaction Control and Testing

Compaction of the cement stabilized subbase/base shall be controlled as the work progresses by means of field density tests.

Field density tests shall be carried out immediately after compaction and before hardening of the material in accordance with AASHTO T 191(1) or AASHTO T 205(2) or as directed by the Engineer. Frequency of testing shall be 1 test every 100 lin. m of laid lane width. Field density of the compacted cement stabilized subbase/base shall not be less than 98% of the reference design maximum dry density.

k. Weather Limitation

Lime stabilized subbase/base shall not be mixed or placed when the atmospheric temperature is over 30° C or when the weather is rainy.

Temperature requirements may be waived but only when so directed by the Engineer. When temperature is higher than 30° C, particular care shall be exercised in order to minimize water evaporation from the mixture.

In this case a test section shall be executed at the high temperature foreseen during the working period in order to evaluate the water content necessary to compensate evaporation and to establish actual setting time.

According to such test section the Engineer may order pre-moistening of aggregates before cement mixing and watering of the granular subbase finished surface level.

Engineer will give approval of the test section not before 7 days from the completion of curing.

3.2.7 Recycled Crushed Aggregate Base Course

3.2.7.1 Description

This specification has been prepared to meet the requirements of the order issued by the Executive Council of the Emirate of Abu Dhabi, dated 26th of July 2010, under number BT9G25/2010 requiring the mandatory use (subject to availability) of a minimum of 40% aggregate (by volume) of recycled construction and demolition waste in roads projects, as well as any other infrastructure projects throughout the Emirate of Abu Dhabi.

The works described below shall consist of furnishing and placing one (1) or more layers of recycled crushed aggregate (RCA), including additives if required on a prepared surface in accordance with the specifications and in conformity with the lines, grades, thicknesses and typical cross-sections shown on the plans or established by the Engineer.

3.2.7.2 Materials

Materials shall conform to the requirements for the class of “Recycled Crushed Aggregate Base Course” specified on the plans or directed by the Engineer. All RCA for base course shall consist of crushed rock, crushed concrete stone fragments including sand.

a. Components

Crushed concrete aggregates shall consist of clean, hard, durable, angular fragments of rock, concrete and sand fragments of uniform quality complying with the general requirements specified in Section 3.2.2 and its use limited as stated in Section 4.3.10 of Chapter 4, Concrete Works, of these Standard Specifications.

The use of crusher fines passing the 4.75 sieve which are not produced from crushing concrete shall be subject to approval in writing by the Superintendent to the proposed source and nature of these materials and the proposed amounts to be added.

b. Physical requirements

All base course RCA shall conform to the physical requirements described, for each Class of Aggregate.

Foreign material in the fraction retained on the 4.75 sieve shall not exceed the percentages by mass specified:

Table 3-14: RCA Base Physical requirements

Foreign Material Type	%
High density materials such as glass, brick and asphalt	10
Metallic items such as steel, aluminum and iron	1
Low density materials such as plastic, rubber, plaster, clay lumps and other liable material	1
Wood and other vegetable or decomposable matter	0.2

c. Grading requirements

Course materials for aggregate base course shall conform to the following requirements:

Table 3-15: RCA Base testing requirements

Properties	Value
50mm	100
37.5mm	95-100

Properties	Value
19mm	70-92
9.5mm	50-70
4.75mm	35-55
0.60mm	12-25
0.075mm	0-8
Loss by Abrasion Test (AASHTO T 96)	40% maximum
Liquid Limit (AASHTO T89)	25 maximum
Plasticity Index (AASHTO T 90)	4 maximum
Sand Equivalent (AASHTO T 176)	35 minimum
CBR on remolded sample (BS 1377 Test 16) after 4 days soaking	120% minimum
Soundness (Magnesium) – AASHTO T104	15% maximum
Flakiness – BS 812	35% maximum
Elongation – BS 812	35% maximum
Sulfate Content – BS 812	2% maximum
Chloride Content – BS 812	2% maximum

3.2.7.3 Acceptance

When the stationary plant method is used, the aggregate will be accepted immediately following mixing, based on periodic samples taken from the pug mill output. When a road mix method is used, the aggregate will be accepted after necessary blending and before laying, based on samples taken from the combined windrow for each layer. When the aggregate is a total aggregate, it may be accepted at the crusher. Acceptance of the material by the Engineer does not constitute acceptance of the base course, only that the material is approved for use in the base course.

3.2.7.4 Equipment

Equipment shall be according to the type and number outlined in the Contractor's detailed Programme of work as approved by the Engineer.

3.2.7.5 Construction requirement

a. Groundwater levels and protection

The contractor must establish the high water table levels (HWT) along the length of the road, relative to the accepted National benchmark (New Abu Dhabi Datum – NADD) should the base of the proposed road be within 1 meter of the HWT, an impermeable barrier will be required to be installed to prevent groundwater coming in contact with the RCA.

b. Sub-grade preparation

Unless other sub-grade preparation is called for on the plans or appears as a pay item in the bill of quantities, the contractor shall, as part of the work and prior to the delivery of materials for the base course, prepare the roadbed surface by sprinkling blading, rolling and lightly scarifying where necessary, until the proper crown is obtained. However, in the process of shaping the roadbed, the originally compacting crust or top portion of the roadbed shall be disturbed as little as possible. When completed and ready for base course construction the roadbed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

c. Method of construction

1. Handling of RCA

Handling of RCA, including the loading of trucks and stockpiling, shall be effected in such a manner as to minimize segregation.

2. Combining aggregates and water

Aggregates for base course shall be combined into a uniform mixture and water added only in a central mixing plant before final placement of the material. Mixing and watering by windows will not be permitted. When binder is to be added, it shall be combined with the aggregate base by thoroughly mixing binder and aggregate base in the central mixing plant.

The moisture added to the aggregates shall be that required, as designated by the Engineer to obtain the specified density thereby preparing an aggregate completely ready for compaction after spreading on the roadbed. In no case will be wetting of aggregates in stockpiles or trucks be permitted.

3. Spreading and combining aggregates

Unless otherwise specified, aggregate for base course shall be delivered to the roadbed as an uniform mixture and shall be placed on the existing roadway, prepared sub-base or prepared sub-grade, as the case maybe in an uniform later or layers not exceeding fifteen (15) centimeters in compacted depth, including any binder that is to be blended on the road. Spreading shall be done by means of approved self-propelled stone box spreaders, distributing the material to the required width and loose thickness. When the required base thickness is greater than fifteen (15) centimeters, the materials shall be spread in layers of equal thickness.

The material shall be so handled as to avoid segregation, if an aggregate spreader causes segregation in the material, or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

No hauling or placement of material will be permitted when, in the judgment of the Engineer, the weather or road conditions are such as hauling operations will cause cutting or rutting of the road surface or cause contamination of the base course material.

4. Compaction

If directed by the Engineer, prior to starting the aggregate base operation, the contractor shall construct the trial lengths in accordance with Section 3.2.1 and Sub-article e of Article 3.2.8.8.

RCA shall be laid and compacted in a manner which will not result in segregation of the material and at a moisture content which allows the compaction stated.

Immediately after placing, the base course material shall be compacted. The material shall be compacted to an average density of 100% of M.D.D. as determined according to AASHTO T 180 Method D with no single value below ninety-eight (98%) percent. The field determination of density shall be made in accordance with AASHTO T 191. The percent of density shall be adjusted to compensate for the weight and volume of aggregate larger than the aggregate used in the compaction control test where acceptable.

Rolling shall be continued until the entire thickness of each layer is thoroughly and uniformly compacted to the density specified. The final rolling of the compacted base course shall be done with a self-propelled roller. Rolling shall be accompanied by sufficient blading in a manner approved by the Engineer, to insure smooth surface free from ruts or ridges and having the proper section and crown. When additional water is required, it shall be added in the amount and manner approved by the Engineer. Each layer of base course must be completely compacted by the contractor and approved by the Engineer, prior to the delivery of the materials for a succeeding layer. The surface of the material shall be free from movement on completion of the compaction.

The surface of the finished base course will be tested with a three (3) metre straight-edge by the Engineer at selected locations. The variation of the surface from the testing edge of the straight-edge between any two (2) contacts with the surface shall at no point exceed six (6) millimetres when measured in any direction. The base course shall be compacted to the thickness and cross-section as shown on the plans and shall not vary by more than five (5) millimetres from the required elevation. All humps and depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

If the material for the base course is laid and compacted in more than one (1) layer, the contractor shall plan and coordinate the work in such a manner that the previously placed and compacted layers be allowed ample time for drying and development of sufficient stability, before vehicles hauling materials for the succeeding layers or other heavy equipment are permitted on the base. Prior to placing the succeeding layers of material, the top of the under layer shall be made sufficiently moist to insure bond between the layers. The edges and edge slopes of the base course shall be bladed or otherwise dressed to conform to the lines and dimensions shown on the plans and present straight, neat and workmanlike lines and slopes as free of loose material as practicable.

The contractor shall also plan the work and handle the various operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If the contractor delays placing of succeeding layers of base course material to the extent that additional water must be applied to prevent raveling or excessive dripping, the application of such water shall be at the contractor’s expense not to be considered as the basis for a claim for additional compensation. Water shall be applied at such times and in such quantities as directed by the Engineer and the Engineer shall have full authority to require the suspension of all other works on the project to ensure the proper maintenance of previously compacted material. If after the base is compacted, any areas are above or below proper grade and true elevations such areas shall be loosened and after having had additional materials added or excess material removed as the case may require, shall be reconstructed as described herein. If after the base is compacted any areas fail to meet the specified density and gradation requirements, they shall be loosened ore removed as directed by the Engineer and reconstructed as described herein.

5. Maintenance of base course

Following the construction of the aggregate base, the compacted base course shall be maintained by the contractor at his expense. The contractor shall blade, broom and otherwise maintain the base, keeping it free raveling and other defects until such time as the bituminous prime or other surface is applied. Water shall be applied at such time and in such quantities as directed by the Engineer.

The Engineer shall determine when the surface of the base course is in the proper condition to permit the bituminous prime and/or surfacing to be applied. If the contractor chooses not to apply the bituminous prime and/or surfacing at the time, he must continue to maintain the surface of the base curse, including the application of the necessary water at his expense until such time as the bituminous prime and/or surfacing is applied. Any additional expense incurred by the contractor because of his failure to apply the bituminous prime and/or surfacing when so permitted by the Engineer will not be considered as the basis for a claim for additional compensation.

3.2.7.6 Minimum test requirements

The Contractor shall test the crushed concrete and any approved components at a frequency which is sufficient to ensure that the material supplied under the contract complies with the specified requirements. The frequency shall not be less than that shown in the Table below, except that the Engineer may agree to a lower frequency where the contractor has implemented a system of statistical process control and can demonstrate that such lower frequency is adequate to assure of the product.

a. Minimum frequency of testing

Table 3-16: RCA Base Minimum Testing requirements

Test	Minimum Frequency of Testing
Grading	On each day – one per 300 tonnes if part thereof
Foreign Material Content	On each day – one per 300 tonnes if part thereof
Moisture Content	On each day – 3 No. One per 200 tonnes or part thereof on each day
Plasticity Index	In each month – one per 5000 tonnes or part thereof
California Bearing Ratio	Prior to the commencement of work and when in the opinion of the Engineer the nature of the material has changed significantly
Los Angeles Abrasion	Once per month or when in the opinion of the Engineer the nature of the material has changed significantly.

3.2.8 Recycled crushed aggregate sub-base

3.2.8.1 Description

This Specification has been prepared to meet the requirements of the Order issued by the Executive Council of the Emirate of Abu Dhabi, dated 28th July, 2010, under number BT9G25/2010 requiring the mandatory use (subject to availability) of a minimum of 40% aggregate (by volume) of recycled construction and demolition waste in roads projects, as well as any other infrastructure projects throughout the Emirate of Abu Dhabi.

The works described below shall consist of furnishing and placing one (1) or more layers of Recycled Crushed Aggregate (RCA), including additives if required, on a prepared surface in accordance with the Specifications and in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

3.2.8.2 Materials

Materials shall conform to the requirements for the class of "Recycled Crushed Aggregate Base Course" specified on the plans or directed by the Engineer. All RCA sub-base material shall be free from dirt, organic matter, shale or other deleterious matter and shall be of such quality that it will bind readily to form a firm stable sub-base.

3.2.8.3 Components

Crushed concrete aggregates shall consist of clean, hard, durable, angular fragments of rock, concrete and sand fragments of uniform quality complying with the general requirements of the Section 3.2.1 and its use limited as stated in Section 4.3.10 of Chapter 4, Concrete Works, of these Standard Specifications.

The use of crusher fines passing the 4.75 sieve which are not produced from crushing concrete. Shall be subject to approval in writing by the Superintendent to the proposed source and nature of these materials and the proposed amounts to be added,

3.2.8.4 Physical requirements

All base course RCA shall conform to the physical requirements described below, for each Class of Aggregate.

Foreign material in the fraction retained on the 4.75 sieve shall not exceed the percentages by mass specified:

Table 3-17: RCA Sub-base Physical requirements

Foreign Material Type	%
High density materials such as glass, brick, and asphalt	10
Metallic items such as steel, aluminum and iron	1
Low density materials such as plastic, rubber, plaster, clay lumps and other friable materials	1
Wood and other vegetable or decomposable meter	0.2

3.2.8.5 Grading requirement

a. Sub-base

Sub-base shall consist of well-graded RCA with sand and silt, conforming to the following requirements:

Table 3-18: RCA subbase requirements

Properties	Value
50mm	100
37.5 mm	95-100
19	65-95
9.5mm	30-65
4.75mm	25-55
2.00mm	15-40
0.425mm	8-20
0.075mm	2-8
Loss by Abrasion Test (AASHTO T 96)	40% maximum
Liquid Limit (AASHTO T89)	25 maximum
Plasticity Index (AASHTO T 90)	4 maximum
Sand Equivalent (AASHTO T 176)	25 minimum
CBR on remolded sample (BS 1377 Test 16) after 4 days soaking	120% minimum
Soundness (Magnesium) – AASHTO T104	15% maximum
Flakiness – BS 812	35% maximum
Elongation – BS 812	35% maximum
Sulphate Content – BS 812	2% maximum
Chloride Content – BS 812	2% maximum

3.2.8.6 Acceptance

When the stationary plant method is used, the aggregate will be accepted immediately following mixing based on periodic samples taken from the pug mill output. When a road mix method is used, the aggregate will be accepted after necessary blending and before laying, based on samples taken from the combined windrow for each layer. Acceptance of the material by the Engineer does not constitute acceptance of the sub-base, only that the material is approved for use in the sub-base.

3.2.8.7 Equipment

Equipment shall be according to the type and number outlined in the Contractor's detailed Programme of Work, as approved by the Engineer.

3.2.8.8 Construction requirements

a. Groundwater levels and protection

The Contractor must establish the high water table levels (HWT) along the length of the road, relative to the accepted National benchmark (New Abu Dhabi Datum (NADD)). Should the base of the proposed road be within 1 meter of the HWT, an impermeable barrier will be required to be installed to prevent groundwater coming in contact with the RCA subbase.

b. Preparation of sub-grade

Unless other sub-grade preparation is called for on the plans or sub-grade preparation appears as a separate item for compensation in the Bill of Quantities, the Contractor shall, as part of the Work of sub-base, prepare the sub-grade. The formation of the sub-grade will vary by either placing the "Granular RCA Sub-base" on the roadway surface as previously constructed or by excavating sufficient material from the roadway and placing the "Granular RCA Sub-base" on the sub-grade obtained thereby. In either case, the sub-grade, shall as hereinafter described, be brought to the lines, grades and typical section shown on the plans for the bottom of the "Granular RCA Sub-base". All soft and yielding material or other portions of the sub-grade, which will not compact readily, when rolled or tamped, shall be removed, and all loose rock or boulders found In the excavation shall be removed or broken off to a depth of not less than fifteen (15) centimeters below the surface of the sub-grade. All holes or depressions made by the removal of material, as described above, shall be filled with approved material and the whole sub-grade brought to line and grade and compacted to density designated on the plans or directed by the Engineer.

c. Spreading

Sub-base aggregates shall be spread on sub-grade which has been approved by the Engineer. Sub-base which has been placed on a sub-grade not approved by the Engineer shall be removed at the Contractor's expense.

Sub-base aggregate shall be spread on the approved sub-grade in layers not exceeding fifteen (15) centimeters in compacted depth. Spreading shall be done by means of approved mechanical box spreaders, distributing the material to the required width and loose thickness. Where the required sub-base thickness is greater than fifteen (15) centimeters, the material shall be placed in layers of equal thickness, In no case shall a layer be less than seven and one half (1.5) centimeters thick. Under no circumstances shall Class A Sub-base be dumped in a pile on the Sub-grade.

The material shall be handled so as to avoid segregation. Segregated materials shall be remixed until uniform. Suitable precautions shall be taken to prevent rutting of the sub-grade during the spreading of the sub-base materials. No hauling or placement of material will be permitted when, in the judgment of the Engineer, the weather or road conditions are such that the hauling operations will cause cutting or rutting of the sub-grade or cause contamination of the sub-base material.

d. Compaction

The moisture content of the sub-base material shall be adjusted prior to compaction, by watering with approved sprinkler trucks or by drying out, as directed by the Engineer, to that required to obtain the specified density for sub-base. Sub-base shall be compacted to an average value of 100% of the M.D.D. as determined according to AASHTO T 180 Method D with no single value below ninety eight (98%).

The sub-base aggregate shall be compacted by means of approved compaction equipment progressing gradually from the outside towards the centre with each succeeding pass uniformly over-lapping the previous pass. Rolling shall continuous until the entire thickness of each layer is thoroughly and uniformly compacted to the specified density. Rolling shall be accompanied by sufficient blading in a manner approved by the Engineer, to insure a smooth surface free from ruts or ridges and having the proper section and crown.

The surface of the material shall on completion of compaction be well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks, or loose materials.

Any area inaccessible to normal compaction equipment shall be compacted by means of mechanical tampers until satisfactory compaction is obtained.

Each layer of sub-base course must be completely compacted and approved by the Engineer, prior to the delivery of materials for a succeeding layer of sub-base.

e. Compaction trials

If directed by the Engineer, prior to the commencement of his sub-base or aggregate base operations, the Contractor shall construct trial lengths, not to exceed one (1) kilometre. The materials used in the trials shall be those approved for use as sub-base or aggregate base, and the equipment used shall be that according to the Contractor's approved detailed Programme of Works.

The object of these trials is to determine the adequacy of the Contractor's equipment, the loose depth measurements necessary to result in the specified compacted layer depths, the field moisture content, and the relationship between the number of compaction passes and the resulting density of the material.

f. Finishing

The Contractor shall programme his operations to avoid the drying out of the sub-base during construction. If any layer of sub-base material or part thereof, is permitted to dry out after compaction, or does not conform to the required density or finish, the Contractor. shall at his own expense, rework, water or recompact the material, as directed by the Engineer, to density specified before the next layer of sub-base or base course is superimposed thereon.

Immediately prior to the placing of the first layer on the sub-base, the final layer of sub-base shall be at the specified density and to the required grade and section. In order to maintain these requirements while placing the next course, it may be necessary to water and reshape the surface of the sub-base, which Work shall be at the Contractor's expense.

The surface of the finished sub-base will be tested with a three (3) meter straight-edge by the Engineer at selected locations. The variation of the surface from the testing edge of the straight-edge between any two (2) contacts with the surface shall at no point exceed six (6) millimeters when measured in any direction. The sub-base shall be compacted to the thickness and cross-section as shown on the plans and shall not vary by more than six (6) millimeters from the required elevation. All humps and depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing the defective Work or by adding new material as directed by the Engineer.

3.2.8.9 Minimum test requirements

One sample every 1,000 m^3 shall be tested for Grading Plasticity index, Sand Equivalent Maximum Dry Density. C.B.R., Loss by Abrasion. One Situ Density Test every 300 m^2 of Granular RCA Sub-base laid.

3.3 Asphalt Concrete Paving Courses

3.3.1 Description

Work constructs an asphaltic concrete paving course on a prepared surface in accordance with these specifications and in compliance with the lines, grades, thicknesses and typical cross-sections shown on the Contract plans, as approved by the Engineer.

3.3.2 Materials

The materials used in asphaltic concrete mixes shall meet the requirements specified in the following sections:

- Superpave mix design materials: Paragraph 1 of Sub-article (a) of Article 3.3.2.5.
- Marshall mix design materials: Paragraph 4 of Sub-article b of Article 3.3.2.5.

3.3.2.1 Storage and Handling of Materials

Materials shall be stored and handled so as to assure the preservation of their quality and fitness for the works. Materials, even though approved before storage or handling, may again be inspected and tested prior to use in the work. Stored materials shall be located so as to facilitate their prompt inspection. All storage sites shall be restored to their original condition at the Contractor’s expense prior to acceptance of the works.

Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes. Stockpiles shall be kept flat and the formation of high cone-shaped piles shall not be permitted. When conveyor belts are used for stockpiling aggregates, the Engineer may require the use of baffle-chutes or perforated chimneys. When trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. Use of tractors or loaders to push material deposited at one location to another location in the stockpile shall not be allowed during the construction of the stockpile and their use shall be limited to leveling the deposited material only. Stockpiles of aggregate located at permanent asphalt plant sites shall be separated by bin walls and shall be constructed on asphaltic or concrete floors. Stockpile locations and procedures at temporary asphalt plant sites shall be as approved by the Engineer.

Intermediate storage of hydrated lime and commercial mineral filler for equipment feeding the asphalt plant shall be silos of adequate size to ensure a minimum of one day's continuous operation.

3.3.2.2 Inspection, Testing and Control of Materials

For verification of weights and measures, character of materials and determination of temperatures used in the preparation of the asphalt mixes, the Engineer shall at all times have access to all portions of the mixing plant, aggregate plant, storage yards, crushers and other facilities used for producing and processing the materials of construction. Engineer will have authority to take samples and perform tests on any material supplied to the site from any source whatsoever in order to establish their compliance with these specifications and to accept or reject as he deems necessary. Samples will also be taken by the Engineer from completed work to determine compliance with these specifications. Frequency of all sampling and testing shall be in accordance with these specifications or as directed by the Engineer.

3.3.2.3 Unacceptable Materials

Materials that do not comply with the requirements of these specifications will be rejected and shall be removed immediately from the site of the works. No rejected material, the defects of which have been corrected, shall be used until approval has been given by the Engineer.

3.3.2.4 Sources of Materials

Materials used in the work shall be tested and approved before use. Contractor shall notify the Engineer of the sources of materials and the material shall not be delivered to site before the approval by the Engineer. Where the source of material does not meet the specification requirements, the Contractor shall furnish material from other sources. Delivery of materials produced from commercial manufacturing processes shall be accompanied by the manufacturer's certification and test report showing the materials comply with these specification requirements.

3.3.2.5 Hot Mix Asphalt Design Requirements

Either the Marshall Method of mix design (Asphalt Institute Manual Series MS-2) or the Superpave Volumetric Design Method (AASHTO MP 2) shall be used in designing the asphaltic concrete mixes, as may be required on the Contract plans, in the particular specifications and as approved by the Engineer.

Bituminous paving course mix designs shall be performed by the Contractor and verified by the Engineer. A certified technician shall perform the mix design.

a. Superpave Volumetric Method

Furnish mixes of aggregate, asphalt binder, and additives that meet the applicable material requirements and the appropriate design parameters in Table 3-24 and are capable of being placed and compacted as specified.

Compact specimens with the gyratory compactive effort specified in Table 3-24 for the specified ESAL or N_{Design}.

1. **Superpave Materials**

Superpave hot asphalt concrete pavement nominal maximum size aggregate is designated as shown in Table 3-21 and Table 3-24. Equivalent single axle loads (ESAL) or number of gyrations at design (N_{Design}) is designated as shown in Table 3-19, Table 3-20, and Table 3-24.

Asphalt binder is designated as shown in AASHTO M 320. Asphalt binder in asphalt mixes for road works shall be minimum PG grade 76-22. Asphalt binder in asphalt mixes for high stress zones such as intersections, roundabouts, steep inclines, areas of low speed with heavy loads, etc. shall be minimum PG grade 82-22. Modifiers shall be organic, inorganic or hybrid types of polymers specifically designed and manufactured for use in a dissolved, dispersed or reacted state within asphalt binders or asphalt mixes. Modifiers should be able to be dissolved, dispersed in or reacted with bitumen in a laboratory sample preparation to assess the properties and performances of the modified binder. The polymer content in asphalt binder or asphalt mixes shall be determined according to AASHTO T 302.

Antistrip additive type is designated as shown in Sub-article a of Article 3.3.2.5. Where no type is designated, use type 3 (lime).

Mineral filler shall conform to AASHTO M 17.

Superpave Asphalt Concrete Pavement Aggregate

Furnish hard, durable particles or fragments of crushed stone, crushed slag, or crushed gravel conforming to the following:

i. Los Angeles abrasion, AASHTO T 96: 35% max
ii. Magnesium sulfate soundness loss of coarse and fine aggregate (5 cycles), AASHTO T 104: 12% max
iii. Fractured faces, ASTM D5821: Table 3-19
iv. Fine aggregate angularity, AASHTO T 304, method A: Table 3-20

v. Flat and elongated particles, 3 to 1 ratio, ASTM D4791: Table 3-20

vi. Sand equivalent value, AASHTO T 176, alternate method no. 2, reference method: Table 3-20

vii. Gradation. See Table 3-21. Size, grade, and combine the aggregate fractions in mix proportions that result in a composite blend between the control points. Nominal maximum size is one sieve size greater than the first sieve to retain more than 10 % of the combined aggregate. Test according to AASHTO T 27 and T 11.

For the surface course, do not use aggregates known to polish or carbonate aggregates containing less than 25 % by mass of insoluble residue when tested according to ASTM D3042.

Table 3-19 Fractured faces coarse aggregate requirements

Traffic ESALs (million)	Fractured faces (1 face % min. / 2 face % min.)
< 0.3	55/-
0.3 to < 3	75/-
3 to < 10	100/85
10 to < 30	100/90
≥ 30	100/100

Note: "100/85" denotes that 100 percent of the aggregate has one fractured surface and 85 percent has two or more fractured faces.

Table 3-20: Superpave aggregate requirements

Traffic ESALs (million)	Uncompacted void content of fine aggregate (% minimum) Depth from surface		Sand equivalent (minimum)	Flat and elongated (% max.) 3:1 ratio
	≤100 mm	> 100 mm		
< 3	40	40	50	10
3 to < 10	45	40	70	
10 to < 30	45	40	70	
≥ 30	45	45	70	

Table 3-21: Superpave aggregate gradation

Sieve size	Nominal maximum aggregate size percent passing grading designation							
	25.0 mm		19.0 mm		12.5 mm		9.5 mm	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
37.5 mm	100							
25.0 mm	90	100	100					
19.0 mm	*	*	90	100	100			
12.5 mm	*	*	*	*	90	100	100	
9.5 mm	*	*	*	*	*	*	90	100

Sieve size	Nominal maximum aggregate size percent passing							
	grading designation							
	25.0 mm		19.0 mm		12.5 mm		9.5 mm	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
4.75 mm	*	*	*	*	*	*	*	*
2.36 mm	*	*	*	*	*	*	*	*
600 µm	*	*	*	*	*	*	*	*
300 µm	*	*	*	*	*	*	*	*
75 µm	3	8	3	8	3	8	3	8

*Contractor specified target values. See Table 3-22 for allowable deviations.

Table 3-22: Allowable deviations for target value gradations

Gradation Range		Allowable deviation
Minimum	Maximum	
70.1	89.9	4
60.1	70.0	5
55.1	60.0	6
45.1	55.0	7
40.1	45.0	6
30.1	40.0	5
21.1	30.0	4
8.1	21.0	3
0	8.0	2

Table 3-23: Coarse and fine gradation classification

Nominal maximum aggregate size	Primary control sieve (PCS) for mixture nominal maximum sieve size			
	25.0 mm	19.0 mm	12.5 mm	9.5 mm
PCS	4.75 mm	4.75 mm	2.36 mm	2.36 mm
PCS control point (% passing)	40	47	39	47

Table 3-24: Superpave hot asphalt concrete pavement design requirements (AASHTO MP2)

Design	Gyratory compaction level	Minimum voids-in-the-mineral aggregate (VMA), %(d)	Voids Filled with	Dust-to-	Minimum Tensile Strength

ESAL (million)	(% theoretical maximum specific gravity, Gmm) AASHTO PP 28			Nominal maximum size aggregate [c]				Asphalt (VFA), %[e] [f]	Binder Ratio[a]	Ratio, AASHTO T 283[b]
	$N_{Initial}$	N_{Design}	N_{Max}	25.0 mm	19.0 mm	12.5 mm	9.5 mm			
< 0.3	6 ≤ 91.5%	50 96%	75 ≤ 98%	12.0	13.0	14.0	15.0	70-80	0.8-1.6	0.80
0.3 to < 3	7 ≤90.5%	75 96%	115 ≤ 98%					65-78		
3 to < 30	8 ≤89%	100 96 %	160 ≤98%					65-75		
≥ 30	9 ≤89%	125 96%	205 ≤98%							

[a]Include non-liquid antistrip, baghouse fines, and other mineral matter added to the mixture. Calculate the ratio using effective asphalt content (calculated by mass of mix).

[b]Prepare specimens in accordance with AASHTO PP 28.

[c]The nominal maximum size is one size greater than the first sieve to retain more than 10 % of the combined aggregate.

[d]When mineral filler or hydrated lime is used, include in the calculation for compliance with the VMA.

[e]For 9.5 mm nominal maximum size aggregate mixtures with ≥3 million ESALs, provide a VFA of 73 to 76 %.

[f]For 25.0 mm nominal maximum size aggregate mixtures with < 0.3 million ESALs, provide a VFA ≥ 67 %.

Combined aggregate gradation is classified as coarse graded when it passes below the primary control sieve control point in Table 3-23. All other gradations are classified as fine graded.

Antistrip Additive

Contractor shall conform to the following:

i. Type 1. Furnish commercially produced, heat stable liquid products that when added to asphalt have the chemical and physical properties to prevent separation of the asphalt from aggregates.

ii. Type 2. Furnish cement conforming to Section 4.3.1 or fly ash conforming to Section 4.3.2

iii. Type 3. Furnish lime conforming to AASHTO M 303.

Recycled Asphalt Pavement Use

Do not use recycled asphalt pavement in the top lift.

Furnish recycled asphalt pavement that is processed in some form (by crushing and screening) to produce a well graded gradation and asphalt content. Process recycled asphalt pavement so that no particle in the mixture made with recycled asphalt pavement will exceed the mixture maximum aggregate size at the time of production. Millings will be considered processed provided they have a uniform gradation and asphalt content. Provide recycled asphalt pavement material with a maximum of 2 % deleterious materials.

Recycling agents shall conform to AASHTO R 14 or use an approved petroleum product additive that restores aged asphalt to the required specifications

Up to and including 15 % recycled asphalt pavement material by mass may be used in the mix without adjusting the asphalt binder grade. For mixes with over 15 % and up to and including 25 %, recycled asphalt pavement material by mass, decrease the asphalt binder grade one performance level for both the upper and lower grade level of the asphalt binder specified or use an approved blending procedure with a recycling agent. Do not use more than 25 % recycled asphalt pavement by mass.

For mixture design, use the specific gravity of the new (virgin) asphalt binder as the specific gravity of the asphalt binder in the recycled asphalt pavement. For calculation purposes, use the effective specific gravity of the aggregate in the recycled asphalt pavement as the bulk specific gravity. When the recycled asphalt pavement contains highly absorptive materials, estimate the amount of absorbed asphalt from historical records, and use the estimate to back-calculate the bulk specific gravity of the aggregate.

2. Submission

Contractor shall submit written job mix formulas for approval at least 30 days before production. Include the location of all commercial mixing plants to be used and a separate job-mix formula for each plant. Include a signed statement prepared by the testing laboratory that certifies that the proposed job-mix formula meets the requirements of the Contract and can be compacted in the field during production to meet Contract requirements. For each job-mix formula, submit the following:

i. Aggregate and mineral filler.

  a) Target values:

    1) Target value for percent passing each sieve size for the aggregate blend

    2) Designate target values within the gradation band specified for the nominal maximum size aggregate grading shown in Table 3-21.

  b) Source and percentage of each aggregate stockpile to be used.

  c) Average gradation of each aggregate stockpile

  d) Representative samples from each aggregate stockpile. Use split samples of material taken at the same time samples are taken for testing by the Contractor's laboratory

    1) 375 kg of aggregates proportioned by stockpile according to the stockpile's proportion in the mix

    2) 10 kg of bag house fines if proposed for the mix

    3) 10 kg of mineral filler if proposed for mix

    4) Results of aggregate quality tests for Contractor selected sources. Include the sand equivalent, fractured faces, Los Angeles abrasion, sodium sulfate soundness, coarse durability, and fine durability results from tests performed within 1 year of aggregate use

ii. Asphalt binder:

  a) Target asphalt binder content

  b) Five 4-liter samples of the asphalt binder to be used in the mix. Do not include antistrip additives in these samples

  c) Recent test results from the manufacturer for the asphalt binder including a temperature-viscosity curve

  d) Material safety data sheets

e) Mixing temperature range and minimum compaction temperature for the performance grade asphalt to be used in the mix

iii. Antistrip additives: If part of the job-mix formula:

a) 0.5 liter of liquid antistrip additive or 5 kg of cement, fly ash, or lime antistrip additive

b) Name of product

c) Manufacturer

d) Material safety data sheet

e) Dosage rate

iv. Recycled asphalt pavement material. If part of the job-mix formula:

a) Source and percentage of recycled asphalt pavement material

b) Average gradation of the recycled asphalt pavement material

c) Percent asphalt binder in the recycled asphalt pavement

d) Target value for the asphalt binder content (that considers the percent asphalt binder in the recycled asphalt pavement) and the percent new (virgin) asphalt binder to be added to the mix

e) 100 kg representative sample of recycled asphalt pavement material. For existing pavements, mill where designated by the Engineer to the pavement removal depth. Sample the removed material and replace it with an approved asphalt concrete mix. Do not use the replacement material in the recycled mix

f) 4 liters of recycling agent, if part of the job-mix formula

3. Verification

Engineer will review and shall perform design verification testing. If verification testing is performed, the information supplied in the Contractor's design must agree with the verification test results within the tolerances shown below.

i. Aggregate gradations: Representative aggregate samples from each stockpile, when combined according to the Contractor's recommendation for stockpile percentages, shall be within the gradation defined by the target values plus or minus the following tolerance for each sieve.

Table 3-25: Aggregate gradation target value tolerances

Sieve Size	Tolerance, % (±)
25 mm	3.0
19 mm	3.0
12.5 mm	3.0
9.5 mm	3.0
4.75 mm	3.0
2.36 mm	3.0
425 μm	2.0
75 μm	1.0

ii. Voids in mineral aggregate (VMA): Contractor's VMA result is verified if the Engineers result is not below the minimum specification limit.

iii. Voids filled with asphalt (VFA). The Contractor's VFA result is verified if the Engineers result is within the specification limits in Table 3-24

iv. Air voids (Va): Contractor's Va result is verified if the Engineers result at the same design asphalt binder content is within 1.0 % of the specification value.

v. Tensile strength ratio (TSR): Contractor's percent retained strength result is verified if the Engineers result is above the minimum specification value.

4. Changes and Resubmissions

If a job-mix formula is rejected or a material source or the recycled asphalt pavement is changed, submit a new job-mix formula for acceptance. Up to 21 days may be required to evaluate a change. Approved changes in target values will not be applied retroactively for payment.

Engineer's job-mix formula evaluation costs will be deducted from the Contractors payment, when resulting from the following:

i. Contractor-requested changes to the approved job-mix formula

ii. Contractor requests for additional job-mix formula evaluations

iii. Additional testing necessary due to the failure of a submitted job-mix formula

5. Acceptance

Do not begin mix production until the job-mix formula is accepted by the Engineer.

b. Marshall Method

All of the criteria shown in

Table 3-27 shall be considered in designing and evaluating each type of mix. Optimum bitumen content determined by the Marshall Method, as per the latest edition of Asphalt Institute MS-2 for calculating the volumetric properties and for fixing the optimum bitumen content of each type of mix and the same, shall be used in preparing specimens for the Immersion compression (AASHTO T-165) test.

1. Types of Asphaltic Concrete

Types of asphaltic concrete mixes shall be as shown on the Contract plans/ typical cross-sections of the contract drawings and the combined grading shall conform to table 3-28

Table 3-26: Aggregate grading of asphaltic concrete mixes

	Base course	Binder course	Wearing course	
			Coarse	Fine
Sieve opening size	**Percent passing by weight**			
37.5 mm	100		-	-
25.0 mm	72-100	100	100	-
19.0 mm	60-89	80-100	86-100	100
12.5 mm	46-76	63-85	69-87	66-95
9.5 mm	40-67	57-77	58-78	54-88
4.75 mm	30-54	40-60	40-60	37-70
2.36 mm	22-43	25-45	25-45	26-52

	Base course	**Binder course**	**Wearing course**	
			Coarse	**Fine**
Sieve opening size	**Percent passing by weight**			
1.18 mm	15-36	20-36	20-37	18-40
600 µm	10-28	13-27	13-27	13-30
300 µm	6-22	8-19	8-19	8-23
150 µm	4-14	5-13	5-13	6-16
75 µm	2-8	2-8	2-8	2-8

Table 3-27 Design criteria for hot mix asphalt (HMA)

Properties	**Bituminous base course**			**Bituminous binder course**	**Bituminous wearing course**		
Type/category of road	**Parking lots, minor roads, driveways, etc. (light, traffic volume)**	**Sector roads (medium traffic volume)**	**Main roads, highways, truck roads, etc. (heavy traffic volume)**	**All roads categories**	**Parking lots, minor roads, driveways, etc. (light, traffic volume)**	**Sector roads (medium traffic volume)**	**Main roads, highways, truck roads, etc. (heavy traffic volume)**
Penetration grade of bitumen*	60/70	40/50 or 60/70	40/50 or 60/70	60/70 or 40/50	60/70	40/50 or 60/70	40/50 or PG
Number of compaction blows each end of specimen by freely held Marshall hammer	75	75	75	75	75	75	75
Stability (Marshall) minimum kg	1000	1100	1200	1300	1400	1500	1600
Flow (Marshall) mm	2 - 4	2 - 4	2 - 4	2 - 4	2 - 4	2 - 4	2 - 4
Stiffness minimum kg/mm (minimum)	400	400	500	500	450	450	550
❖ Percent air voids in mix	3 - 5	4 - 7	5 - 7	5 - 7	3 - 5	4 - 7	5 - 7
❖ Percent voids in mineral aggregate (VMA), % minimum	11	13	13	13	13	14	**14.5**
❖ Percent voids filled with	60-75	55-70	50-65	50-70	60-75	55-70	50-65

Properties	Bituminous base course			Bituminous binder course	Bituminous wearing course		
Type/category of road	**Parking lots, minor roads, driveways, etc. (light, traffic volume)**	**Sector roads (medium traffic volume)**	**Main roads, highways, truck roads, etc. (heavy traffic volume)**	**All roads categories**	**Parking lots, minor roads, driveways, etc. (light, traffic volume)**	**Sector roads (medium traffic volume)**	**Main roads, highways, truck roads, etc. (heavy traffic volume)**
Asphalt Binder %							
Bitumen content % by weight of mix	3.3-4.0	3.2-3.9	3.1-3.8	3.4-4.1	3.4-4.4	3.4-4.2	3.4-4.2
Loss of Marshall stability by submerging specimens in water at 60^{O} C for 24 hours as compared to stability measured after submersion in water at 60^{O} C for 30 minutes (max. % loss)	25	25	25	20	20	20	20
Residual voids in total mix checked on the Job standard grading but upper percentage limit of binder content applying **600 blows on each face**	-	2	2	2	-	**2**	**2**
OR Residual voids in total mix by PRD as per BS 598-104	-	2	2	2	-	3	3
Filler to bitumen ratio	0.8 – **1.4**						

Material for asphaltic concrete shall be combined so as to be well graded within the limits given in Table 3-28. Combined gradations which approach maximum limits on some sieves and minimum limits on other sieves shall be avoided.

2. Job Mix Formula and Allowable Tolerances

The Contractor shall be responsible for the design and performance of all bituminous mixes. The Contractor shall submit, for the Engineer's approval, a proposed "Laboratory Design Mixture" together with all applicable design data meeting these specifications and requirements of Table 3-26 and

Table 3-27 at least 30 days prior to commencement of the works.

Engineer will review the proposed job-mix formula by the Contractor and shall perform design verification testing. The Engineer will take samples of materials proposed for use in the mix in order to check their quality and to cross check the proposed mix design for which the Contractor shall repeat the laboratory design exercise in the site laboratory under the supervision of Engineer to confirm the Marshall properties submitted by the Contractor and fix the job mix formula.

The information supplied by the contractor for the laboratory design mixture must agree with the verification test results

After receiving the approval of aggregate and bitumen from the Engineer, the Contractor shall make a written request for the approval of the job mix formula prepared by the Contractor under the supervision of the Engineer in the laboratory.

Approval of the job mix formula by the Engineer shall in no way relieve the Contractor of his responsibilities and obligations stipulated in the contract and the Contractor shall be responsible for the soundness of the asphalt paving mixes and the satisfactory execution and performance of the asphalt paving courses.

After the job mix formula has been established and approved the contractor shall carry out plant and site trials. All mixes from the plant shall be produced within the following tolerance as indicated to table 3-30.

Table 3-28: Job mix tolerance (for plant produced mix)

Aggregate retained on 4.75mm sieve or large	± 5.0 %
Aggregate passing 4.75mm sieve and retained on 1.18mm sieve	± 4.0 %
Aggregate passing 1.18mm sieve and retained on 0.075mm sieve	± 2.0 %
Aggregate passing 0.075mm sieve	± 1.0 %
Bitumen Binder	± 0.2 %
Temperature of mixing	± 10^{O} C

The approved Laboratory Design Mixture shall be used for agreeing the approved Job Standard Mixture.

Consistently produce a mixture with asphalt content at the target value. Do not use the above operational tolerance as a means to alter the asphalt content target value.

3. Acceptance Sampling and Testing of HMA Mixture

Samples of loose asphaltic concrete mix shall normally be taken behind the paver before compaction and shall be obtained in accordance with AASHTO T-168. Samples of compacted asphaltic concrete shall be obtained by coring in accordance with Method B of AASHTO T-230. Determination of bitumen content and extraction gradation may be performed on either loose or compacted samples in accordance with AASHTO T-164 and AASHTO T-30 except that the ash correction shall be determined by using a bitumenometer. Specific gravity of the compacted asphalt concrete cores will be measured in accordance with AASHTO T-230.

4. Marshall Mix Materials

a. Fine Aggregate

Fine aggregate is that portion of the mineral aggregate passing the 2.36 mm sieve. Fine aggregate shall consist of crushed sand and shall be of such gradation that when combined with other aggregates in proper proportions, the resultant mixture shall meet the required gradation. Source of crushed fine aggregate is considered as the crusher site at which it is produced. Crushed sand shall be produced by crushing clean coarse aggregate and shall not be thin, flaky or elongated.

Fine aggregate including filler shall be obtained from 100% crushed gravel or crushed rock pre-screened to exclude natural uncrushed fine material or weathered unsound fines. Use of dune sand will not be permitted.

Fine aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental materials. Individual stockpiles of aggregate containing more than 10 % by weight of fine aggregate shall be tested for sand equivalent. Fine aggregates shall meet the additional requirements listed in Table 3-29

Table 3-29: Hot mix asphalt concrete fine aggregate requirements

Mix design tests	Test method	Requirements
Sampling	AASHTO T-2	-
Sieve analysis	AASHTO T-27 and AASHTO T-11	-
Sand equivalency	AASHTO T-176	Min. 55 %
Sodium sulfate soundness	AASHTO T-104	Max. 10 %
Magnesium sulfate soundness	AASHTO T-104	Max. 12 %

b. Coarse aggregate

Coarse aggregate is that portion of the mineral aggregate retained on the 2.36 mm sieve. Coarse aggregate shall consist of crushed natural stones and gravel. Crushed particles shall be cubic and angular in shape and shall not be thin, flaky or elongated. Gradation shall be such that when combined with other aggregate fractions in proper proportions, the resultant mixture shall meet the required gradation. Source of crushed aggregate is considered to be the crushing site from which it is produced.

Coarse aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental material. Coarse aggregate shall meet the requirements of Table 3-30 and Table 3-31.

Table 3-30: Hot mix asphalt concrete coarse aggregate requirements

Project control and mix design tests	Test method	Requirements
Sieve analysis	AASHTO T-27 and AASHTO T-11	-
Sampling	AASHTO T-2	-
Fractured faces base course	AASHTO TP-61	90 % min. (Two fracture faces)
Fractured faces wearing course	AASHTO TP-61	90 % min. (Two fracture faces)

Project control and mix design tests	Test method	Requirements
Flakiness	B.S. 812	Less than 30 %
Sodium sulfate soundness	AASHTO T-104	10 % max.
Abrasion loss	AASHTO T-96	40 % max.
Plasticity index (blending with sand to eliminate plasticity will not be permitted)		Non plastic
Absorption of coarse aggregate	AASHTO T 85	2 % max.

Table 3-31: Hot mix asphalt concrete aggregate source requirements

Source requirement tests	Test methods	Requirements
Percentage of wear (500 Rev.)	AASHTO T96	37 % max.
Soundness (coarse aggregate) (5 Cycles, magnesium sulfate)	AASHTO T104	10 % max loss
Soundness (coarse aggregate) (5 Cycles, magnesium sulfate)	AASHTO T104	12 % max. loss
Absorption of coarse aggregate	AASHTO T85	2 % max.
Specific gravity (fine aggregate)	AASHTO T84	2.75 min.
Specific gravity (coarse aggregate)	AASHTO T85	2.75 min.

c. Steel slag aggregate

Steel slag aggregate shall be accepted for use in HMA mixtures, as partial or complete replacement of natural crushed aggregate, for all projects only within the geographical areas under the jurisdiction of Abu Dhabi City Municipality. The percentage of replacement of natural aggregates with steel slag aggregate shall be based on suitable trials and tests to demonstrate compliance with performance criteria. Steel slag aggregate and HMA mixtures with steel slag aggregate shall meet the requirements specified in the Appendix 1 of Chapter 3 of these specifications.

d. Commercial mineral filler

Commercial mineral filler shall consist of finely ground particles of limestone, cement, or hydrated lime in accordance with AASHTO M-17. It shall be thoroughly dry and free from lumps and shall meet the gradation requirements of AASHTO M-17.

When hydrated lime is used as mineral filler, the hydrated lime shall comply with the following requirements:

- Hydrated lime shall comply with the definitions given in ASTM C51
- Sampling, packaging and marking of hydrated lime shall be in accordance with ASTM C50
- Storage and use of the hydrated lime shall at all times be such as to protect the material from the weather
- Hydrated lime shall comply with the gradation shown in Table 3-32 when tested in accordance with AASHTO T-219.

Table 3-32: Gradation of hydrated lime

Sieve Size	Minimum % passing
600 µm	95
75 µm	80

- When tested by ASTM C25, hydrated lime shall comply with the chemical requirements shown in Table 3-33

Table 3-33: Chemical requirements for hydrated lime

Test	Requirement	
	Min.	Max.
Free moisture (%)	-	3.0
Available lime index as CaO (%)	50	-
Carbon dioxide CO_2 (%)	-	8
Unhydrated lime (%)	-	9

When cement is used as mineral filler, it shall meet the requirements of Type V cement in accordance with AASHTO M-85 (ASTM C150).

e. Asphalt Binder

Unless otherwise required in the particular specifications, asphalt binder specified for use in the asphalt mixes shall be 60-70 or 40-50 penetration grade as per Table 3-34, in accordance with AASHTO M-20 and as shown in Table 3-34. Asphalt binder for Marshall mix designs requiring a performance graded (PG) bitumen shall meet the requirements of article 3.3.2.5, sub-article (a), point 1.

Table 3-34: Penetration grade Asphalt Binder

	60 – 70		40 - 50	
Test	**Min**	**Max**	**Min**	**Max**
Penetration @ 25° C, 100 g 5 sec	60	70	40	50
Flash point, Cleveland open cup, °C	232	-	232	-
Ductility at 25° C, cm	100	-	100	-
Solubility in trichloroethylene, %	99	-	99	-
Kinematics viscosity (centistokes) at 135 ° C	-	240	-	280
Softening Point Ring & Ball apparatus	48	52	51	55
Thin film oven test, 3.2 mm, 163° C, 5-hour loss on heating, %	-	0.8	-	0.8
Penetration of residue, % of original (after thin film oven test)	54	-	58	-
Ductility of residue @ 25° C, ° C, 5 cm per minute, cm	50	-	-	-

Asphalt Binder not meeting the requirements of 60-70 penetration grade may be accepted if it complies with viscosity grade AC-40 in accordance with AASHTO M 226 as shown in Table 3-35.

Table 3-35: AC 40 Viscosity grade Asphalt Binder

Test	Min.	Max.
Viscosity, 60° C, Ns/m² (PaS)	320	480
Viscosity, 135° C, Cs (mm²/sec)	300	-
Penetration, 25° C, 100 g, 5 sec	20	-
Flash point, Cleveland open cut, ° C	232	-
Solubility in trichloroethylene, percent	99.0	-
Test on residue, Rolling Thin Film Oven Test:		
Viscosity, 60° C	-	16,000
Ductility, 25° C, 5 cm per min, cm.	10	-

Asphalt Binder shall be prepared by the refining of petroleum or from crude oil (no other process shall be used). It shall be uniform in character and shall not foam when heated to 175° C.

- ❖ Should there be a need for improved performance and service life of the pavement e.g. increased resistance to rutting, cracking, raveling, etc. the particular specification and the contract drawing shall indicate the use of binder modified with polymer. Depending on the specific requirements of the project, specific performance grade of binder shall be specified which shall comply with the latest edition of AASHTO M320. Mixes produced using polymer modified binder (PMB) shall, in all respects (mix design process, sampling and testing of the mix laid on site and their compliance requirements) be identical to those made by Marshall method using conventional penetration grade binder (i.e. only the binder will be different).

3.3.3 Construction Requirements

This work consists of performing all operations and furnishing all materials, labor, tools, equipment and appurtenances that may be required to construct and maintain the roadways, or other asphalt works as shown on the Contract plans, as specified herein and/or in the particular specifications, included in the bills of quantities, as approved by the Engineer.

Placing of asphaltic material shall be performed as a continuous operation. Mixing and placing of the asphalt shall progress at a rate so that contamination of previous asphalt work by dust/dirt or loss of bonding capability shall not occur. If due to a breakdown in the plant or other emergency it shall be impossible to carry out this requirement, or if more than 48 hours has elapsed between asphalt placement operations, a prime coat or tack coat complying with the requirements of Section 3.4, as directed by the Engineer, shall be applied to the surface and no separate payment will be made by the department for such tack or prime coat.

3.3.3.1 Equipment

Equipment for asphalt works to be provided by the Contractor shall include, but not be limited to, that specified herein, as required and as directed by the Engineer.

All equipment shall be checked and/or calibrated and approved by the Engineer prior to use. Equipment shall be satisfactorily maintained and shall be used in an approved manner to produce asphaltic concrete pavements in accordance with these specifications. Adequate equipment and labor shall be used so that there is continual production and distribution of the asphalt course being constructed. Intermittent or “STOP & GO” type of operations will not be permitted by the Engineer.

Equipment approved for use shall not be removed from the site without the approval of the Engineer.

Contractor shall furnish the Engineer with the manufacturer's catalogues, specifications and other published data for the equipment and machinery he proposes to use.

a. Mixing Plant

All plants used by the Contractor for the preparation of asphalt hot mixes shall comply with all the requirements of Paragraph 1 of Sub-article (a) of Article 3.3.3.1. In addition, batch mixing plants shall comply with the requirements of Paragraph 2 of Sub-article (a) of Article 3.3.3.1.

1. Requirements for all Plants

Automatic Operation

Plant shall be designed, coordinated and operated so as to continually produce asphalt mix within the job mix tolerances specified. Plant shall be equipped and operated so that the proportioning of the hot aggregate, commercial filler and bitumen, together with the dry and wet mixing cycles, are all controlled automatically. Positive interlock shall be provided so that proportioning, mixing and discharge are accomplished by one operation without manual control of the separate phases.

Cold Feed System

Plant shall include a sufficient number of cold storage bins so that there is at least one bin for each different stockpile of material being used. Intermixing of material from different stockpiles in one bin or on the ground prior to putting into the bin is prohibited. Cold bins and loading equipment used shall be compatible to prevent overflow between bins. Baffle plates shall also be used between bins to prevent overflow of one bin into another. Each cold bin shall include an accurate means for continuously feeding the required amount of mineral aggregate so that uniform production shall be approved by the Engineer and shall be checked and calibrated as often as he may deem necessary to ensure its continued accuracy. Change of settings shall be made only with the approval of the Engineer.

Drier

A drier of satisfactory design shall be provided. Drier shall be capable of uniformly drying and heating the aggregate to the moisture and temperature required without leaving any visible unburned oil or carbon residue on the aggregate when discharged from the drier.

Dust Collector

Plant shall be provided with a dust collector designed to waste, or to return in a constant and uniform flow to the hot elevator, all or part of the material collected. Prior to permitting the return of such collected dust, the Engineer will examine its characteristics in relation to the mix requirements and will designate the quantity to be returned.

Plant shall have a screen cover and such additional housings and emission control equipment as may be necessary to ensure the proper control of dust in accordance with all local regulations relating to control of dust.

Screens

Plant screens shall be capable of screening all aggregates to the specified sizes and proportions. They shall have capacities equal to or greater than the maximum rated capacity of the plant. Screens shall be placed directly above the storage bins for the heated aggregate and shall receive the material coming from the drier. They shall have an operating efficiency such that the aggregate deposited in any bin shall not contain more than 10 % of oversize or undersize material. This screen tolerance shall not invalidate the job mix tolerances specified.

Hot Bins

Plant shall include at least three storage bins for hot aggregate of sufficient size to supply the pugmill when it is operating at full capacity. They shall be arranged to ensure separate and adequate storage of appropriate fractions of the aggregate. Each compartment shall be provided with an overflow pipe that shall be of such size and at such location as to prevent any backing up of material into other bins or against the screens. Bins shall be so constructed that samples can be readily obtained therefrom. An additional dry storage bin shall be provided for commercial mineral filler and provision shall be made for proportioning this filler into the mix.

Equipment for Preparation of Bituminous Material

Tanks for storage of bituminous material shall be equipped for heating the material, using positive and automatic control at all times, to a temperature within the specified range. Heating shall be accomplished by steam coils, hot oil, electricity or other approved means such that no flame shall come in contact with the heating tank. Circulating system for the bituminous material shall be of adequate size to ensure proper and continuous circulation during the entire operating period. Suitable means shall be provided either by steam or hot oil jackets or other insulation for maintaining the specified temperature of the bituminous material in the pipeline, meters, weigh buckets, spray bars, and other containers and flow lines. Storage tank capacity shall be sufficient for at least one day's operation. Circulation return lines to the asphalt storage tanks shall be submerged to the same elevation in the storage tanks as the feeder line (two or three vertical slots may be cut in the return line above the high level mark to break vacuum when reversing the pump).

Contractor shall provide a sampling outlet in the bituminous material feedline connecting the plant storage tanks to the bituminous material weighing or metering box. Outlet shall consist of a valve installed in such a manner that samples may be withdrawn from the line slowly at any time during plant operation. Location of the sampling outlet shall be readily accessible and free from obstruction. A drainage receptacle shall be provided for flushing the outlet prior to sampling.

Thermometric Equipment

An armored thermometer reading from 38° C to 204° C shall be fixed in the bituminous feed line at a suitable location near the discharge valve at the pugmill. Similar devices shall be fixed in the heating and storage tanks.

Plant shall be further equipped with either an approved dial-scale, mercury-actuated thermometer, an electric pyrometer, or other approved thermometric instruments placed at the discharge chute of the drier and in the hot fines bin so as to register automatically or indicate the temperature of the heated aggregates. For better regulation of the temperature of the aggregates, replacement of any thermometer by an approved temperature-recording apparatus may be required by the Engineer and he may further require that daily temperature charts be submitted to him by the Contractor.

Control of Mixing Time

Plant shall be equipped with positive means to govern the time of mixing and to maintain it constant unless changed at the direction of the Engineer.

Pugmill

Pugmill shall include equipment to deliver the bituminous materials in a thin uniform sheet or in multiple sprays over the full length of the mixer.

Temporary Storage of Mix

Plants may be equipped with skiffs or elevators for delivering hot mix to hoppers or silos before discharging to hauling units. Skiffs or elevators shall not be sprayed with diesel or other solvents; where necessary they may be sprayed with a minimum amount of lime water, soap or detergent solution. Hoppers or silos shall be of such design that no segregation or loss in temperature of the mix occurs.

Safety Requirements

Adequate and safe stairways to the mixer platform and guarded ladders to other plant units shall be placed at all points required for accessibility to all plant operations. Accessibility to the top of truck bodies shall be provided by means of a platform or other suitable device to enable the Engineer to obtain mixture temperature data. To facilitate handling scale calibration equipment, sampling equipment, etc., a hoist or pulley system shall be provided to raise or lower the equipment from the ground to platform or vice versa. All gears, pulleys, chains, sprockets and other dangerous moving parts shall be thoroughly guarded and protected. Ample and unobstructed passage shall be maintained at all times in and around the truck loading space. This space shall be kept free from drippings from the mixing platform.

Environmental Control

Prior to the Engineer's approval of the asphalt plant, current certifications must be submitted that establishes the Department has inspected and approved the environmental control devices fitted to the plant and that it is in full compliance with the Government's current regulations related to protection of the environment.

2. Special requirements for Batching Plant

Weigh Box Hopper

Plant shall include means for accurately weighing each size of aggregate in a weigh box or hopper, suspended on scales, ample in size to hold a full batch without hand raking or running over. Weigh box or hopper shall be supported on fulcrums and knife edges so constructed that they will not be easily thrown out of alignment or adjustment. All edges, ends and sides of weighing hoppers shall be free from contact with any supporting rods and columns or other equipment that shall in any way affect the proper functioning of the hopper. There shall also be sufficient clearance between hoppers and supporting devices to prevent accumulations of foreign materials. Discharge gate of the weigh box shall be so hung that the aggregate shall not be segregated when dumped into the mixer and shall close tightly when the hopper is empty so that no material is allowed to leak into the batch in the mixer during the process of weighing the next batch.

Scales and Meters

Scales or meters used for proportioning aggregate, commercial filler and bitumen shall be accurate to one percent of the indicated quantity. Scales and meters shall be substantially constructed and those that are sensitive and that easily get out of adjustment shall be replaced. Scales shall be constructed and located so as to prevent vibration in the dial pointer.

Scales for weighing aggregate and commercial filler may be either the beam or springless dial type and shall be of standard make and design. Graduation intervals shall be not more than 0.1 % of the nominal scale capacity. Dial scales shall be equipped with adjustable pointers for controlling automatically the weighing of each aggregate and filler. Pointer shall be set close to the dial face to prevent excessive parallax and all dial faces shall be so located that they shall be in plain view of the operator at all times. Weighing sequence of hot aggregates shall progress from coarse to fine.

Bituminous material shall be automatically proportioned by either weighing or metering. The minimum graduation shall be not more than 1 liter or 1 kg. Bituminous scales and weigh buckets shall be such that the required amount of bitumen is provided in a single weighing and delivered to the pugmill without loss due to overflow, splashing or spillage. Bituminous weigh buckets shall be satisfactorily insulated to prevent loss of heat in the bitumen or accumulation of bitumen in the bucket. Bituminous metering devices shall be rotating positive displacement pumps and shall be capable of providing the designated quantity of material for each batch.

All scales and meters shall be approved by the Engineer and shall be checked and calibrated as often as he may deem necessary to ensure their continued accuracy. Contractor shall provide and have at hand the necessary standard weights and other necessary equipment in order to perform testing and calibration of all scales and meters in a practical manner. An accurate platform scale with a capacity of 250 kg or more and an accuracy of 0.5 % of the load shall also be provided.

Pugmill Mixer

Batch mixer shall be an approved twin pugmill type, capable of producing a uniform mixture within the job-mix tolerances. Batch mixer shall be of such design to permit visual inspection of the mix. Mixer shall be so constructed as to prevent leakage of contents and its capacity shall not be less than 600 kg per batch. Mixer shall be enclosed and shall have an accurate time lock to control the operation of a complete mixing cycle by locking the weigh box gate after the charging of the mixer until the closing of the mixer gate at the completion of the cycle. Mixer shall lock the bitumen supply throughout the dry mixing period and shall lock the mixer gate throughout the dry and wet mixing periods. Dry mixing period is defined as the interval of time between opening of the weigh box gate and the start of application of bitumen.

Wet mixing period is the interval between the time the bituminous material is spread on the aggregate and the time the mixer gate is opened. Control of the time shall be flexible and capable of being set at intervals of not more than five seconds throughout cycles up to three minutes. A mechanical batch counter shall be so designed as to register only completely mixed batches.

Mixer shall be equipped with a sufficient number of paddles or blades in a suitable arrangement to produce a proper and uniformly mixed batch. The clearance of blades from all fixed and moving parts shall not exceed 20 mm except in the case of aggregates having a nominal maximum size of over 25.4 mm in which case the clearance shall be so adjusted as to prevent undue breakage of the coarse aggregate during the mixing operation.

Asphalt Plant shall meet the requirements of ASTM D 995. The plant shall be equipped with facilities to provide computer printout. The print out shall indicate the quantity of the materials in each batch against their respective target value. The print out shall contain the following information:

Batch time , temperature of aggregates , temperature of bitumen , temperature of mix, quantity of aggregates from different hot bin , the quantity of filler and quantity of bitumen (by weight of total mix).

A copy of full set of computer printout covering full day’s protection shall be handed over to the Engineer at the end of the day’s production

Hauling Equipment

Vehicles used for the transport of aggregates or bituminous mix shall have tight, clean and smooth metal beds and shall be free from dust, screenings, petroleum oil, volatile or other mineral spirits which may affect the material being hauled. Vehicle metal bed shall, if required, be sprayed with a minimum amount of soapy water or lime solution to prevent bituminous mix from adhering to the bed. After spraying, the truck shall be raised and thoroughly drained; no excess solution shall be permitted. Use of diesel or other solvents to spray in the truck bed is prohibited. Provision shall be made for covering truck loads with canvas or other suitable material of such size as to protect the bituminous mix from the weather.

When necessary, in order that a bituminous mixture be delivered on the road at the specified temperature, truck beds shall be insulated to obtain workable temperature of the mix and all covers shall be securely fastened. Any truck causing excessive segregation of material by its spring suspension or other contributing factors, or that shows oil leaks in detrimental amounts, or that causes undue delays, shall, upon the direction of the Engineer, be removed from the work until such faults are corrected. End dump trucks shall be equipped with chains on the tail gates for control when dumping the mix into the paving machine.

Contractor shall provide an adequate number of trucks of such size, speed and condition to ensure orderly and continuous operations of the work.

b. Pavers

Use pavers that are self-contained, power-propelled units, provided with an activated screed or strike-off assembly, heated if necessary, and capable of spreading and finishing courses of bituminous mixture in lane and shoulder widths applicable to the specified typical section and thicknesses shown on the plans.

Pavers shall be equipped with a receiving hopper having sufficient capacity for a uniform spreading operation. It shall be equipped with the screed with automatic controls which will make adjustments in both transverse and longitudinal direction. External longitudinal reference devices used to pick up grade information for the automatic sensing control shall conform to the following:

1. When picking up grade information from an underlying base, the external longitudinal reference device shall be a floating beam at least 9 m long or an 8 m non-contact averaging ski with a minimum of 4 sensors
2. When picking up grade information from an adjacent compacted pavement course or a concrete surface, the external longitudinal reference device shall be a floating beam or a non-contact averaging ski with a minimum of 2 sensors. Either referencing device shall be at least 3 m in length.
3. When using a floating beam to pick up grade information, place the sensing device in the middle third of the floating beam. A non-contact sensor may be used to pick up grade information from a newly placed adjacent compacted course only when approved.

Should the automatic controls fail to function properly, finishing the half shift with manual controls may be approved. Do not resume until the controls are repaired.

Pavers shall employ mechanical devices as equalizing runners, straight edge runners, even arms or other compensating devices to maintain trueness of grade and to confine the edges of the pavement to true lines without the use of stationary side forms. Equipment shall include blending or joint leveling devices for smoothing and adjusting longitudinal joints between lanes. Assembly shall be designed and operated in such manner that it shall place the material at the required compacted thickness.

Electronic screeds shall include automatic feed controls to maintain a constant level of material along the full length of the screed, automatic profile grade control and automatic slope control. Profile grade controller shall be activated by a travelling, articulated averaging beam of not less than 9.14 m in length or taut stringline (wire) set to grade. Automatic slope control shall be equipped with a proportioning manual override to enable smooth transition of changing slope rates. Automatic screed controls shall be approved by the Engineer prior to use.

If, during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities that are not satisfactorily corrected by scheduled operations, the use of such equipment shall be discontinued and other satisfactory spreading and finishing equipment shall be provided by the Contractor.

c. Rollers

Rolling equipment shall consist of vibratory steel-wheeled rollers, steel wheel rollers and pneumatic-tired rollers as required by the Engineer for proper compaction and finishing of the asphalt surface. Unless otherwise permitted, rollers shall be equipped with reversible or dual controls to allow operation both forward and backward with the operator always facing in the direction of movement.

Breakdown rollers shall be a 2 axle tandem steel wheeled weighing not less than 9.1 metric tons and capable of rolling with or without vibration.

Steel wheel rollers shall be self-propelled and equipped with power units of not less than four cylinders and under working conditions shall develop contact pressures under the compression wheels of 44-64 kN per meter of width.

Rollers shall be equipped with adjustable scrapers to keep the wheel surface clean and with efficient means of keeping them wet to prevent mixes from sticking. These surfaces shall have no flat areas or projections which shall mar the surface of the asphalt courses. Vibratory steel-wheeled rollers shall have dual drums with a minimum weight of 62 kN. Vibrating frequency shall be between 2000 to 3000 cycles per minute with individual controls for each tandem.

All steel-wheeled rollers shall be in good condition and the contractor shall furnish to the Engineer the manufacturer's technical data for each roller and no roller shall be used except after approval of the Engineer.

Pneumatic tired rollers shall weigh not less than 12 tons and be equipped with pneumatic tires of equal size and diameter mounted on 2 axles attached to a rigid frame equipped with a loading platform or body suitable for ballast loading. Minimum width between the outer edge of the outside tires on a given axle is 1.5 m. Use tires with satisfactory treads. Space the tires on the rear axle so that the entire gap between adjacent tires on the front axle will be covered by the tread of the rear tires. Uniformly inflate the tires so that the air pressure in the tires will not vary more than 35 kPa. Use the tire manufacturer's recommended inflation pressure. Use a minimum tire size of 185 mm x 375 mm, 4 ply. Fully skirt roller with rigid material to within 25 mm of the pavement surface.

Pneumatic-tired rollers shall be in good condition and with enough ballast space to provide uniform wheel loadings as may be required

Contractor shall furnish to the Engineer charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of tire loadings for each type and size compactor tire furnished and used in pneumatic-tired rollers.

Total operating weight and tire pressure may be varied by order of the Engineer to obtain contact pressures which shall result in the required asphalt course density.

Finish roller shall be 2-axle tandem steel wheeled weighing not less than 7.2 metric tons.

d. Asphalt Distributor

Asphalt distributor truck shall be of the pressure type with insulated tanks. Use of gravity distributors will not be permitted by the Engineer. Distributor shall have pneumatic tires of such width and number that the load produced on the road surface shall not exceed 98 kN per meter of tire width.

Spray bars shall have a minimum length of 2.04 meters and shall be of the full circulating type. Spray bar extensions shall also be of the full circulating type. Spray bar shall be adjustable to maintain a constant height above the surface to be treated. Spray bar nozzles shall be slotted and shall be of such design so as to provide a uniform unbroken spread of bituminous material on the surface. Valves shall be operated by levers so that one or all valves may be quickly opened or closed in one operation. Distributor shall be equipped with a hose and nozzle attachment to be used for spotting areas inaccessible to the distributor. Distributor and booster tanks shall be so maintained at all times as to prevent dripping of bituminous material from any part of the equipment.

Distributor shall be equipped with devices and charts to provide for accurate and rapid determination and control of the amount of bituminous material being applied and with a tachometer of the auxiliary wheel type reading speed in meters per minute. Spreading equipment shall be provided with a separate power unit for the pump or a variable displacement pump driven by a hydrostatic transmission so that a uniform application of bituminous material, in controlled amounts, may be made ranging from 0.15 to 5.0 kg/m^2 and with a range of pressure from 441 to 1,324 kN/m^2. Distributor shall have satisfactory heating equipment and thermometers in order to provide the full range of application temperatures for the bituminous material being used.

Prior to the commencement of the work and as required by the Engineer, the bituminous distributor shall be checked and calibrated such that the rate of transverse spread or longitudinal spread shall not vary more than ten percent from the required rate of application.

e. Cold Planer

Cold planer proposed for use shall meet the following minimum requirements:

1. Specialized equipment designed specifically for the purpose of removing, and/or surface treating or leveling asphaltic or concrete pavement using a rotating cutter mandrel.
2. Capable of cutting flush to kerbs or other vertical objects.
3. Control system capable of maintaining profiles and cross-slopes such that after planing the resulting surface will be within plus or minus four millimeters of the required profile and cross-slope.
4. Capable of performing single pass cuts of up to 150 mm depth.
5. Approved by the Engineer for the specific use intended.

f. Unacceptable Equipment

Engineer will have the right to stop the use of any equipment or plant which he deems to be inferior to the quality required and to instruct the removal of such equipment and to have it replaced by suitable equipment or to alter the method of operation at any time.

Contractor shall immediately comply with such instructions without being entitled to any indemnities or extensions as a result of such instructions. Contractor shall not be allowed to use any equipment or plant before obtaining the approval of the Engineer, and the Contractor shall undertake to follow sound technical methods of operation and to engage skilled and trained operators, mechanics and labor to carry out the works. Engineer will have the right to expel any operators, mechanics or labor and to instruct suitable replacement thereof at any time he deems such action is necessary.

3.3.3.2 Field Trial

On the first day of bituminous mix production, produce trial mixture of 450 metric tons at the optimum binder content. Complete production of the trial mixture the same shift. Produce the trial mixture at the medium speed used during the plant calibration. Trial mixture may be placed on the shoulder of the roadway or the passing lane of four lane roadways and become a section of the completed roadway. For other roadways, place trial mixture at an approved location. Field trial mixture shall conform to job-mix formula.

Acceptance of the plant produced trial mixture will be based on test results meeting the requirements of this section with the aggregate gradation within the job mix ranges given and the in-place densities meeting the requirements of Article 3.3.3.8.

When test results of the trial mixture do not meet the requirements, additional plant trial mixture may be required and the required tests performed.

A revised job-mix formula (if applicable) will be required based on the results of the tests performed on the field trial plant produced mixtures. Asphalt content will be selected, based on meeting the specifications for Marshall stability and percent air voids.

Should there be a change in sources of material, establish a new approved mix design and a new job-mix formula

3.3.3.3 Weather Limitations

Production and spreading of asphaltic concrete mix shall not be permitted when the ambient temperature is less than 8°C, nor during rain, fog, dust-storms or other unsuitable weather.

3.3.3.4 Surface Preparation

Areas to be paved shall be true to lines and grades shown on the Contract plans and shall have a properly prepared surface prior to the start of paving operations. Areas to be paved shall be prepared in compliance with these specifications and the particular specifications.

When an asphaltic concrete pavement course is to be placed on top of an existing pavement, the existing pavement surface shall be prepared in accordance with Article 3.3.4.2.

Priming or tacking of surfaces to be paved shall be in accordance with 3.4.

Surface of kerbs, vertical faces of existing pavements and all structures in actual contact with asphalt mixes shall be painted with a thin and complete coating of tack coat, as approved by the Engineer, to provide a closely bonded, watertight joint.

All openings or structures in the road for water, drainage and other specified utilities shall be constructed and their positions and levels determined before the start of paving operations.

All utility trenches, cut in the bituminous road surfaces shall be backfilled, compacted and prepared, all in accordance with Article 3.3.4.2.

3.3.3.5 Preparation of Asphaltic Concrete Mixes

a. Preparation of Asphalt Binder

Asphalt Binder shall be heated to a temperature to yield viscosities in the range of 150-300 mm^2/sec. (75-150 seconds Saybolt-Furol) when delivered to the mixer, as determined from the temperature viscosity chart of the product used. Asphalt Binder shall not be used if foaming occurs nor shall it be heated above 177° C at any time.

b. Preparation and Handling of Mineral Aggregate

Coarse and fine aggregate shall be stored at the asphalt plant in such a manner that the separate stockpiles will not become intermixed. Stockpiles shall be of sufficient size to provide a minimum quantity of one week's continuous production of asphalt mix. Aggregates brought to the asphalt plant to supplement stocks should be tested and approved prior to placing in the existing approved stockpiles.

Cold bins shall be calibrated with the materials to be used and the settings shall be such as to produce a combined gradation in accordance with the job mix. Proportioning shall be such that surpluses and shortages in the hot bins shall not cause breaks in the continuous operation. All the above shall be as approved by the Engineer.

Materials shall be thoroughly dried and heated so that their temperature is within 8° C of the temperature needed to satisfy the viscosity requirements of the Asphalt Binder. In no case shall the materials be introduced into the pugmill with a temperature, including the 8° C tolerance permitted, of more than that at which the Asphalt Binder has a viscosity of 75 seconds Saybolt-Furol. Moisture content of the heated and dried materials shall not exceed 0.5 %. Quantity of materials fed through the drier shall in all cases be held to an amount which can be thoroughly dried and heated within the limits specified.

Heated materials shall be screened into sizes such that they may be combined into a gradation meeting the requirements of the job mix formula and the hot aggregate storage bins shall be such as to minimize segregation and loss of temperature of aggregate. Hot bins shall be drawn and cleaned of material at the end of each day's operation.

c. Proportioning and Mixing

Heated ingredients together with the mineral filler and Asphalt Binder shall be combined in such a manner so as to produce a mixture which, when emptied from the pugmill, complies with the requirements of the job mix formula. Plant settings, once established, shall not be changed without the approval of the Engineer.

Temperature of the aggregate immediately prior to mixing shall be within ±8° C of the temperature of the Asphalt Binder and the temperature of the aggregate and asphalt prior to mixing shall be approximately that of the completed mix as defined in the job mix formula approved by the Engineer. Mix temperature shall be within the limits set out in the job mix formula when emptied from the mixer

Mineral filler in a cold dry state shall be proportioned into the mixer either with the aggregate or after the introduction of the Asphalt Binder to avoid loss of filler that may occur in dry mixing as a result of turbulence in the mixer.

When anti-stripping additive is required, the additive device shall be calibrated and set so that the specified amount of anti-stripping additive is thoroughly mixed with the bitumen just prior to entering the pugmill.

d. Control of Mixing Time

In a batch type plant, the Engineer will designate the length of time of both dry and set mixing periods to ensure a uniformly and completely coated mix. Mixing period time shall not be altered unless so ordered by the Engineer. A dry mixing period of not less than four seconds shall precede the addition of the Asphalt Binder to the mix. Excess wet mixing shall be avoided. Wet mixing shall continue as long as is necessary to obtain a thoroughly blended mix but shall not exceed 75 seconds nor be less than 40 seconds.

In continuous type plants, the weights shall be determined for the job from tests made under the supervision of the Engineer and the determination of mixing time shall be by the weight, unless otherwise required:

$$\text{Mixing time, sec.} = \frac{\text{Pugmill dead capacity, kg}}{\text{Pugmill output, kg per sec.}}$$

Equation 3-1: Mixing Time

Maximum mixing time in batch or continuous type plants shall be limited as directed by the Engineer to avoid undue changes in the characteristics of the asphalt material.

3.3.3.6 Delivery of the Asphaltic Concrete Mixes

Dispatching of the hauling vehicles to the job site shall be so scheduled that all material delivered may be placed in daylight, unless the Engineer approves the use of artificial light. Delivery of material shall be at a uniform rate and in an amount well within the capacity of the paving and compacting equipment.

The mix shall be delivered to the paver at a temperature determined from the temperature-viscosity curve.

All precautions shall be taken to protect the mix from the weather.

3.3.3.7 Spreading and Finishing

a. General

Spreading and finishing equipment complying with Article 3.3.3.1 shall be used. Mix shall be laid upon an approved surface in accordance with the specifications and only when weather conditions are suitable. Upon arrival at the point of use, the asphalt mix shall be spread and struck off to the grade, elevation and cross-section shape intended, either over the entire width or over such partial width as may be required. If the mix does not comply with the requirements, it shall not be used but shall be discarded. All bituminous mixes shall be introduced to the paver at a temperature not less than 135 deg. C and not more than 163 deg. C. Mixes outside this temperature range shall be discarded.

Asphalt course shall be constructed to proposed levels and shall be homogeneous and providing, after compaction, an even surface free from undulations, rises or depressions, and within the tolerances stipulated. In no case shall construction of a new asphaltic concrete course begin until the previously laid course has been tested and approved in accordance with these specifications.

Asphalt course shall be laid in more than one layer, with no layer exceeding 100 mm in thickness unless otherwise shown on the Contract plans or approved by the Engineer. Bitumen mixtures except on levelling course shall be spread in a placement thickness so that, after rolling the normal thickness of the compacted bituminous material shall be:

- Base Course: Min. 6 cm. Max. 10 cm.
- Binder Course: Min. 5 cm. Max. 8 cm.
- Wearing Course: Min. 4 cm. Max. 6 cm.

Where successive layers are to be placed, second layer shall be placed as soon as practicable after the first layer has been finished, rolled and cooled. Unless otherwise directed by the Engineer, the surface of the existing layer shall be cleaned and a thin tack coat will be applied.

Transverse joints in succeeding layers shall be offset at least 2 m. Longitudinal joints shall be offset at least 150 mm. All joints shall be a minimum of 150 mm from all pavement markings.

Use of motor graders or hand spreading of the asphalt mix shall not be permitted except in places where it is impractical to use pavers and shall be only with the specific permission of the Engineer. This shall be to avoid segregation of the asphalt mix and shall comply with all conditions regarding trueness of level, thickness and homogeneity of the mix.

Automatic screed controls shall be required on all pavers and shall be used for paving courses as approved by the Engineer.

b. Preliminary Survey and Reference String Line

The Contractor shall make the survey required for the reference grade. When the survey is approved by the Engineer, the Contractor shall erect and maintain an approved reference string line and operate the paver to conform to the string line for the initial layer and/or any other layers as directed. Elevation control point stakes for the first layer of bituminous paving course shall be set at a maximum spacing of twenty (20) metres. For subsequent layer, control point shall be set at ten (10) metres maximum spacing. The Contractor shall furnish and maintain an approved mobile string line for all layers not laid with the erected string line. The string line shall be erected parallel to the reference grade, and the bituminous mixture shall be spread at a constant elevation above, below or at the string line elevation as directed.

The use of the automatically controlled bituminous paver, to provide both longitudinal and transverse control, shall include the furnishing and maintaining of a string line, whether it be erected or mobile, by the Contractor. The longitudinal and transverse controls shall operate independent of each other, to the extent that the surface of the bituminous mixture will conform to the string line and will be uniform in cross-section or crown.

The Contractor shall establish the centreline points and shall maintain the location of the points until the completion of the surfacing or as directed. When directed by the Engineer, the Contractor shall erect a string line, to be used as a guide for the finishing machine, in order to maintain a uniform edge alignment. If any other method is proposed by the Contractor, it shall be approved by the Engineer.

c. Machine Spreading

The Contractor shall make a survey of the centreline profile and crown of the existing surface or base and determine or calculate a Reference Grade Line and shall furnish to the Engineer for reference and approval the full values at each profile point necessary to erect the Reference String Line.

On the initial traffic lane paving operation, the asphaltic mixture shall be spread with the bituminous paver to a grade line constant to the Reference String Line.

The erection and maintenance of the Reference String Line shall be so coordinated that the string will be taut and free from sags at the time it is in use as a guide for the paver.

On the second and subsequent layers, the asphaltic mixture shall be spread as described for the initial layer except that the spreading of the asphalt shall conform to a Mobile String Line.

The Mobile String Line or equivalent shall be used as the reference guide on all paving operations, except when the Reference String Line is used or other provisions are made and approved by the Engineer.

On new construction, where paving starts on fresh earth subgrade, the survey may, if approved by the Engineer, be delayed to the surface of the first layer and the use of the Reference Grade Line may be delayed to the first lay- down operation of the second course.

If the existing surface is one of acceptable centreline grade, as determined by the Engineer from the Contractor's profile survey, the Engineer may permit the use of the mobile String Line for all layers.

No mixture shall be placed prior to the Engineer's approval of the Contractor's proposed methods and procedures for placing the mixture.

d. Levelling Course

A levelling course, consisting of a layer of bituminous material of variable thickness may be used to eliminate irregularities in existing surfaces or based and to vary existing cross-section elements of roadways.

In areas where levelling courses are required, as determined by the Engineer, the Contractor shall make survey of the existing surface or base. When the survey is approved, the Engineer will determine and inform the Contractor of the precise locations and thicknesses of levelling course to obtain the smoothest possible riding surface. Upon receipt of the locations and thicknesses from the Engineer, the Contractor shall proceed with the placement of the "Levelling Course".

3.3.3.8 Compaction

Compaction Temperature must be checked against appropriate values determined from Temperature-Viscosity Curves.

Rolling equipment for use in compacting asphalt mixes shall meet the requirements of section 3.3.3.1.c. At least three rollers shall be required at all times: one self-propelled pneumatic-tired and two steel-wheeled rollers. As many additional rollers shall be used as necessary to provide specified asphalt course density and surface characteristics in an orderly, efficient and continuous manner.

Immediately after the asphalt mix has been spread and struck off, the surface shall be checked and any irregularities adjusted and then compacted thoroughly and uniformly by rolling.

To prevent adhesion of the mix to steel-wheeled rollers, the wheels shall be kept properly moistened but excess water will not be permitted by the Engineer.

After the longitudinal joints and edges have been compacted, rolling shall start longitudinally at the sides of the road and shall gradually progress towards the center. On super-elevated sections, rolling shall begin on the low side and progress to the high side, overlapping on successive trips by at least one-half the width of tandem rollers and uniformly lapping each preceding track. Rollers shall move at a slow but uniform speed with the drive wheels nearest the paver. Speed shall not exceed 4.8 km/hr. for steel-wheeled rollers or 8.0 km/hr. for pneumatic-tired rollers. Operating speed shall be approved by the Engineer.

Line of rolling shall not be changed suddenly or the direction of rolling reversed suddenly. If rolling causes displacement of the material, the affected areas shall be loosened at once with hand tools and restored to the original grade of the loose material before being re-rolled. Heavy equipment or rollers shall not be permitted to stand on the finished surface before it has been compacted and has thoroughly cooled.

When paving in a single width, the first lane placed shall be rolled in the following order:

1. Transverse joints
2. Longitudinal joints
3. Outside edge
4. Initial or breakdown rolling, beginning on the low side and progressing towards the high side
5. Second rolling
6. Finish rolling

When paving in echelon, five to ten centimeters of the edge which the second paver is following shall be left unrolled. Edges shall not be exposed more than fifteen minutes without being rolled. Particular attention shall be given to the construction of the transverse and longitudinal joints in all courses.

a. Transverse Joints

Transverse joints shall be carefully constructed and thoroughly compacted to provide a smooth riding surface. Joints shall be checked with a straight-edge to assure smoothness and true alignment. Joints shall be formed with a bulkhead, such as a board, to provide a straight line and vertical face. If the joint has been distorted by traffic or by other means, it shall be trimmed to line and the face shall be painted with a thin coating of emulsified asphalt before the fresh material is placed against it. To obtain thorough compaction of these joints, the material placed against the joint shall be tightly pushed against the vertical face with a steel-wheeled roller. Roller shall be placed on the previously compacted material transversely so that not more than 150 mm of the rear rolling wheel rides on the edge of the joint. Roller shall be operated to pinch and press the mix into place at the transverse joint. Roller shall continue to roll along this line, shifting its position gradually across the joint, in 150 to 200 mm increments, until the joint has been rolled with the entire width of the roller wheel. Rolling shall be continued until a thoroughly compacted, neat joint is obtained more than 150 mm of the rear rolling wheel rides on the edge of the joint. Roller shall be operated to pinch and press the mix into place at the transverse joint. Roller shall continue to roll along this line, shifting its position gradually across the joint, in 150 to 200 mm increments, until the joint has been rolled with the entire width of the roller wheel. Rolling shall be continued until a thoroughly compacted, neat joint is obtained.

b. Longitudinal Joints

Longitudinal joints shall be rolled directly behind the paving operations. First lane placed shall be true to line and grade and have a vertical face. Material being placed in the abutting lane shall then be tightly pushed against the face of the previously placed lane. Before rolling, the coarse aggregate in the material overlapping the joint shall be carefully removed with a rake and discarded. Rolling shall be performed with a steel-wheeled roller.

Roller shall be shifted over onto the previously placed lane so that not more than 150 mm of the roller wheel rides on the edges of the newly laid lane. Rollers shall then be operated to pinch and press the fine material gradually across the joint. Rolling shall be continued until a thoroughly compacted, neat joint is obtained.

When the abutting lane is not placed in the same day, or the joint is distorted during the day's work by traffic or by other means, the edge of the lane shall be carefully trimmed to line, cleaned and painted with a thin coating of emulsified asphalt before the abutting lane is placed.

c. Edges

Edges of the asphalt course shall be rolled concurrently with or immediately after rolling the longitudinal joint.

Care shall be exercised in consolidating the course along the entire length of the edges. Before it is compacted, the material along the unsupported edges shall be slightly elevated with hand tools. This will permit the full weight of the roller wheel to bear on the material to the extreme edges of the mat.

d. Breakdown Rolling

Breakdown rolling shall immediately follow the rolling of the longitudinal joints and edges. Rollers shall be operated as close to the paver as possible to obtain adequate density without causing undue displacement. In no case shall the mix temperature be allowed to drop below 110° C prior to breakdown rolling. If it is so happens, such areas shall be identified on site, removed from the permanent work and replaced with approved mix complying with all applicable requirements. If the breakdown roller is steel-wheeled, it shall be operated with the drive wheel nearest the finishing machine. Pneumatic-tired rollers may be used as breakdown rollers.

e. Intermediate Rolling

Pneumatic-tired rollers or steel-wheeled rollers described in c) shall be used for the intermediate rolling. Intermediate rolling shall follow the breakdown rolling as closely as possible and while the paving mix is still of a temperature that will result in maximum density from this operation. Rollers shall be used continuously after the initial rolling until all of the mix placed has been thoroughly compacted. Turning of rollers on the hot paving mix which causes undue displacement will not be permitted by the Engineer.

f. Finish Rolling

Finished rolling shall be accomplished while the material is still warm enough for the removal of roller marks.

All rolling operations shall be conducted in close sequence.

In places inaccessible for the operation of standard rollers as specified, compaction shall be performed by manual or mechanical tampers of such design as to give the desired density.

After final rolling, the smoothness, levels, cross falls, density and thickness shall be checked and any irregularity of the surface exceeding the specified limits and any areas defective in texture, density or composition shall be corrected as directed by the Engineer, including removal and replacement at the Contractor's expense as directed by the Engineer.

3.3.3.9 Protection of the Asphalt Courses

Sections of the newly finished work shall be protected from traffic of any kind until the mix has been properly compacted and cooled to ambient temperature. In no case shall traffic be permitted less than 12 hours after completion of the asphalt course unless a shorter period is authorized by the Engineer.

3.3.3.10 Testing and Acceptance of Completed Asphaltic Concrete Courses

Each completed asphalt concrete course shall be tested and approved in accordance with the following requirements prior to placing any subsequent asphalt concrete course.

Contractor shall, at his own expense, cut samples from each completed asphalt course during the progress of the work and before final acceptance of the project, all as directed by the Engineer. Compacted samples shall be taken by coring in accordance with AASHTO T-230, for testing by the Engineer. Where the Contractor fails to provide cores as required by the Engineer, the Engineer may arrange for the taking of cores at the Contractor's expense. Samples shall be taken of the asphalt mix for the full depth of the course from the location directed by the Engineer at a rate of not less than one sample per 200 linear meters of road.

Whenever deficiencies are noted in loose mix samples or core samples, the Engineer may direct the taking of additional cores at the Contractor's expense in order to define the area of pavement involved.

Hot asphalt mix shall be placed and compacted in holes left by sampling.

a. Requirements for compaction of asphalt concrete courses

Degree of compaction is the ratio of the specific gravity of the pavement sample to the specific gravity of the laboratory Marshall specimens prepared in accordance with the job mix formula.

Minimum degree of compaction required for the various types of asphalt concrete, expressed as a percentage, shall meet the requirements of Table 3-36.

Table 3-36: Minimum degree of required compaction

Type of Mix	Minimum degree of compaction required
Base Course	98 %
Binder Course	98 %
Wearing Course	98 %

In the event the specific gravity of samples cut from any asphalt concrete course fail to comply with the minimum required, this will be considered a major defect in the work on the basis of which the portion of the asphalt course represented by these samples shall be rejected.

Degree of compaction in excess of 101.5% shall not be permitted. The specific gravity of compacted asphalt cores shall be measured in accordance with ASTM D 2726/AASHTO T-230.

Degree of compaction for all asphalt layers with respect to maximum theoretical Specific gravity shall be calculated and documented.

b. Requirements for Air Voids, Asphalt Content and Gradation

Samples of the mixed materials shall be taken from the first two hundred tones and from every two hundred tones thereafter to determine aggregate grading and binder content. Samples of loose asphaltic concrete mix shall be taken behind the paver before compaction and shall be obtained in accordance with, ASTM D-979. Samples of compacted asphaltic concrete shall be obtained by coring in accordance with Method B of AASHTO T-230.

If the grading of the mix falls outside of the Job Mix Limit (JML) the second part of the mix shall be checked. If the average grading indicate a maximum of three (3) sieves out of JML by maximum 1% or a maximum of two (2) sieves out of JML by maximum 2% the material shall be accepted in the permanent works when an additional one year guarantee shall be provided by the contractor on condition that the laid mix meet all other aspects of the specification. However, if it so happens twice within 15 days' time, the works shall be suspended, hot bin samples re-cheeked and adjustment made in the plant and if required re-designed.

Determination of bitumen content and extraction gradation may be performed on either loose or compacted samples in accordance with AASHTO T-164 and AASHTO T-30 except that the mass of mineral matter in the total volume of the extract shall be determined by using a bitumen meter or other equipment and procedures which give equally satisfactory results. The specific gravity of compacted asphalt course shall be measured in accordance with AASHTO T-230. Gmm as per ASTM D-2041shall be checked on daily bases and used for calculating air voids.

If any of these tests show results which are not in accordance with approved job standard mix within permissible variations the material shall be rejected and suitable adjustments shall immediately be made to ensure compliance therewith. Samples of the mixed material shall be taken at least twice a day or as determined by the Engineer for making Marshall Specimens to determine stability, flow and unit weight. For the samples to be taken for the making of daily Marshall Specimens the mixing pug mill temperature shall be set to the mixing temperature as specified in AASHTO T-245 and the compaction temperature of the moulds shall also be in accordance with AASHTO T-245. Should for practical reasons the pug mill temperature be different from that used in AASHTO T-245 then the Engineer shall set the compaction temperatures for the moulds to so compensate. All approved sampling and testing required under the sub-clause of this clause shall be undertaken by the

Engineer. Sampling and testing by the Engineer in no way relives the Contractor of his responsibility for regular quality control testing in order to ensure compliance with the Specifications.

If the Marshall stability of the mix is found a maximum of 200 kgf less than the minimum specified requirement, fresh hot bin samples shall be taken and six Marshall Specimens made on the average grading and bitumen content of the production date. If the stability is found satisfactory the material laid on site shall be accepted without any deduction. If not, the material shall be removed and replaced at contractor's cost.

The density of the compacted mixes shall be related to the daily Marshall Density, which shall be determined by taking the average of four standard Marshall specimens made from samples of the mix taken from the mixing plant or paver. The density of each sample shall be determined and compared with the mean value. Any individual result which varies from the mean by more than 0.015 gm/cc shall be rejected. Marshall tests shall be repeated on a daily basis to establish the daily Marshal Density for that particular day's production. The daily Marshall Density shall not vary from the job mix Design Density by more than + 0.75%. If it does, the higher of the densities (daily Marshall Density or Job Standard Density) shall be applied to satisfy the requirements of in-situ compaction. However, the in-situ air voids shall not be less than 4.5% and more than 8.5% if it so happens the matter shall be investigated. In the event of recurrent the hot bin samples shall be immediately taken, the specific gravity rechecked and the situation rectified – if needed the mix redesigned.

The "Job Standard Mixture Reference Density" (JSMD) shall be obtained by making six standard Marshall Specimens from samples of the approved "Job Standard Mixture" determining the relative density or each and comparing them with the mean values of the six. Any individual result which differs from the mean by more than 0.015 gm/cc shall be rejected and provided not more than two results are so rejected the mean of the remaining results shall be designated the "Job Standard Mixture Reference Density". Generally the average density of the specimens made for checking the loss of stability of the mix shall be taken as JSMD unless otherwise directed by the Engineer.

In the event it transpires from the analysis conducted on samples of loose mix or cores that the asphalt content or aggregate gradation are beyond the permissible tolerances specified for the job mix formula established for each respective asphalt course mix, as determined by the Engineer, such variation affects the characteristics of the asphalt mix as far as its compliance with the Contract conditions and specifications is concerned, this shall be considered a major defect in the work on the basis of which the portion of the asphalt course represented by these samples shall be rejected.

c. Requirements for Thickness

Total constructed thickness of asphaltic concrete base course or asphaltic concrete wearing course used for new construction, reconstruction or roadway widening shall not vary more than 6 mm from the total thickness shown on the Contract plans and included in the bills of quantities.

In the event the constructed thickness of the asphaltic concrete base course or asphaltic concrete wearing course is 6 mm more than the total thickness shown on the Contract plans, the area shall be corrected as directed by the Engineer by removing the excess material in an approved manner to provide the required thickness.

In the event the constructed thickness of the asphaltic concrete base course or asphaltic concrete wearing course is 6 mm less than the total thickness shown on the Contract plans, the Contractor shall provide additional material in the next course (base course or wearing course). In no case shall the deficiency of the base course exceed 12 mm and in no case shall the deficiency of the wearing course exceed 8 mm. In the event the total thickness of the wearing course is less than the total thickness required by the Contract plans by more than 6 mm, the Contractor shall remove the top layer of 50 mm or to a depth as directed by the Engineer and a new layer constructed so the total thickness of the wearing course is within the limits indicated on the Contract plans and as specified herein.

Asphaltic concrete base course and the asphaltic concrete wearing course shall be constructed to the grade level as shown on the Contract plans, as specified and as approved by the Engineer.

In no case shall the total sum thickness of the subbase, base course and wearing course be less than the total sum thickness of all courses shown on the Contract plans.

Tolerances specified herein shall not invalidate the tolerances set forth for the evenness of surfaces of the asphaltic concrete courses.

d. Requirements for Evenness of Surface

Engineer shall test the evenness of surface for each course of the various asphalt concrete courses incorporated in the Contract to ascertain their compliance with the conditions, these specifications and the Contract plans with regard to levels, longitudinal falls, cross-sections and evenness of surface.

Contractor shall put at the disposal of the Engineer a five-meter straight-edge and a crown template of sturdy construction and approved design and enough labor to assist in the checking operations.

Any layer containing deviations or variations exceeding the following tolerances shall be corrected or removed and replaced, at the expense of the Contractor, to the satisfaction of the Engineer and according to the following specifications:

1. Variation in the levels of the profile grade line after construction shall not exceed one centimeter from the levels indicated on the Contract plans.
2. When tested by a five-meter straight-edge placed at right angle and parallel to the road centerline at intervals not exceeding two meters, or when tested by a crown template placed at right angle to the road centerline at intervals not exceeding half the template length, variation of the surface of the road from the testing edge between any two contacts with the surface shall not exceed the following maximum tolerances:
   i. Base Course: 6 mm
   ii. Wearing Course: 4 mm

   Tolerances herein specified for evenness of surface shall not invalidate the tolerances set forth for thickness of the asphalt concrete courses.
3. In no case shall the final surface of the roadway be constructed such that surface water will stand on the roadway in depths exceeding the above maximum tolerances.
4. The rideability of the completed final wearing course, or other desired surface courses, shall be tested using laser road surface profile measurement equipment complying with the latest edition of ASTM E950, Class 1 device (or other equivalent and internationally recognized standard). The device shall measure both wheel paths with laser height sensing instruments and it shall have a valid calibration certificate.

   The IRI shall be computed according to the latest edition of ASTM E1926 (or other equivalent and internationally recognized standard) from the longitudinal profile measurements of the road surface
5. Rideability of the finished wearing course when tested with a laser road surface testing machine shall have an International roughness index not exceeding the following values:
   i. Average value over a 400 m section
      a) For posted speed ≥ 100 km/hr: ≤ 0.90
      b) For posted speed 80 km/hr: ≤ 1.10
      c) For posted speed 60 km/hr: ≤ 1.30
      d) For posted speed < 60 km/hr: ≤ 1.50
   ii. Peak value over a 25 m section: ≤ 1.5 (not more than 2 values per 400 meters)

All humps and depressions exceeding the specified tolerance shall be corrected by removing the defective work and placing it with new material as directed by the Engineer at the Contractors cost.

3.3.4 Cold Planning

Cold planning shall be performed as shown on the plans or directed by the Engineer to areas which will receive an overlay.

3.3.4.1 Surface Preparation

Prior to cold planning begins, the Engineer will approve that the existing pavement surface is sound and it does not exhibit any structural failure. Any structural failure based on the Engineer's judgment shall be removed in accordance with Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications.

If the existing pavement will be overlaid, the Contractor shall profile the pavement as follows, unless otherwise directed by the Engineer.

1. Contractor shall remove the required thickness of asphalt by means of cold planning. Contractor is responsible for controlling dust to the approval of the Engineer.
2. Final surface elevation of the milled surface shall not vary more than 4 mm from the final surface elevations in profile and cross-section.
3. Milled material shall be stockpiled off-site for future use by the department, if directed by the Engineer. Otherwise, the removed asphalt shall become the property of the Contractor.

3.3.4.2 Surface Preparation for Overlays/ Rehabilitation

Contractor shall prepare the existing pavement as shown on the Contract plans for an application of overlay. Preparation shall include, but not by way of limitation, all cleaning, scraping and performing various types of repairs necessary to correct structural failures, deterioration, drainage and grade elevations in compliance with lines, grades, thicknesses and typical sections shown on the Contract plans, or as required by field conditions, and shall be carried out as required herein or as directed by the Engineer.

a. Materials

Materials required for various repairs shall be in accordance with the requirements of applicable sections of these specifications.

b. Construction

Before the application of an overlay, the existing pavement surface shall be swept clean of all dirt, loose and foreign matter by the use of hand brooms or mechanical sweepers of approved type in a manner approved by the Engineer. All sand, mud, dust and other loose material so swept off shall then be disposed of in accordance with Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications.

Filling and compacting of ruts and depressions with wearing course material to the general level of the surface shall immediately follow the operation of cleaning the surface. Contractor shall check the level of patch work with a straight edge and make corrections as required.

When directed by the Engineer, the Contractor shall make all necessary repairs to the existing pavement surface (potholes, failed areas, depressed areas, utility cuts, cracks, or other damaged areas).

Immediately prior to the placement of the overlay, tack coat material shall be applied to the areas to be resurfaced.

Care shall be exercised to prevent spraying tack coat materials upon adjacent sidewalks, structures, plants and shrubbery, adjacent property and improvements, and any other improvements and facilities not specifically mentioned. Any of the above mentioned facilities so damaged shall be cleaned or replaced to the satisfaction of the Engineer at the expense of the Contractor.

Contact surfaces of kerbs, gulleys, inlets, catch basins, manholes and other structures shall be painted with a thin uniform coating of tack coat material immediately before asphaltic material is placed against them. Tack coat shall be carefully applied and in such a manner that the tack coat shall not show above the surface of the finished pavement, all in accordance with Section 3.4.2.

In executing the construction of the single lift surface treatment, the Contractor shall adhere to the steps described above. However, in left or right turning areas the following steps shall be followed, unless otherwise directed by the Engineer.

1. Comply with the applicable requirements of maintenance of traffic and related work, of these specifications.
2. Contractor shall remove completely the existing kerb, including haunching and blinding at the road shoulder or median, and the resulting excavation shall be filled with borrow material compacted to 95 % maximum dry density as specified in Section 2.5.3 of Chapter 2, Earthworks, of these Standard Specifications.
3. Cut the existing pavement to neat lines at a distance of 250 mm from the removed kerb edge of the pavement. Remove the existing wearing and base courses in accordance with Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications. Exposed 250 mm of existing subgrade shall be prepared prior to placing asphaltic concrete overlays, as specified in Section 3.62.6 of Chapter 2, Earthworks, of these Standard Specifications
4. Subgrade area shall be compacted and prepared in compliance with lines, grades, thickness and typical sections shown on the Contract plans and as specified in Section 2.5.3 of Chapter 2, Earthworks, of these Standard Specifications.
5. Prior to placement of permanent pavement, the Contractor shall prime coat the subgrade area as shown on the Contract plans and as specified in Section 3.4.1. Where existing pavement has been removed, the top 300 mm of subgrade shall be compacted to 95 % modified proctor density as specified in Section 3.62.6 of Chapter 2, Earthworks, of these Standard Specifications.
6. Final surface of the subbase course shall be finished so that after final compaction and just prior to placement of base or pavement courses, the surface elevation shall not vary more than 10 mm from a five-meter straight-edge at any location. Surface shall be completed to the above tolerance and approved by the Engineer prior to any work at a given location or placing an overlying course, all in accordance with Sub-article b of Article 3.2.2.3.
7. Place tack coat as directed by the Engineer on the sand-asphalt subbase course immediately prior to placing an asphaltic base course, or on the base course in those cases where the base course has been utilized by traffic prior to the placement of the wearing course, all in accordance with Section 3.4.2.
8. Construct new kerbs in accordance with Section 7.6.3 of Chapter 7, Incidental construction, of these Standard Specifications.
9. Place and compact asphaltic concrete base, thickness of 160 mm or as shown on the Contract plans, placed in the widened areas, in two lifts of 80 mm each, all in accordance with the requirements for Section 3.3.3.
10. Place tack coat as directed by the Engineer immediately prior to placing any new asphaltic material over a previously placed asphaltic course, where the previous course has become “dirty” as the result of traffic using the surface, all in accordance with Section 3.4.2.
11. Place and compact asphaltic concrete wearing course, 60 mm minimum thickness over the turn area in one lift unless otherwise shown on the Contract plans or directed by the Engineer, all in accordance with the requirements for 3.3.3.
12. Place and compact asphaltic concrete wearing course, 40 mm minimum thickness, over the turning lanes and existing pavement in one lift unless otherwise shown on the Contract plans or directed by the Engineer, all in accordance with the requirements for Section 3.3.3.

13. Install pavement markings in accordance with Chapter 8, Traffic markings and signs, of these Standard Specifications

3.4 Bituminous Prime and Tack Coats

3.4.1 Medium Cure Liquid Asphalt Prime Coat

3.4.1.1 Description

This work shall consist of furnishing and applying liquid asphalt prime coat to previously prepared and approved granular sub-base/ aggregate base courses or wet mix macadam prior to placement of hot mix overlay. Such work shall be performed as specified herein or as directed by the Engineer.

3.4.1.2 Materials

a. Liquid Asphalt

Liquid asphalt shall be of the medium curing type MC-70 grade and shall comply with AASHTO M-82 as modified by the Table 3-37. Application rate shall be between 0.6 and 1.0 kg/m$^{2.}$ However the exact rate of application will be determined by the engineer following trials to be carried out by the contractor.

Table 3-37: Medium cure liquid asphalt

Description	MC-70	
	Min.	Max.
Saybolt furol viscosity @ 50° C, sec.	60	120
Flash point (tag open cut), ° C	38	-
Distillation: Distillate (% of total distillate to 360° C) To 225° C To 260° C To 315° C	 0 20 65	 20 60 90
Residue from distillation to 360° C, percent by volume	55	
Tests on residue from distillation: Penetration 25° C, 100 g, 5 sec. Ductility, 25° C, cm Solubility in Trichloroethylene, % Water, %	 120 100 99 -	 250 - 0.2

The surface to be prime coated shall be uniformly smooth and firm and true to the grades and cross-section shown on the drawings within specified tolerances, and so maintained throughout prime coating. Prime coat shall not be placed on a soft, uneven base. When required, the surface to be primed shall be lightly bladed and compacted and the Engineer may instruct a light application of water to facilitate penetration. Priming will not be permitted when the surface is wet.

Prime coat shall not be applied when the ambient temperature is less than 13 deg. C or during rain, fog, dust storms or other unsuitable weather. The application temperature for MC-70 liquid asphalt shall be between 50deg. C and 80 deg. C as approved by the Engineer.

Traffic shall be kept off the prime coat until it has penetrated the subgrade or road base and fully cured. It should be left undisturbed for a sufficient period of time to allow adequate penetration of the prime coat or as otherwise-directed by the Engineer. The required period of time for penetration of the prime coat shall be determined by site trials conducted by the contractor to allow a minimum of 10mm of penetration of prime coat into the subbase, base or wet mix macadam course with no visible wet spots at the surface.

The Contractor shall furnish and spread at his cost sufficient clean fine sand, of an approved quality, to blot up areas which show an excess of prime coat.

The primed surface shall be maintained in a good, clean condition at all times until the next course is placed. Any surface irregularities or holes in the primed surface, however caused, shall be repaired and corrected to the Engineer's satisfaction.

b. Blotter Material

Blotter material, if required, shall be clean natural sand and shall comply with the requirements of the specifications given in Paragraph 4 of Sub-article b of Article 3.3.2.5.

3.4.1.3 Construction Requirements

a. Weather limitations

Prime coat shall not be applied when the ambient temperature is less than 13° C nor during rain, fog, dust-storms or other unsuitable weather.

b. Application Temperature

Application temperature for the MC-70 liquid asphalt shall be between 60° C and 85° C as directed by the Engineer.

c. Equipment Required

Equipment used by the Contractor shall include an asphalt distributor in accordance with Sub-article d of Article 3.3.3.1 as well as a power broom and a power blower. Power broom shall be self-propelled and equipped with a cylindrical, rotating nylon bristle brush of not less than 760 mm in diameter and not less than 1.8 m in length. Brush shall be capable of being angled to the right and left with adjustable ground pressure. Where necessary for the proper preparation of the surface, motor graders, rollers, water trucks, and other related equipment shall also be provided.

d. Surface Preparation

Immediately before applying the prime coat, all loose dirt, earth and other objectionable material shall be removed from the surface with a power broom of approved design and/or a power blower as required, and any ruts, soft spots or unacceptable irregularities in the surface shall be repaired in accordance with the instructions of the Engineer. If the Engineer so requires, the surface shall be lightly bladed and rolled immediately prior to the application of the prime coat, in which case brooming or blowing may not be required. Engineer may direct that a light application of water be made just prior to the application of liquid asphalt to facilitate penetration. Priming will not be permitted by the Engineer when there is free water present on the surface.

e. Method of Operation

After preparing the road surface as above, the liquid asphalt shall be applied by means of the distributor at the temperature and rate directed by the Engineer. Hand-spraying of restricted, inaccessible areas is permitted, subject to the approval of the Engineer.

Prime coat shall usually be applied to one half or one third of the road width at a time. When applied in two or more lanes, there shall be a 150 mm overlap of asphalt material along adjoining edges of the lanes. It should be noted that no overlapping is allowed at the transverse joints and that thick paper shall be used at the joint to protect the previous application and the joining application shall begin on the paper. After use, the paper shall be removed and satisfactorily disposed of by the Contractor. Care shall be taken that the application of bituminous material at the junctions of spreads is not in excess of the specified amount. Excess bituminous material shall be removed from the surface.

Prime coat shall be uniformly applied with the distributor within a maximum of 48 hours preceding placement of asphaltic concrete paving. Do not place plant mix bituminous courses until the prime coat has set.

f. Maintenance and Traffic

Traffic shall not be permitted on the primed surface until the asphaltic material has penetrated and dried and, in the judgment of the Engineer, will not be picked up under traffic. If it becomes necessary to permit traffic prior to that time, but in no case sooner than 24 hours after the application of the asphaltic material, blotter material shall be applied as directed by the Engineer and traffic shall be permitted to use the lanes so treated. Blotter material shall be spread from trucks operated backward so that the wheels will not travel in uncovered wet asphaltic material. When applying blotter material to an asphalt treated lane that adjoins a lane that has not been treated, a strip at least 200 mm wide along the adjoining edge shall be left devoid of blotter material in order to permit an overlap of asphalt material.

Contractor shall maintain the primed surface in a good clean condition and prior to the application of the next course, any surface irregularities shall be corrected and all excessive blotter material, dirt or other objectionable materials shall be removed.

3.4.2 Emulsified Asphalt Prime Coat

3.4.2.1 Description

This work shall consist of furnishing and applying emulsified asphalt prime coat to previously prepared and approved granular subbase/aggregate base courses or wet mix macadam prior to placement of hot mix asphalt layer. This work shall be performed as specified herein or as directed by the Engineer.

3.4.2.2 Materials

Emulsified asphalt shall be of slow setting type and shall comply with the following properties as shown in Table 3-40. Application Rate shall be between .8 l/m2 to 1.2 l/m2.However, the exact rate of application will be determined by the Engineer following trials to be carried out by the contractor:

Table 3- 40 Emulsified Asphalt Prime Coat

Property	Specification	Test Method
Water content (%m/m)	**42-46**	**ASTM D244**
Saybolt Furol Viscosity @ 50C (sfs)	**10-35**	**ASTM D 7496**
Residue on Sieving %	**<.10**	**ASTM D 6933**
Particles >710 micron		
Particles >150 micron	**<.25**	
Particle Charge	**Positive**	**ASTM D244**

***Emulsified asphalt prime coat shall be kept in a tank with proper agitation facilities to keep it homogenous**

3.4.2.3 Construction Requirements

The surface to be prime coated shall be uniformly smooth and firm and true to the grades and cross- section shown on the drawings within specified tolerances, and so maintained throughout prime coating.

Emulsified asphalt Prime coat shall not be applied when the ambient temperature is less than 10C, or during rain, fog, dust storms or other unsuitable weather. The emulsified asphalt can be applied cold, or it can be heated up to maximum temperature of 45C. and as approved by the Engineer.

Traffic shall be kept off the prime coat until it has penetrated the subgrade or road base and fully cured. It should be left undisturbed for a sufficient period of time to allow adequate penetration of prime coat or as otherwise directed by the Engineer. The required period of time for penetration of the emulsified asphalt prime coat shall be determined by site trials conducted by the contractor, which shall not be less than 6 hours to allow for a minimum of 8mm of penetration into the subbase, base ,or wet mix macadam with no visible wet spots at the surface.

The contractor shall furnish and spread at his own cost sufficient clean fine sand of an approved quality to blot up areas which shows an excess of prime coat.

The primed surface shall be maintained in a good clean condition at all times until the asphalt course is placed. Any surface irregularities, or holes, in the primed surface, however caused shall be repaired and corrected to the Engineers satisfaction.

3.4.3 Tack Coat

3.4.3.1 Description

This work shall consist of furnishing and applying slow setting emulsified asphalt tack coat to asphaltic base course, an existing road surface, concrete bridge deck, approach slabs and other concrete surfaces prior to placing asphaltic concrete wearing course in accordance with these specifications and the Contract plans or as directed by the Engineer.

3.4.3.2 Material

Emulsified asphalt shall be of the slow-setting Cationic or Anionic type of the CSS-1h or SS-1h grades respectively. Emulsified asphalt CSS 1h shall be in accordance with AASHTO M208 and SS 1h shall be in accordance with AASHTO M 140.

Approved emulsion will be diluted with approximately an equal quantity of water and thoroughly mixed as directed by the Engineer. Diluted emulsion shall be applied at a rate of 0.18 to 0.35 kg/m^2, unless shown otherwise on the Contract plans or as directed by the Engineer.

Specific gravity of asphaltic material shall be determined by ASTM D3142 standard which shall establish the kilograms per liter based on the specific gravity at 15.5° C for the material furnished.

3.4.3.3 Construction

a. Weather Limitations

Tack coat shall not be applied when the ambient temperature is less than 13° C nor during rain, fog, dust-storms or other unsuitable weather.

b. Application Temperature

Application temperature for the diluted emulsified asphalt shall be between 10° C and 60° C or as directed by the Engineer.

c. Equipment required

Equipment used by the Contractor shall include an asphalt distributor in accordance with Sub-article d of Article 3.3.3.1, as well as a power broom and a power blower. Power broom shall be self-propelled and equipped with a cylindrical, rotating nylon bristle brush of not less than 760 mm in diameter and not less than 1.82 m in length. Brush shall be capable of being angled to the right and left with adjustable ground pressure. In addition, the Contractor shall supply and utilize efficient and approved equipment for diluting the emulsified asphalt with water.

d. Surface Preparation

Full width of the surface to be treated shall be cleaned with a power broom or power blower to remove dust, dirt or other objectionable materials. All fatty or unsuitable patches, excess cracks or joint filler and all surplus bituminous material shall be corrected in accordance with the instructions of the Engineer. Surface shall be dry when treated.

e. Method of Operation

Immediately after cleaning the surface, the diluted emulsified asphalt shall be applied by means of the distributor truck at the temperature and rate directed by the Engineer. Hand spray of inaccessible areas is permitted, subject to the approval of the Engineer.

Mixing and placing of the asphaltic material shall progress at a rate so that contamination of previous lifts by dust and dirt and/or loss of bond capability shall not occur. If, in the opinion of the Engineer, loss of bond capability has taken place, an additional tack coat shall be applied to the surface of the previous lifts as directed by the Engineer.

Surface of structures, ~~kerb~~stones and other appurtenances adjacent to areas being treated shall be protected in such a manner as to prevent their being spattered or marred.

After application, the surface shall be cured prior to placement of asphalt concrete. Tack coat surface shall be protected prior to placement of the asphalt concrete.

Tack coat shall be uniformly applied with the distributor within 24 hours preceding the placement of the covering course.

If the tack coat is unavoidably damaged by rain or dust, or paving operations delayed longer than 24 hours, it shall be allowed to dry, shall be cleaned again by a power broom or power blower and, when directed by the Engineer, a subsequent light application of tack coat applied to the surface. No additional payment will be made by the department for this work.

Where, in the opinion of the Engineer, a tack coat is not necessary between layers of freshly placed courses, he may by written direction eliminate the tack coat, in which case there will be no payment for tack coat for the areas concerned. Any cleaning required in these areas shall be considered to be included in the overlaying asphaltic concrete course and no separate payment will be made.

3.5 Bituminous Surface Treatment

3.5.1 Single or Multiple Asphalt Surface Treatment

3.5.1.1 Description

This work consists of constructing a single or multiple asphalt surface treatment with aggregate or pre-coated aggregate. This work also includes constructing an asphalt fog seal without aggregate.

3.5.1.2 Material

a. Aggregates

Furnish hard, durable particles or fragments of crushed stone, crushed slag, or crushed gravel. Use only one type of aggregate on a project. Size, grade, and combine the aggregate fractions in mix proportions conforming to the following:

1. Los Angeles abrasion, AASHTO T 96: 40 % max.
2. Sodium sulfate soundness loss, AASHTO T 104: 12 % max.
3. Density, AASHTO T 19M: 1100 kg/m^3 min.

4. Coating and stripping of bitumen-aggregate Mixtures, AASHTO T182: 95 % min.
5. Adherent coating on the aggregate, ASTM D 5711: 0.5 % max.
6. Fractured faces, ASTM D5821: 75 % min.
7. Flakiness index, BS 812: Part 10: Section 105.1.: 30 max
8. Durability index (coarse), AASHTO T 210: 35 min.
9. Durability index (fine), AASHTO T 210: 35 min.
10. Free from Clay lumps and friable particles, AASHTO T 112.
11. Free from organic or other deleterious material

Do not use lightweight aggregate according to AASHTO M 195.

Grading shall be per designation type shown on the Contract plans or as included in the bills of quantities, as approved by the Engineer and as described in Table 3-38.

b. Asphalt

Asphalt is designated as shown in AASHTO M 20 or M 226 for asphalt binder and AASHTO M 140 or M 208 for emulsified asphalt.

Table 3-38: Target value ranges for single and multiple course surface treatment aggregate gradation

Sieve Size	Percent by mass passing designated sieve (AASHTO T 27 and AASHTO T 11)					
	Grading designation					
	A	B	C	D	E	F
37.5 mm	100*					
25 mm	90-100(3)	100*				
19 mm	0-35(5)	90-100(3)	100*			
12.5 mm	0-8(3)	0-35(5)	90-100(3)	100*		
9.5 mm	–	0-12(3)	0-35(5)	85-100(3)	100*	100*
4.25 mm	–	–	0-12(3)	0-35(5)	85-100(3)	85-100*
2.36 mm	–	–	–	0-8(3)	0-23(4)	–
75 µm	0-1*	0-1*	0-1*	0-1*	0-1*	0-10*

*Statistical procedures do not apply.
(X) Allowable deviations (±) from the target values

c. Submittals

Submit the following information and samples for approval at least 21 days before placement:

1. Aggregate samples: 35 kg from each stockpile produced and the gradation range represented by each
2. Aggregate gradation target values: Proposed percentage of each stockpile to be used and the proposed target value for each sieve size.

3.5.1.3 Application temperatures

Apply asphalt at temperatures according to construction requirements

3.5.1.4 Construction Requirements

a. Equipment

Furnish equipment as follows:

1. Asphalt distributor
   i. Capable of heating asphalt evenly
   ii. Adjustable full circulation spray bar to 4.6 m width
   iii. Positive controls including tachometer, pressure gauge, volume measuring device, or calibrated tank to uniformly deposit asphalt over the full width within 0.08 liter per square meter of the required rate
   iv. Thermometer for measuring the asphalt temperature in the tank
2. Asphalt samples: Two 1-liter samples of asphalt binder or emulsified asphalt from the same source and of the type to be used for the surface treatment
3. Spread rates: Proposed spread rate for the aggregate and asphalt material.

Table 3-39: Asphalt application temperatures – degrees C

Type and grade of asphalt	Temperature ranges minimum - maximum	
	Spraying temperatures	Mixing temperatures a
Cut-back asphalt		
MC-30	30 - [b]	
RC or MC-70	50 - [b]	
RC or MC-250	75 - [b]	60 - 80[c]
RC or MC-800	95 - [b]	75 - 100[c]
RC or MC-3000	110 - [b]	80 - 115[c]
Emulsified asphalt		
RS-1	20 - 60	
RS-2	50 - 85	
MS-1	20 - 70	20 - 70
MS-2, MS-2h	20 - 70	20 - 70
HFMS-1, 2, 2h, 2s	20 - 70[d]	10 - 70
SS-1, 1h, CSS-1, 1h CRS-1	50 - 85	20 - 70
CRS-2	60 - 85	
CMS-2, CMS-2h	40 - 70	50 - 60
Asphalt Binder All grades	180 max	180 max

[a] Temperature of mix immediately after discharge.
[b] Maximum temperature at which fogging or foaming does not occur.
[c] Temperature may be above flash point. Take precautions to prevent fire or explosion.

[d] For fog seals and tack coats.

4. Rotary power broom
   i. Self-propelled

ii. Capable of controlling the vertical broom pressure

5. Pneumatic-tire rollers. Furnish a minimum of two pneumatic-tire rollers both with the following capabilities:
   i. Self-propelled
   ii. Minimum compacting width – 1.5 m
   iii. Gross weight adjustable within the range of 3.5 to 6.5 kg per mm of compaction width
6. Aggregate spreader
   i. Self-propelled
   ii. Minimum of 4 pneumatic tires on 2 axles
   iii. Positive controls to uniformly deposit the aggregate over the full width of asphalt within 10 % by mass of the required rates
7. Other equipment: Other equipment of proven performance may be used in addition to or in lieu of the specified equipment when approved by the Engineer. Provide two-way communication between the asphalt distributor and the aggregate spreader if the roadway alignment does not permit visual contact.

b. Surface Preparation

On existing asphalt surfaces, ensure that the surface is dry. Immediately before placing the layer, remove loose dirt and other objectionable material from the surface by approved methods. Fog seal patches using a slow setting emulsion diluted with equal part water. Apply the diluted emulsion at a rate of 0.65 liters per square meter.

On existing aggregate surfaces, prime the surface according to Section 3.4.1. Allow the primed surface to cure at least 5 days for cutback asphalt or 24 hours for asphalt emulsions. Ensure that the primed surface is dry for surface treatments using asphalt binder or slightly damp for surface treatments using emulsified asphalt.

c. Weather Limitations

Apply surface treatments with aggregate only when ambient air and surface temperatures are above 16° C and rising, when the weather is not foggy or rainy, and when rain is not anticipated for at least 24 hours after application.

Apply fog seals only when the ambient air and surface temperatures are above 10° C and rising, when the weather is not foggy or rainy, and when rain is not anticipated for at least 24 hours after application.

Complete all surface treatment applications 2 hours before sunset.

d. Production Start-up Procedures for Surface Treatments

At least 10 days before the start of constructing all surface treatments containing aggregate, arrange for a pre-surface treatment conference. Coordinate attendance with the Engineer and any applicable subcontractors. Be prepared to discuss or submit the following:

1. Proposed schedule of operations
2. List of all equipment and personnel to be used in the production and construction of the work
3. Proposed traffic control plan
4. Establish minimum frequency schedule for process control sampling and testing (to be performed by the Contractor)
5. Discuss asphalt and aggregate application procedures
6. Discuss spill prevention and safety contingency plan

7. Provide 7 days advance notice before constructing all asphalt surface treatments containing aggregate. Also use these start-up procedures when resuming production after termination due to nonconforming work

On the first day of placement of each surface treatment layer, or whenever there is a change in the surface texture or aggregate gradation, construct a 150-meter control strip that is one-lane wide.

Construct the control strip using material, lay-down, and compaction procedures intended for the remainder of the surface treatment. Cease production after construction of the control strip until the material and the control strip are evaluated and accepted.

Acceptable control strips may remain in place and will be accepted as a part of the completed surface treatment.

Repeat the control strip process until an acceptable control strip is produced.

e. Asphalt Application

Calibrate the asphalt distributor spray bar height, nozzle angle, and pump pressure and check longitudinal and transverse spread rates weekly according to ASTM D 2995. If different asphalt distributors are used, calibrate each before use on the project. Ensure that the length of the spread is no more than can be covered with aggregate immediately after application.

Protect the surfaces of nearby objects to prevent spattering or marring. Spread building paper on the surface for a sufficient distance from the beginning and end of each application so the flow through the distributor nozzles may be started and stopped on the paper.

Engineer will approve the exact application rate, temperature, and area to be treated before application and may make adjustments for variations in field conditions. Apply the asphalt uniformly with an asphalt distributor. Move distributor forward at the proper application speed at the time the spray bar is opened. Use care not to apply excess asphalt at the junction of spreads.

Correct skipped areas or deficiencies. Remove and dispose of paper or other material used.

f. Aggregate Application

When using asphalt binder, the aggregate surface should be dry. When using emulsified asphalt, the aggregate surface should be moist.

Engineer will approve the exact application rate and area to be treated before application. Apply the aggregate uniformly with an aggregate spreader immediately after the asphalt is applied. Operate aggregate spreader so the asphalt is covered with the aggregate before wheels pass over it. During part-width construction, leave uncovered a strip of sprayed asphalt approximately 150 mm wide to permit an overlap of asphalt material.

Immediately correct excesses and deficiencies by brooming or by the addition or removal of aggregate until a uniform texture is achieved. Use hand methods in areas not accessible to power equipment.

When pre-coated aggregates are used, they may be mixed on the job or at a central mixing plant. Uniformly coat the aggregate with 1.0 to 2.0 % residual asphalt, by weight of aggregate. Maintain the flow qualities of the pre-coated aggregate, so it is satisfactorily spread with an aggregate spreader.

Operate rollers at a maximum speed of 8 km/hr. Do not permit the aggregate to be displaced by pickup or sticking of material to the tire surface. Sufficiently roll the surface to uniformly and thoroughly bond the aggregate over the full width. Complete rolling within 1 hour after the asphalt is applied to the surface.

g. Single-Course Surface Treatment

A single-course surface treatment consists of applying asphalt material onto an existing surface immediately followed by a single, uniform application of aggregate. Apply the asphalt and aggregate at the approximate rates shown in Table 3-40. Determine the exact rates based on approved control strips.

During the initial 45 minutes after completion of rolling, limit the traffic speeds to 15 km/hr. Limit traffic speeds to 30 km/hr for 24 hours.

Lightly broom the aggregate surface on the morning after construction. Maintain the surface for 4 days to absorb any free asphalt and by repairing areas deficient in aggregate. Sweep excess material from the surface using a rotary power broom when the temperature is less than 24 °C. Do not displace embedded material.

Table 3-40 Quantities of material for single-course surface treatment

Designation	Nominal maximum size of aggregate	Aggregate gradation[(a)]	Estimated quantity of aggregate [(b)] kg/m^2	Estimated quantity of emulsified asphalt[(c)] L/m^2	Estimated quantity of asphalt binder[(c)] L/m^2
1A	19.0 mm	B	22 – 27	1.8 – 2.5	1.2 – 1.7
1B	12.5 mm	C	14 – 16	1.4 – 2.0	0.9 – 1.4
1C	9.5 mm	D	11 – 14	0.9 – 1.6	0.6 – 1.1
1D	4.75 mm	E	8 – 11	0.7 – 1.0	0.5 – 0.8
1E	Sand	F	5 – 8	0.5 – 0.8	0.4 – 0.7

(a) See Table 3-38 for aggregate gradations.
(b) Aggregate masses are for aggregates having a bulk specific gravity of 2.65, as determined by AASHTO T 84 and T 85. Make proportionate corrections when the aggregate furnished has a bulk specific gravity above 2.75 or below 2.55.
(c) Adjust the asphalt content for the condition of the road.

Table 3-41: Quantities of material for double course surface treatments

Designation (Thickness)	Nominal maximum size of aggregate	Aggregat e gradation [(a)]	Estimated quantity of aggregate [(b)] kg/m^2	Estimated quantity of emulsified asphalt[(c)] L/m^2	Estimated quantity of asphalt Binder[(c)] L/m^2
2A (12.5 mm)					
1st Application	9.5 mm	D	14 – 19	0.9 – 1.4	0.5 – 1.0
2nd Application	4.75 mm	E	5 – 8	1.4 – 1.8	0.8 – 1.3
2B (16.0 mm)					
1st Application	12.5 mm	C	16 – 22	1.4 – 1.8	0.8 – 1.3
2nd Application	4.75 mm	E	8 – 11	1.8 – 2.3	1.1 – 1.5
2C (19.0 mm)					
1st Application	19.0 mm	B	22 – 27	1.6 – 2.3	1.0 – 1.5
2nd Application	9.5 mm	D	11 – 14	2.3 – 2.7	1.5 – 1.9

(a) See Table 3-38 for aggregate gradations.
(b) Aggregate masses are for aggregates having a bulk specific gravity of 2.65, as determined by AASHTO T 84 and T 85. Make proportionate corrections when the aggregate furnished has a bulk specific gravity above 2.75 or below 2.55.

[(c)] Adjust the asphalt content of the first application for the condition of the road.

h. Double and Triple-Course Surface Treatment

Double- and triple-course surface treatments consist of applying multiple layers of asphalt and aggregate. Apply each asphalt and aggregate layer according to the approximate rates shown in Table 3-41 and Table 3-42. Determine the exact rates based on approved control strips.

No wait is required between surface treatment applications when using an asphalt binder. Wait at least 24 hours between applications when using emulsified asphalt.

Table 3-42: Quantities of material for triple-course surface treatments

Designation (thickness)	Nominal maximum size of aggregate	Aggregate gradation[(a)]	Estimated quantity of aggregate [(b)] kg/m^2	Estimated quantity of emulsified asphalt[(c)] L/m^2	Estimated quantity of asphalt binder[(c)] L/m^2
3A (12.5 mm)					
1st Application	9.5 mm	D	14 – 19	0.9 – 1.4	0.5 – 1.0
2nd Application	4.75 mm	E	5 – 8	1.1 – 1.6	0.7 – 1.2
3rd Application	Sand	F	5 – 8	0.9 – 1.4	0.5 – 1.0
3B (16.0 mm)					
1st Application	12.5 mm	C	16 – 22	0.9 – 1.4	0.5 – 1.0
2nd Application	9.5 mm	D	8 – 11	1.4 – 1.8	0.8 – 1.3
3rd Application	4.75 mm	E	5 – 8	0.9 – 1.4	0.5 – 1.0
3C (19.0 mm)					
1st Application	19.0 mm	B	19 – 25	1.1 – 1.6	0.7 – 1.2
2nd Application	9.5 mm	D	11 – 14	1.4 – 1.8	0.8 – 1.3
3rd Application	4.75 mm	E	5 – 8	1.1 – 1.6	0.7 – 1.2

[(a)] See Table 3-38 for aggregate gradations.
[(b)] Aggregate masses are for aggregates having a bulk specific gravity of 2.65 as determined by AASHTO T 84 and T 85. Make proportionate corrections when the aggregate furnished has a bulk specific gravity above 2.75 or below 2.55.
[(c)] Adjust the asphalt content of the first application for the condition of the road.

i. Acceptance

See Table 3-43 for sampling and testing requirements. Asphalt binder, and emulsified asphalt and aggregate will be evaluated under Article 3.5.1.2.

Table 3-43: Sampling and testing requirements

Material or product	Type of acceptance	Characteristic	Test methods specifications	Sampling frequency	Point of sampling	Split sample	Report time
Aggregate surface treatment source quality [(a)]	Measured and tested for conformance	LA abrasion	AASHTO T96	1 per type and source of material	Source of material	Yes, when requested	Before using
		Sodium sulfate soundness	AASHTO T104	1 per type and source of material	Source of material	Yes, when requested	Before using
		Fractured faces	ASTM D5821	1 per type and source of material	Source of material	Yes, when requested	Before using
		Flat and	ASTM D4791	1 per type	Source of	Yes, when	Before

Material or product	Type of acceptance	Characteristic	Test methods specifications	Sampling frequency	Point of sampling	Split sample	Report time
		elongated		and source of material	material	requested	using
		Durability index (coarse and fine)	AASHTO T210	1 per type and source of material	Source of material	Yes, when requested	Before using
		Clay lumps and friable particles	AASHTO T112	1 per type and source of material	Source of material	Yes, when requested	Before using
Aggregate surface treatment aggregate (a)	Statistical	Gradation	AASHTO T27 and T11	1 per 750 t	Production belt or spreader	Yes	24 hours
	Measured and tested for conformance	Fractured faces	ASTM D5821	1 per 750 t	Production belt or spreader	Yes	24 hours
		Liquid limit (b)	AASHTO T89	1 per 750 t	Production belt or spreader	Yes	24 hours
Asphalt binder(c) or emulsified asphalt(c)	Measured and tested for conformance	Quality	AASHTO M 20 or M 226 for asphalt binder AASHTO M 140 or M 208 for emulsified asphalt	1 per tanker truck including trailer	Point of shipment delivery	Two 1-litre samples	-

(a) Applies to each aggregate grade furnished. (b) For blotter material only. (c)Applied to each asphalt material furnished.

3.5.2 Micro Surfacing Specifications

Micro Surfacing is a cold mix blend of high quality aggregates, polymer modified emulsions, water and mineral fillers mixed according to a predetermined mix design from a laboratory.

It is applied to existing, higher volume, heavy traffic roads and highways that are still in fair to good condition, as a means of a cost effective preventative maintenance. It can reduce deterioration by sealing, prevents further oxidization, corrects raveling and provides or replaces a high degree of skid resistance. It can also correct wheel rutting, (up to 38mm thick) or re-profile a road. It has a life expectancy exceeding seven years.

It is applied to existing pavements using a specialized micro box, (more comparable to a paver screed than a slurry box) which is connected to the micro mixing unit, as shown on the right. The micro box is variable width, allowing total coverage of a single lane in one pass.

Crews ahead of the unit set up traffic control, and sweep the road before applying the micro surface. Operators of the units monitor the mixing and application. After a short curing time traffic will be allowed to resume use of the freshly rehabilitated lane.

There are 3 different classes of Micro Surfacing, each using different size aggregates:

1. Type I: (fine aggregate) Recommended for Maintenance work.
   Recommended application rates are 4.5 - 6.5 kg/ m^2
2. Type II: (6.4mm aggregate) Recommended for Urban and Residential Streets and Airport Runways. Recommended application rates are 5.4-10.8 kg/ m2
3. Type III: (9.5mm aggregate) Recommended for highways and wheel ruts.
   Recommended application rates are 8.1-16.3 kg/ m2

3.5.2.1 Description

The Contractor shall furnish all labour, equipment, material, supplies, signage, traffic control, and other incidentals necessary to provide Micro Surfacing. Micro Surfacing shall consist of a mixture of an approved polymer-modified emulsified asphalt, mineral aggregate, water, and specified additives, proportioned, mixed and uniformly spread over a properly prepared asphalt surface. The completed Micro Surfacing shall leave a homogeneous mat, adhere firmly to the prepared surface, and have a skid-resistant surface texture throughout its service life.

3.5.2.2 Materials

a. Emulsified Asphalt Material

The emulsion for Micro Surfacing shall be Emulsified Asphalt grade (CQS-1P) conforming to ASTM D 2397 and AASHTO M 208. The modified emulsion shall contain a minimum of 3% polymer, SBR latex, or natural latex by weight.

Table 3-44: Emulsified asphalt material requirements

Test on Emulsion	Minimum	Maximum	AASHTO Test
Viscosity, Say bolt Furol, 25o C,s	15	100	T-59
Storage Stability Test, One day, %		1	T-59
Particle Charge Test	Positive		
Sieve Test, %(a)		0.1	T-59
Distillation:			
Oil distillate, by volume, %	-	.5	T-59
Residue, %	62*	-	T-59
Test on Residue from Distillation:			
Penetration, 25o C, 100g, 5s	40	90	T-49
Ductility, 25o C, 50 mm / sec	50	-	T-51
Solubility in Trichloroethylene, %	97	-	T-44
Softening Point, Ring-and-Ball, C	57.2	-	T-53

*The standard distillation procedure shall be modified as follows:

The temperature on the lower thermometer shall be brought slowly to 175^{o} C ±5^{o} C and maintained at this point for 20 minutes. The total distillation shall be completed in 60 ±5 minutes from the first application of heat.

b. Aggregate

The aggregate shall consist of manufactured granite crusher fines. The smooth_textured crusher fines shall have less than 1.25% water absorption. The aggregate shall be grey in colour and clean and free from organic matter, other deleterious substances and clay balls.

Oversized granular material and/or presence of clay balls will require the project to be stopped and shall meet the following requirements:

Table 3-45: Gradation Table Aggregate (percent passing)

Sieve Size	Type I	Type II	Type III	Tolerance
9.50 mm	-	100	100	
4.76 mm	100	90-100	70-90	+ or - 5%
2.38 mm	90-100	65-90	45-70	+ or - 5%
1.19 mm	60-90	45-70	28-50	+ or - 5%
0.60 mm	40-65	30-50	19-34	+ or - 5%
0.30 mm	-	18-30	7-18	+ or - 4%
0.15 mm		10-21	7-18	+ or - 3%
0.075 mm	10-20	5-15	5-15	+ or - 2%
Resistance to Degradation		(ASTM C131grading D)		15% maximum loss
Soundness of Aggregate		(ASTM C88)		10% maximum loss
Sand Equivalent Value		(ASTM D2419A)		65 minimum
LA Abrasion		(AASHTO T96)		20% maximum loss

c. Mineral Filler

Cement, or other approved filler meeting the requirements of AASHTO M 17 or ASTM D242 shall be used if required by the mix design. They shall be considered as part of the dry aggregate.

d. Water

All water used shall be potable and free of dissolved materials which may affect the mix characteristics or finished characteristics of the product. Filler shall be of the specific type specified in the mix design.

e. Additives

Additives may be used to accelerate or retard the break-set of the Micro Surfacing or to improve the resulting finished surface. The use of additives in the Micro Surfacing mix (or individual materials) shall be made initially in quantities predetermined by the mix design with field adjustments, if required, after approval by the Engineer.

3.5.2.3 Micro Surfacing Mix Design Specifications

Before work begins, the Contractor shall submit a mix design covering the specific materials to be used on the project. The manufacturer of the polymer modified emulsion shall develop the job mix formula and present certified test results for the Contractor's approval. Compatibility of the aggregate and polymer modified emulsified asphalt shall be certified by the emulsion manufacturer. The mix design shall be in accordance with the ISSA TB-136 Wet Track Abrasion Loss, Six Day Soak with a maximum loss of 807.4 grams/m^2. The emulsion supplier shall also provide a base line of emulsion to the Owner for testing of latex percentages. The Micro Surfacing mixture shall meet the specifications shown in Table 3-46.

Table 3-46: Micro Surfacing Mixture specification

ISSA TEST NO.	DESCRIPTION	SPECIFICATION
ISSA TB-113	Mix Time at 23.9°C	Controllable to 120 seconds minimum
ISSA TB-114	Wet Stripping	Pass (90% Minimum)
ISSA TB-139	Wet Cohesion	

ISSA TEST NO.	DESCRIPTION	SPECIFICATION
	@ 30 Minutes Minimum (Set) @ 60 Minimum Minimum (Traffic)	12 kg-cm Minimum 20 kg-cm or Near Spin Minimum
ISSA TB-100	Wet-Track Abrasion Loss One-hour Soak Six-day Soak	 540 g/m² Maximum 800 g/m² Maximum
ISSA TB-147	Lateral Displacement Specify Gravity after 1,000 Cycles of 55 kg	5% Maximum 2.10 Maximum
ISSA TB-109	Excess Asphalt by LWT Sand Adhesion	540 g/m² Maximum
ISSA TB-144	Classification Compatibility	11 Grade Points Minimum (AAA, BBA)

*ISSA – International Slurry Surfacing Association

3.5.2.4 Composition of Mixture

The Owner shall approve the design mix and all Micro Surfacing materials and methods prior to use and shall designate the proportions to be used within the following limits:

- Residual Asphalt: 5.5% to 10.5% by dry weight of aggregate
- Mineral Filler: 0% to 3% by dry weight of aggregate
- Polymer Based Modifier: Shall be a minimum of 3% solids content
- Water (Potable): As required to provide proper consistency

3.5.2.5 Construction Requirements

a. Equipment

The machine shall be specifically designed and manufactured to apply Micro Surfacing. The material shall be mixed by an automatic-sequenced, self-propelled Micro Surfacing mixing machine. It shall be a continuous-flow mixing unit that accurately delivers and proportions the mix components through a revolving multi-blade, double-shafted mixer. Sufficient storage capacity for all mix components is required to maintain an adequate supply to the proportioning controls.

When specifying continuous machinery to minimize transverse joints, the specified machine must be capable of loading materials while continuing to apply Micro Surfacing. The continuous-run machine shall be equipped to provide the operator with full control of the forward and reverse speeds during application. It shall be equipped with opposite-side driver stations to assist in alignment. The self-loading device, opposite-side driver stations, and forward and reverse speed controls shall be of original-equipment-manufacturer design.

b. Spreading Equipment

The mixture shall be agitated and spread uniformly in the surfacing box by means of twin shafted paddles or spiral augers fixed in the spreader box. A front seal shall be provided to insure no loss of the mixture at the road contact point. The rear seal shall act as a final strike-off and shall be adjustable. The spreader box and rear strike-off shall be so designed and operated that a uniform consistency is achieved and a free flow of material is provided to the rear strike-off. The spreader box shall have suitable means provided to side shift the box to compensate for variations in the pavement geometry.

c. Calibration

Each mixing unit to be used in the performance of the work shall be calibrated in the presence of the Engineer prior to the start of the project. Previous calibration documentation covering the exact materials to be used may be acceptable, provided that no more than 60 days have lapsed. The documentation shall include an individual calibration of each material at various settings that can be related to the machine metering devices. Any component replacement affecting material proportioning requires that the machine be recalibrated. No machine will be allowed to work on the project until the calibration has been completed and/or accepted. ISSA Inspector's Manual describes a method of machine calibration. ISSA contractors and/or machine manufacturers may also provide methods of machine calibration.

d. Lines

Care shall be taken to insure straight lines along kerbs and shoulders. No runoff on these areas will be permitted. Lines at intersections shall be kept straight to provide a good appearance.

e. Handwork

Approved hand squeegees, with burlap drags, shall be used to spread Micro Surfacing in areas not accessible to the Micro Surfacing spreader box. Care shall be exercised in leaving no unsightly appearance from handwork.

f. Curing

Areas receiving Micro Surfacing will be allowed to cure from one to three hours or until the treated pavement will not be damaged by traffic. The Contractor will protect the area with suitable barricades or markers for the full curing period. Areas which are damaged within 24 hours of application of Micro Surfacing, or prior to moving to new work locations, shall be repaired by the Contractor at his expense.

g. Surface Preparation

Immediately prior to applying the Micro Surfacing, the surface shall be cleared of all loose material, oil spots, vegetation and other objectionable material. Any standard cleaning method will be acceptable. If water is used, cracks shall be allowed to dry thoroughly before Micro Surfacing. Manholes, valve boxes, drop inlets and other service entrances shall be protected from the Micro Surfacing by a suitable method. The Engineer shall approve the surface preparation prior to surfacing.

h. Weather Limitations

Micro surfacing shall not be applied if either the pavement or air temperature is below 10°C and falling, but may be applied when both pavement and air temperatures are above 7°C and rising. No Micro Surfacing shall be applied when there is the possibility of freezing temperatures at the project location within 24 hours after application. The Micro Surfacing shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

i. Notification

All homeowners and businesses affected by the paving shall be notified 24 hours in advance of the surfacing. Suitable tow-away signs may be posted prior to the surfacing. Should work not occur on the specified day, a new notification will be distributed. The notification shall be in a form of written posting, stating the time and date that the surfacing will take place.

j. Traffic Control

Suitable methods shall be used by the contractor to protect the Micro Surfacing from damage from all types of vehicular traffic. Opening to traffic does not constitute acceptance of the work. The Engineer shall be notified of the methods to be used. In areas that are subject to an increased rate of sharp-turning vehicles, additional time may be required for a more complete cure of the Micro

Surfacing mat to prevent damage. Slight tire marks may be evident in these areas after opening but will diminish over time with rolling traffic. If these areas are not severely rutted, they should be considered as normal characteristics of a Micro Surfacing.

k. Clean Up

All areas, such as man-ways, gutters and intersections, shall have the Micro Surfacing removed as specified by the Engineer. The Contractor shall remove any debris associated with the performance of the work on a daily basis.

3.6 Miscellaneous Pavement Items

3.6.1 Coloured Bituminous Pavement

3.6.1.1 Description

This work consists of supplying and applying coloured bituminous pavement surfaces of the type and colour as shown in the Contract plans or as included in the Particular Specifications. This Specification provides the requirements for the following types of coloured pavement:

1. Coloured bituminous paving final top course, where the colour additives are added to the bituminous mixture at time of mixing in the batch plant.
2. Colour additives included in the emulsified asphalt used for surface treatment.
3. Coloured surface coatings.

3.6.1.2 Materials

a. Contractor Submittals

Contractor shall prepare and submit to the Engineer for approval trial pavement samples of the type and colours as shown on the Contract plans or as included in the Particular Specifications. Trial sample sizes, numbers and methods shall be agreed with the Engineer prior to preparation which may require a full size trial section for final approval by the Owner.

For coloured bituminous paving final course and surface treatments the submittal shall include the pigment manufacturers name, pigment name and number and details of the final mix, stipulating where this mix deviates from the approved wearing course final layer bituminous pavement mix or surface treatment materials. Details shall include such items as quantity of the pigment added and mixing time, any use of clear asphalt, any use of coloured aggregate, and associated details as needed to supply a consistent and Owner accepted coloured pavement surfacing.

The Contractor submittals for coloured surface coatings shall meet the requirements of Article 8.2.2.8 of Chapter 8, Traffic Marking and Signs, of these Standard Specifications.

b. Bituminous Mixes

Materials for coloured top course bituminous mixes shall meet the applicable requirements in Section 3.3.2 with the addition of a pigment (colorant) that is usually added at the time of the asphalt mixing in a powder or pelletized form. Replacement of the bitumen binder with a clear binder or the aggregate with coloured aggregate may be necessary to achieve the require colour tint. Such replacement shall be done with materials of similar properties as otherwise specified and approved by the Engineer. Application rates of the pigment and mixing requirements shall be made as per the initial suggestions of the pigment supplier or manufacture, and then adjusted as necessary to meet the final approved colour tint, as approved by the Engineer.

Materials for coloured surface treatments shall meet the requirements of Article 3.5.1.2 with the addition of an approved colour pigment pre-mixed with the bitumen prior to application. Replacement of the bitumen binder with a clear binder or the aggregate with coloured aggregate may be necessary to achieve the require colour tint. Such replacement shall be done with materials of similar properties as otherwise specified and approved by the Engineer. Application rates of the pigment to the bitumen shall be made as per the initial suggestions of the pigment supplier or manufacture, and then adjusted as necessary to meet the final approved colour tint, as approved by the Engineer.

c. Coloured Surface Coatings

Materials for coloured-surface coatings shall meet the requirements of Article 8.2 of Chapter 8, Traffic Marking and Signs, of these Standard Specifications.

3.6.1.3 Construction Requirements

Installation of coloured top course bituminous pavement shall meet the requirements of Section 3.3.3. Installation of coloured bituminous surface treatment shall meet the requirements of Article 3.5.1.4. Installation of coloured epoxy surface coatings shall meet the requirements of Section 8.2 of Chapter 8, Traffic Marking and Signs, of these Standard Specifications.

3.6.2 Speed humps

3.6.2.1 Description

Work consists of construction of speed humps, or installation of temporary speed humps, as shown in the Contract plans, specified in the Particular Specifications, and as approved by the Engineer.

3.6.2.2 Materials

a. Asphalt Concrete

Asphalt concrete shall meet the requirements of either Sub-article a) of Article 3.3.2.5 or Paragraph 1 of Sub-article b of Article 3.3.2.5 as defined for wearing course layers for hot mix asphalt.

b. Tack Coat

Tack coat shall meet the requirements of Article 3.4.3.2.

c. Temporary Speed Humps

Temporary speed humps to be provided by the Contractor shall be new prefabricated rubber product in accordance with traffic calming safety standards and specifications outlined by Institute of Transportation Engineers (ITE), that are capable of being removed and reinstalled numerous times without showing signs of excessive wear and tear. Type of temporary speed humps shall be as shown on the Contract plans or described in the Particular Specifications, and as approved by the Engineer.

d. Striping

Striping for speed humps shall be white plastic preformed permanent pavement marking tape material meeting the requirements of Article 8.2.2.11 or a white Thermoplastic marking material meeting the requirements of Article 8.2.2.5, or of type as shown on the Contract plans and as approved by the Engineer .

Temporary speed humps will normally be pre-striped by the manufacture, and if not, the striping material shall meet the requirements of this Specification Section.

e. Signing

Signing for speed humps shall be the type and size shown on the Contract plans meeting the applicable requirements of Section 9.5, of Chapter 9, Traffic Control System, of these Standard Specifications.

3.6.2.3 Construction Requirements

a. General

Contractor shall submit a method statement to the Engineer for approval prior to the start of construction of speed humps. Method statement shall include schedule, timing, construction methods and details including type and number of equipment to be used, material to be used with the necessary material approval submittals, and detailed traffic management plan.

If construction of speed humps is on existing streets where no other construction work having traffic detours is already in place, Contractor shall apply for and provide to the Engineer proof of acceptance that the necessary street traffic closure has been approved by the concerned authorities. Closures shall be temporary, with work performed during the day and the street reopened to traffic by the end of the normal work day, all as approved by the Engineer.

Speed humps shall be constructed at the locations and to the shapes and configurations shown in the Contract plans. Speed humps are to be constructed of asphalt top (wearing) course, across and 60 cm narrower than width of existing pavement, leaving 30 cm wide open area between outer most edge of speed hump and pavement edge for drainage purposes.

Use any method necessary to form parabolic shape and to achieve proper height of speed hump. One such proven method for forming a parabolic shape of speed hump is to construct template from minimum 5 m long wooden board, with centre portion of bottom of template cut into basic parabolic shape of speed hump, leaving 60 cm flat area at each end of template. To stiffen template and to minimize any bending of template, attach aluminium or steel channel section to top portion of template.

After initial placement of asphalt (before compaction and while asphalt is still fresh and pliant) form asphalt surface into basic parabolic shape using template. With flat ends of template resting on abutting pavement surface, drag or shimmy template across asphalt surface forming basic parabolic shape of speed hump. During compaction it may be necessary to remove excess asphalt material, or place additional asphalt material. Repeat template operation until speed hump is fully compacted and has achieved its proper height and shape.

Do not perform final rolling operation until required parabolic shape of each speed hump has been approved by the Engineer

Pavement markings and striping are to be installed per the layout and configurations shown on the Contract plans and per the requirements included in Section 8.2.3 of Chapter 8, Pavement Marking and Signs, for the respective approved striping materials. Signing shall be installed as shown on the Contract plans and per the appropriate signing types as included in Section 9.5.3 of Chapter 9, Traffic Control System, of these Standard Specifications.

b. Installation of Speed Humps on Existing Pavement

Construct keyway 60 cm wide in shape of speed hump and across existing pavement where speed hump is to be installed. Keyway is to be constructed by saw cutting existing pavement minimum of 38 mm deep along outer most edge of speed hump, then milling on bias to 0 mm at inner edge of keyway. Thoroughly clean pavement surface, and apply tack coat making sure to completely cover surface area. Tack coat must be applied before placement of any new asphalt material, and between any and all subsequent asphalt courses.

c. Installation of Speed Humps as Part of New Pavement Laying or Pavement Resurfacing Work

Finish paving street with asphalt top course up to outer most limits of speed hump before constructing speed hump. Take extra steps to ensure that portion of asphalt top course placed within 30 cm wide open area between outer most edges of speed hump and pavement edge is properly compacted. Speed hump is to be constructed on top of the asphaltic base course. Thoroughly clean pavement surface, and apply tack coat making sure to completely cover surface area. Tack coat must be applied before placement of any new asphalt material, and between any and all subsequent asphalt courses.

If Contractor elects to, or inadvertently, paves the entire street without making allowances for speed hump construction, speed hump is to be constructed in accordance with Sub-article b of Article 3.6.2.3.

d. Installation of Temporary Speed Humps

Speed hump warning signs are to be installed minimum of 10 calendar days in advance of installation of temporary speed humps. Speed hump warning signs are to be installed on sign posts at each temporary speed hump location. Speed hump warning signs are to be covered until temporary speed humps have been installed.

Temporary speed hump is to be installed across and 60 centimetre shorter than width of existing pavement, leaving 30 centimetre wide open area between outer most edge of temporary speed hump and pavement edge for drainage purposes. Prior to installation of temporary speed hump, existing pavement area is to be thoroughly cleaned. Installation of temporary speed humps is to be in accordance with manufacturer's instructions. Maintain temporary speed humps, making any adjustments or re-installation necessary to ensure that temporary speed humps remain properly situated.

If temporary speed humps do not come pre-striped, pavement markings are to be installed using methods described in Sub-article a) of Article 3.6.2.3.

For Owner supplied speed humps, Contractor shall obtain the temporary speed humps including all appurtenances and mounting hardware from the Owners stores and otherwise install as required in this Specification Section. Contractor shall supply any additional mounting equipment, hardware and bonding agent as may be needed to properly install the Owner supplied temporary speed humps as recommended by the manufacturer.

Contractor shall remove any temporary speed humps and hardware when directed by the Engineer within the project limits, permanently restore existing pavement, filling in all holes necessitated for installation of temporary speed hump anchoring system.

Removed temporary speed humps will remain the property of the Contractor to be removed from the site, except where required in the Contract Documents that they remain the property of the Owner. Contractor shall protect, package and deliver to Owner store yards as directed by the Engineer, all temporary speed humps and hardware that are to remain the property of the Owner. Any materials to remain the property of the Owner, that are damaged beyond repair, are to be replaced with new materials.

3.6.3 Sand asphalt for foot path

3.6.3.1 Introduction

When bituminous materials are being applied, the surface of all structures, foot path, wheel guards, guard rail, kerbs and gutters, and other, roadway appurtenances shall be protected in an approved manner to prevent them from being splattered with bituminous material. The contractor shall at his own expense, remove all the trace of bituminous material, and repaired all the damage, and leave the appurtenance in an approved condition.

3.6.3.2 Material and Mix Design

a. Aggregate

Aggregate should be crushed rock or gravel. Aggregate gradation for sand asphalt concrete is shown in the following table:

Table 3-47: Sand Asphalt Gradation

ASTM test sieve (mm)	Percent passing by weight
9.5	100
4.75	80 – 100
2.36	65 – 100
1.18	40 – 80
0.600	25 – 65
0.300	7 – 40
0.150	3 – 20
0.075	2 – 10
Asphalt Binder by weight of total mix	5 – 12 %

b. Bitumen grade

The binder shall be normal black bitumen (penetration grade 40 – 50)

c. Design criteria

Marshall Method of mix design (Asphalt Institute Manual series MS – 2) will be used in designing the asphaltic concrete mix. The contractor proposed mix design shall be cross checked prior to approval.

The mix design for the sand asphalt shall be as follows:

Table 3-48: Sand Asphalt Mix requirements

Properties	Sand Asphalt Mix
Marshall Stability (kgf)	900 Min
Flow (mm)	2 – 5
Percentage air voids (VIM)	3 – 18
Design Binder Content	5 – 12

3.6.3.3 Construction Requirements

a. Laying of sand asphalt

The sand asphalt shall be laid by paving machine unless otherwise approved by the Engineer.

b. Trial area

The contractor shall prepare trial area 2 meter wide by 10 meter long as part of acceptance procedure of the mix.

c. Weather limitation for paving operations

- Hot bituminous mix shall be placed when weather is not dusty, fogy, or rainy and when the existing surface is free from moisture. Bituminous mix shall not be placed during sand storms.
- Prime and tack coat should only be applied when ambient temperature 16˚C.
- No paving operation shall be started if rain is imminent.

3.6.4 Recycled Asphalt Pavement in Hot Mix Asphalt

3.6.4.1 Scope

This specification provides the minimum requirements for the inclusion of recycled asphalt pavement to replace a percentage of the raw materials in new hot mix asphalt.

3.6.4.2 Description

Recycled asphalt pavement (RAP) shall consist of a blend of clean, hard, durable crushed rock, sand, filler and bitumen which is available from pavement rehabilitation or rejected and surplus asphalt production.

It generally comprises 3 to 5% bitumen by mass with the balance generally consisting of clean hard durable aggregate. RAP is used as aggregate and bitumen in new asphalt pavement layers.

RAP is typically recovered by milling or excavating existing asphalt pavements or as waste from asphalt production. RAP that is recovered by milling or as plant waste is generally clean RAP with no contaminants. RAP that is recovered to full depth by conventional excavation can become contaminated during the removal process and is not normally suitable for reuse in new asphalt.

3.6.4.3 Materials

a. Stockpile Management Plan

The contractor/supplier shall prepare a Stockpile management plan for the RAP to ensure a consistent quality product is achieved. The management plan shall be submitted to the Engineer for acceptance, before the RAP can be used on the project

The Stockpile Management Plan shall detail the stockpiling, processing, storage and testing requirements of each Lot and should be in place at each RAP processing / storage facility.

Each stockpile shall be defined as a Lot to ensure traceability.

b. Processing and Storage

1. RAP shall be maintained in a separate stockpile prior to processing for use in asphalt. RAP shall be crushed and screened so that the maximum aggregate size is not greater than the aggregate size of the asphalt mix being produced. The processed RAP shall be a well-graded, free-flowing and consistent product. Where the stored RAP is not free flowing it shall be screened and/or crushed again.
2. Processed RAP shall be stored in conical or longitudinal stockpiles. Processed RAP must not be agglomerated or be allowed to congeal in large stockpiles.

c. Unacceptable Materials

1. The contactor shall ensure that RAP delivered to the stockpiles is devoid of construction contaminants including amongst others, crushed gravel, timber, concrete and other building waste.
2. RAP shall be free of tar and/or asbestos.
3. RAP shall be free from any metal contamination.

d. Sources of Materials

The contractor shall distinguish the RAP sources as either combined or single source RAP.

Single Source RAP

RAP that is won from a single source by milling shall be stockpiled individually to ensure it remains uncontaminated. Testing shall be carried out as indicated to determine the representative properties of the stockpile.

Combined source RAP

RAP that is combined from different projects should be blended to construct a uniform stockpile prior to additional processing including crushing, screening or fractionating. Testing of the blended samples is required to determine the representative properties and variability of the RAP.

e. Moisture Management

The RAP stockpile areas shall be well drained and laid to falls to prevent build-up of moisture. The contractor shall take adequate precautions to keep the stockpile dry to ensure that unnecessary moisture is not incorporated into the mix.

The moisture of the hot mix asphalt produced shall not exceed 0.5% by dry mass immediately after manufacture.

The moisture of the completed asphalt layer shall not exceed 0.30% by dry mass when cores are extracted using dry ice coring (for bit cooling).

f. Quantity of RAP to be Included

RAP may be added to the mix so that the contribution of the RAP binder does not exceed 15% of the mix design binder content by mass.

3.6.4.4 Physical Requirements

RAP aggregate after extraction of bitumen shall conform to the physical requirements described in the following sections of the Standard Construction Specifications:

- Superpave mix design materials: Paragraph 1 of Sub-article a of Article 3.3.2.5; OR
- Marshall mix design materials: Paragraph 4 of Sub-article b of Article 3.3.2.5

3.6.4.5 Minimum Testing Requirements of RAP

Characterisation testing shall be carried out on completed stockpiles to determine the stockpile characteristics as listed in Table 5-1 below. Samples shall be taken from at least ten random locations around the stockpile. The individual samples from different parts of the stockpile shall not be combined, as tests need to be performed on individual samples to assess uniformity. A minimum of ten samples is required to allow statistical analysis of the stockpile.

For continuously replenished stockpiles the stockpile sampling regime shall be continued at a frequency of one per 1,000 tons of RAP.

Table 3: Minimum Testing Requirements for Static Stockpiles

Test	Method	Frequency
Gradation	AASHTO T30	1 per 1000 tons (min 10)
Asphalt binder content	AASHTO T164	1 per 1000 tons (min 10)
Bulk specific gravity	AASHTO T308 then	1 per 1000 tons (min 10)

Test	Method	Frequency
	AASTHO T84 and T85	
Aggregate properties1	See Standard Construction Specifications	1 per 5000 tons (min 2)
Moisture content	AASHTO T110-03	3 per 1000 tons (min 2)
Foreign material	Table 3-14 Standard Construction Specifications	1 per 5000 tons (min 2)

Aggregate properties evaluation testing includes:

- Los Angeles abrasion
- Magnesium sulfate soundness loss of coarse and fine aggregate
- Sodium sulphate soundness
- Fractured faces
- Fine aggregate angularity
- Flat and elongated particles, 3 to 1 ratio
- Flakiness
- Abrasion loss
- Sand equivalent value
- Water absorption of coarse aggregate

a. Environmental Testing

The contactor or stockpile owner shall take a representative sample of every 10,000 tons of unprocessed RAP and conduct a Toxicity Characteristic Leaching Procedure (TCLP) test to analyse the specific contamination concentration (SCC) and the leachable concentrations for the following pollutants:

- Polycyclic aromatic hydrocarbons(PAHs); and
- Heavy Metals: Barium, Cadmium, Chromium, Lead, Nickel, Arsenic, and Mercury.

The testing will be undertaken by a laboratory approved by Abu Dhabi Quality and Conformity Council (ADQCC) or accredited with Emirates Standardisation and Metrology Authority (ESMA).

The results will be compared against the *Threshold Values for Specific Contaminant and Leachable Concentrations* listed in Annex 1 of the Environment Agency Abu Dhabi (EAD) 2016, *Waste Classification Technical Guideline* (EAD-EQ-PR-TGD-01).

If contaminants of interest reported SCC and TCLP concentrations below threshold limits, the material will be congruent with being non-hazardous waste, which once milled will become a reusable construction product.

3.6.4.6 Acceptance of RAP

a. Statistical Evaluation

The Contractor shall summarise the results of the testing in a spreadsheet which includes the stockpile name/description and date of sampling and submitted with the job-mix formula. The spreadsheet shall calculate the average and standard deviation for each property. The allowable variation for key properties is shown in Table 3.

b. Exceedance of Statistical Deviation

Where the standard deviation exceeds the maximum allowable standard deviation the material source shall be rejected until such time as additional processing improves the variability to within the allowable limit.

c. Acceptance Criteria for RAP

The Contractor shall ensure that the processed RAP complies with the maximum standard deviation limits in Table 3.

Table 3: RAP Stockpile Maximum Variability

RAP Property	Maximum Standard Deviation (%)	AASHTO Test Methods
Asphalt Binder Content	0.5	T 164
% Passing Median Sieve (2mm)	5.0	T-30
% Passing 0.075 mm Sieve	1.5	T-30
Bulk specific gravity (Gsb)	±50 kg /m3	T 84 and T 85

3.6.4.7 Mix Design Requirements

A separate job-mix design shall be prepared for each RAP stockpile. The average asphalt binder content, gradation and specific gravity of the nominated RAP stockpile shall be used in the mix design.

Grading and Marshall characteristics of the mixture shall be in compliance with the Standard Construction Specifications Part- 1- Roads.

The procedure outlined in the latest edition of Asphalt Institute MS-2 under sub title "Recycled Asphalt Materials in the Mix Design Process" shall be used for laboratory mix design.

a. Plant mix trials

- Trial mixes shall be carried out by manufacturing small quantities in the plant at three different binder contents, targeting the optimum binder content found in the laboratory mix, as well as at bitumen contents 0.2% above and below the optimum.
- The results of tests on these trial mixes shall be examined, to identify any shift in properties between mixes produced in the laboratory compared to those manufactured full-scale.
- The Contractor shall make final adjustments to the plant to ensure the job mix properties obtained from laboratory testing are achieved.
- The Contractor shall check the moisture content of the final product to ensure that the mix complies with maximum moisture requirements.

3.6.4.8 Production Requirements

a. RAP Cold Feed

The Contractor shall provide a separate cold feed bin for each RAP stockpile required by the mix design. The cold feed bins shall be equipped with accurate mechanical means for feeding the aggregate uniformly into the plant in the proportions required for the finished mix to maintain uniform production and temperature. Oversized RAP shall be prevented from being incorporated into the completed mixture by the use of a grizzly or grid over the RAP bin; in-line roller or impact crusher; screen; or other suitable means. If oversized RAP material appears in the completed recycled mix, the appropriate corrective action shall be taken immediately.

During asphalt production the recycled mix shall be sampled and tested daily as summarised in Table 3. Where testing indicates that the recycled mix fails to meet the job-mix formula within the tolerances specified plant operations shall be stopped.

b. RAP Heating and Blending

RAP shall be heated through indirect heat only with no exposure of the RAP to naked flame.

c. Production Testing

The contractor shall carry out production testing as scheduled in the Standard Construction Specifications and as specified in Table 3.

Table 3 Production Testing

Test	AASHTO Method	Frequency	Tolerances
Retained 4.75 mm sieve and larger	T 30	1 per day	± 5.0 %
Passing 4.75 mm and retained 75 mm sieves	T 30	1 per day	± 4.0 %
Passing 75 mm sieve	T 30	1 per day	± 1.5 %
Asphalt binder content	T 164	1 per day	± 0.2 %
Moisture content	T 110-03	2 per day	<0.15%

3.7 Bituminous Pavement Repairs

3.7.1 Description

This work consists of performing all operations and furnishing all materials, labor, tools, equipment and appurtenances that may be required for the various pavement repair items. This work is required to correct structural failures, grade elevations, drainage and deterioration and/or to prepare the existing pavement surface prior to placing asphaltic concrete overlays or seal coats as shown on the Contract plans, as specified herein and/or in the particular specifications and included in the bills of quantities.

3.7.2 Materials

The materials required for the various pavement repair items shall be as specified and shall be in accordance with the requirements of Sections 3.3 through 3.5.

3.7.3 Construction Requirements

3.7.3.1 Equipment

Contractor shall be responsible to supply all the equipment and labor necessary to perform the work described for the various types of pavement repair items in accordance with these specifications and as directed by the Engineer. Major equipment shall conform to Sub-article (a) of Article 3.2.2.3.

3.7.3.2 Pavement Repair Types

a. Repair of Potholes (isolated holes in asphaltic concrete pavements of less than one square meter) using hot asphalt mixture

Contractor shall perform the following:

1. Saw cut the failed pavement 0.3 to 1.0 meter beyond the perimeter of the failed area as directed by the Engineer. Make the cut square or rectangular with faces straight and vertical. One pair of faces shall be at right angles to the direction of traffic
2. Remove and dispose the cut pavement and loose unsuitable material in compliance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.
3. If base material is removed, fill the excavation with a Gradation ‘C’ (sand-gravel), which has been premixed to optimum moisture content. Place the material in 150 mm lifts and compact each lift to at least 95 % modified Proctor density (AASHTO T 180) with mechanical compactors; same treatment is to be applied to subgrade before filling the excavation with sand-gravel
4. Wire broom clean the cut edges of the pavement and paint with bituminous emulsion
5. Prime the compacted soil or the upper surface of the sand-gravel with a light coating of MC-70 when directed by the Engineer. Place Type II wearing course of hot asphaltic concrete mix with minimum thickness as the existing pavement and compact in lifts not exceeding 70 mm to the same level as the adjacent surface. Vibratory compactors shall be used to compact the hot asphalt concrete
6. Check level of the patch with a straight edge and make corrections as required

b. Repair of potholes (Isolated holes in asphaltic concrete pavement) Using Cold Emulsion Asphalt Mixtures

1. Description

This work shall consist of performing all operations and furnishing all materials, labour, tools, and equipment that may be required for the asphalt pavement repair of potholes and similar works. This work shall be performed during any season of the year and as specified herein or as directed by the Engineer.

2. Materials

The materials of the cold mixture are obtained by blending dense crushed fine and coarse aggregate, bitumen emulsion with bio oil to give the mixture the required workability. The mixture shall be a homogeneous distribution of the binder on the aggregate and provides excellent coating properties, easy, long lasting workability, and good immediate mechanical performance. The grading and binder content of this mixture shall be as follows:

Property	Ranges
Percent Passing 2.0mm	**30 to 50**
Percent Passing 0.08mm	**4 to 8**
Residual binder content, ppc	**4-6**

The mixture is manufactured in cold mix plant or by using mixers adapted to the quantities manufactured. The mixture shall be a storable cold mix ready for use, available in bags ideal for roadway maintenance work and shall have certification from ADQCC or Equivalent.

3. Mixture Performance

The cold mixture shall have the following properties:

Test Characteristics	Test Method	Specification
Marshall Stability	**AASHTO T245**	**Min 500 kg f**
Marshall Flow	**AASHTO T245**	**1-3 mm**
Stiffness	**Stability/Flow**	**250kgf/mm**
Loss of Marshall stability	**Submerging specimens in water at 60 C for 24 hours as compared to stability measured after submersion in water at 60 C for 30 minutes (max. % loss)**	**30%**

4. Construction Requirements

i. Equipment

Contractor shall be responsible to supply all the equipment and labour necessary to perform the work described for patching potholes in accordance with these specifications and as directed by the Engineer.

ii. Repair of potholes

Contractor shall perform the following:

- Clean the cavity by removing any water present and all unbound items (fines, stones, topsoil, etc.) to ensure good adhesion of the asphalt mix to the support.
- place cold asphalt mixture manually into the cavity by distributing evenly in layers. Establish an additional thickness on the surface.

- Compact with a hand-held tamper or a vibrating plate for larger areas. A small cylinder, used in either smooth or vibrating mode, is also suitable. This operation is essential to accelerate the increase in cohesion and sealing of cold asphalt mixture and to ensure waterproofing of the surface.
- If the level of the repaired area after compaction is lower than that of the road, scarify the already compacted surface and add the emulsion cold mixture, and compact again. The level of the repaired area must be the same as that of the pavement.
- After compaction, the cold asphalt mixture shall provide a closed surface, limiting rainwater seepage into repaired potholes.
- A primer is recommended when the fill thickness is thin, or when the ambient temperature is low

iii. Re-open the road to traffic immediately after compaction is completed

iv. During traffic, any sticking of asphalt emulsion cold mixture to vehicle tires can be avoided by a light surface sanding

c. Repair of Failed Pavement (deep patch)

Contractor shall perform the following:

1. Saw cut the failed pavement 1 meter beyond the perimeter of the failed area as directed by the Engineer. Make the cut square or rectangular with faces straight and each asphalt layer stepped back from the one below it by a step width at least equal to the layer thickness. One pair of faces shall be at right angles to the direction of traffic
2. Remove the cut pavement and excavate the underlying soil to a depth of not less than 300 mm. Engineer may, when deemed necessary, order substantially greater depths of excavation payable at daily works schedule rates. Remove and dispose the cut pavement and loose unsuitable material in compliance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.
3. Thoroughly compact the subgrade soil with mechanical compactors to at least 95 % of modified Proctor density
4. Place aggregate base course meeting Gradation ‘B’, which has been premixed to optimum moisture content to the bottom of asphalt concrete. Place the material in 150 mm lifts and compact each lift to at least 95 % modified Proctor density (AASHTO T 180) with mechanical compactors; same treatment is to be applied to subgrade before filling the excavation with sand-gravel
5. Wire broom clean the cut edges of the pavement and paint with bituminous emulsion
6. Lightly prime the compacted sand-gravel with MC-70 when directed by the Engineer
7. Place and compact a Type II wearing course of asphaltic concrete in the excavation in 70 mm lifts to the same level as the adjacent surface. Thoroughly and uniformly compact the pavement by rolling. Lower lift shall be compacted with a vibratory compactor and the top lift shall be compacted with a steel wheel roller by first compacting the hot asphaltic concrete 150 mm from the two traffic edges and then by rolling in the direction of traffic. Drive wheel of the roller shall be in a forward position. Use of an asphaltic concrete pavement finisher will depend on the size of the area being patched.

d. Repair of Depressed Pavement (skin patch)

In cases where the pavement has depressed but the asphaltic concrete has not fractured and the pavement appears stable, the Contractor shall perform the following:

1. Mill the upper 50 mm of the pavement starting just in back of the depression. Dispose the milling in accordance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.
2. Wire broom clean the surface and lightly tack the surface and paint the edges of the cut with bituminous emulsion at the rate of 0.25 to 0.50 kg/m^2 of tack coat as shown on the Contract plans or as directed by the Engineer.
3. Place wearing course hot mix asphaltic concrete and compact with a steel wheel roller by first compacting the hot asphaltic concrete 150 mm from the two traffic edges and then by rolling in the direction of traffic. Drive wheel of the roller shall be in the forward position.
4. Check the level of the patch with a straight edge and make corrections as required.

e. Repair of Utility Cuts (open pavement and depressed pavement)

Contractor shall perform the following:

1. In cases where the asphaltic concrete pavement is broken or cracked:
    i. Saw cut the pavement 1 m beyond the perimeter of the failed area. Make the cut rectangular with faces straight and each asphalt layer stepped back from the one below it by step width at least equal to the layer thickness. One pair of faces shall be approximately parallel to the utility cut.
    ii. Remove the cut pavement and excavate the underlying soil to a depth of not less than 300 mm. Engineer may, when deemed necessary, order substantially greater depths of excavation payable at daily works schedule rates. Dispose the excavated material in accordance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.
    iii. Thoroughly compact the subsoil with mechanical compactors to at least 95 % of modified Proctor density.
    iv. If base material is removed, fill the excavation with a Gradation 'B' (table 3-6 of clause 3.2.2), which has been premixed to optimum moisture content. Place the material in 150 mm lifts and compact each lift to at least 95 % modified Proctor density (AASHTO T 180) with mechanical compactors; same treatment is to be applied to subgrade before filling the excavation with sand-gravel.
    v. Wire broom clean the cut edges of the pavement and paint with bituminous emulsion.
    vi. Prime the compacted sand-gravel with a light coating of MC-70 when directed by the Engineer.
    vii. Place wearing course of asphaltic concrete in the excavation in 70 mm lifts to the same level as the adjacent surface. Thoroughly and uniformly compact the pavement by rolling. Lower lift shall be compacted with a vibratory compactor and the top lift shall be compacted with a steel wheel roller by first compacting the hot asphaltic concrete 150 mm from the two traffic edges and then by rolling in the direction of traffic. Drive wheel of the roller shall be in a forward position. Use of an asphaltic concrete pavement finisher will depend on the size of the area being patched. Use of a vibratory compactor on the top lift shall be only with the approval of the Engineer.
    viii. A vibratory plate compactor shall be used to compact the hot asphaltic concrete against kerbing and inlets, catch basins or gullies.

ix. Check the level of the patch with a straight edge and make corrections as required.

2. In cases where the utility cut has been patched and the patch is depressed but the pavement is not fractured and the asphaltic concrete appears stable, perform the following:

   i. Mill and remove the upper 30 mm of the pavement starting just in back of the depression. Dispose of the removed pavement in accordance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.

   ii. Wire broom clean the surface and lightly tack the surface and paint the edges of the cut with bituminous emulsion at the rate of 0.25 to 0.50 kg/m^2 of tack coat as shown on the Contract plans or as directed by the Engineer.

   iii. Place wearing course of asphaltic concrete in the excavation in 70 mm lifts to the same level as the adjacent surface. Thoroughly and uniformly compact the pavement by rolling with a steel wheel roller by first compacting the hot asphalt concrete 150 mm from the two traffic edges and then by rolling in the direction of traffic. Drive wheel of the roller shall be in a forward position

   iv. Check the level of the patch with a straight edge and make corrections as required.

f. Sealing Cracks in Asphaltic Concrete Pavement

Depending on the type & nature of Cracks, appropriate method shall be applied to seal the cracks with approved sealant which, as a minimum, shall comply with requirements specified herein. The contractor shall be required to carry out a thorough site investigation identifying the exact location of different type of cracks and shall submit to the Engineer for his approval, full details of the proposed crack sealant along with manufactures brochure, a method statement & a track record of performance of the product in UAE or under similar climatic condition. Acceptance of the sealant shall be subject to satisfactory site trials. The manufacturer shall provide a guarantee letter for a minimum of 5 years performance when the material is applied on site as per his recommended method statement. The applicator shall have adequate experience and be familiar with the application process of the product as recommended by the manufacturer.

This sealant shall be hot pourable, polymer modified bituminous binder with the characteristics of good adhesion, high ductility with high elastic recovery and shall meet the following requirements:

Test	Specification	Test method designation
Cone Penetration @ 25 °C	45 dmm max.	ASTM D – 5329
Softening point, °C, min	99 min.	ASTM D – 36
Ductility @ 25 °C, min	30 cm. min.	ASTM D – 113
Resilience @ 25 °C,	30% min.	ASTM D – 5329
Flow @ 60 °C	3 mm max.	ASTM D – 5329
Viscosity	100 poise max.	Brookfield Viscometer

Note: Manufacturer's recommendation shall be followed for cleaning of the cracks as well as preparation & application of sealant. However a general requirement is outlined hereunder.

- Cracks shall be thoroughly cleaned by hot air compressor.

- The sealant shall be heated in a pre-heater unit provided with agitation paddles to the recommended temperature.

- The heated material shall be transferred to a bucket & hand drawn screed box or a specialized applicator having a direct connecting pressure hose type extruding device with nozzles shaped for insertion into the pre-warmed crack. Manufacturer's recommended temperature for application shall be maintained.

- Where instructed by the Engineer the crack shall be chased out using a mechanical router and the hole shall be cleaned free of all dust, dirt, and dampness by the use of hot compressed air lances prior to the application of the heated sealant.

- Every attempt shall be made to avoid application of excess sealant. However, if any, the surface shall be scrapped to avoid formation of ridges & the sealant being picked up by the traffic.

- It is to be noted that any crack sealant other than those specified above can be proposed by the Contractor for Engineers review and consideration. Following site trial if the material appears to serve the purpose for which it is intended the Engineer with Client's concern may approve the material on condition that a five (5) years performance guarantee provided by the manufacturer is endorsed by the main Contractor.

g. Restoration of Kerbing

Contractor shall perform the following:

1. Remove pavement and tiles adjacent to the kerbing and break the mortar joint between the sound kerbstone and the kerbstones to be removed or reset.
2. Remove all broken and loose kerbstones and rubble and chisel off the mortar from the exposed edges of the sound kerbstones.
3. Excavate the soil in back of the kerb to the depth of the kerb foundation.
4. Clean and reinstate the kerb foundation as required. This may require raising a maximum height of 150 mm. If so, the contractor shall raise the foundation using Class C15 concrete, unreinforced, mixed with maximum aggregate size of 19 mm and formed the same width as the existing foundation and to the required height. No separate payment will be made by the department for this work.
5. Wet the kerb foundation and set and grout the replacement kerbstones to proper alignment allowing 10 mm for mortar joints and 10 mm for expansion joints.
6. Wet the joints and fill with a cement and sand mortar of 1:2 mix, clean, point and cure with a liquid curing compound as directed by the Engineer.
7. Fill the expansion joints with bituminous preformed joint filler conforming to AASHTO M-33.
8. Form and cast a 100 x 150 mm Portland cement concrete toe against the front of the kerbstone using a Class C15 unreinforced concrete, mixed with maximum aggregate size of 19 mm. Cure with a liquid curing compound and as directed by the Engineer.
9. Cast a 200 x 200 mm Portland cement concrete haunching of Class C15 concrete to the back of the kerbstone and cure it with a liquid curing compound as directed by the Engineer.
10. Expansion joints shall be constructed each 10 meters in the new kerbing and in between new or reset kerbstone and existing kerbstone.
11. Strip all forms from the concrete and fill the excavation in back of the kerbstone with soil to a depth 100 mm below the top of the kerbstone.
12. Paint bituminous emulsion on the face of the concrete and kerbstone which will be in contact with the asphaltic concrete.
13. Reinstate the asphaltic concrete pavement and tiles adjacent to the repair.

h. Restoration of Sidewalk Tiles

Contractor shall restore all sidewalk tiles removed, damaged or otherwise disturbed by his construction operations. Unless otherwise directed by the Engineer, such tile shall be restored on a base and shall match existing adjacent surfaces.

Where existing concrete sidewalk tiles are to be restored, and unless otherwise directed by the Engineer, the sidewalk tiles shall be installed as follows:

1. Remove carefully the existing sidewalk tiles, clean, chisel off the mortar from the exposed faces, protect, load, transport and unload the sound and unbroken tiles at a location approved by the Engineer. Removal of the existing tiles shall be by hand, so as to preserve the tiles; cart away and dispose of the remainder of the tiles at a location approved by the Engineer. Break, remove and cart away the mortar or any base, including concrete base laid below the tiles, to the approved location.
2. Excavate the foundation soil to a depth of 50 mm. Dispose the excavated material at a location approved by the Engineer. Level, sprinkle with water, fill as required to bring the level of the soil to the required depth below the top level of the new tiles. In the event fill is required, add water too. Turnover and mix the soil thoroughly. Compaction operations shall achieve a minimum of 90 % of the standard Proctor (AASHTO T 99) density. Contractor shall take into consideration that the leveling of the natural ground surface shall be done according to the proposed grades and slopes. Any objectionable material and unsuitable soil shall be removed from the site and disposed of by the Contractor in accordance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications or as directed by the Engineer.
3. A layer of clean sand, average thickness 80 mm, shall be spread and water shall be added in order to obtain the proper grades and levels before placing the concrete tiles.
4. Precast concrete tiles shall be placed directly on the sand layer without using any cement mortar.
5. In placing concrete tiles, care must be exercised so that no spaces shall be left between tiles. Sides of tiles shall be touching each other as closely as possible.
6. Tiles shall be secured in place using light compactors in order to achieve the proposed levels and grades.
7. A thin layer of sand shall be utilized as filler between tiles. Water shall be sprayed to flush the sand into the voids.
8. Placing of tiles shall be carried out in lengths not exceeding 10 meters separated by expansion joints according to the instructions of the Engineer. Expansion joint filler shall be 10 mm thick bituminous preformed joint filler conforming to AASHTO M-33.
9. Concrete tiles shall be placed in a proper pattern, no tiles or any part thereof shall be cast in-situ.
10. An additional or substitute pattern, if needed, may be used for laying tiles only after a written approval from the Engineer is obtained by the Contractor.
11. Where existing quarry tile sidewalks are to be restored, and unless otherwise directed by the Engineer, the sidewalk tiles shall be reinstated to original condition.
12. Where other types of existing sidewalks are to be restored, and unless otherwise directed by the Engineer, the installation shall be as specified in these specifications.

i. Adjust, or Demolish and Reconstruct Existing Inlets, Manholes, or Service Facilities to New Pavement Elevations

Contractor shall adjust, or demolish and reconstruct to finished pavement grade or level all existing service facilities including, but not by way of limitation, all utility or service vaults, valve boxes, inlets, manholes, jointing boxes, sewerage house connection service chambers used as restaurant grease traps and similar structures within the limits of the Contract as specified herein and as directed by the Engineer or as required by the respective utility agency. Contractor shall perform the work per the following:

1. Adjust existing inlets, manholes or service facilities to new pavement elevation: At locations where there is a minor level difference between the new pavement elevation and the cover level of existing inlets, manholes or service facilities, the Contractor shall adjust these existing facilities to the cover grade and level matching the new pavement level and slopes. This work consists of, but is not limited to, the removal of frames and covers, placing or removal of minor amounts of concrete and reinforcement as necessary to raise or lower the inlet, manhole or service facility to match new pavement levels and slopes, refixing the frames and covers and all associated works, except the supply of covers and frames, as specified herein, as per the following items:

   i. Contractor shall reuse the removed covers and frames unless otherwise directed by the Engineer. If the Contractor is required to replace the existing cover and frame with a new cover and frame, separate measurement and payment will be made as specified herein for the items, remove and transport the existing cover and frame and replace with new covers and frames.

   ii. When an existing utility manhole requires level adjustment, prior to commencement of the works specified herein, the Contractor shall contact the applicable utility authority and request their field supervision and approval for the work. Contractor shall provide necessary temporary protection as approved by the utility authority and the Engineer to insure safety of existing utility lines while executing the works specified herein.

   iii. Contractor shall perform the following items:

      a) Submit shop drawings for approval by the Engineer prior to start of the work, which show how the Contractor intends to proceed with the work for each site including traffic routing. The shop drawing shall also indicate the existing structure portion and how the height is to be adjusted showing additional height construction details including the portion to be removed, reinforcement, construction joints, frame and cover type, attachment method for the frame, and pavement base replacement method around the chambers.

      b) Barricade the immediate work site to protect workmen and motorists without closing the entire roadway lane to traffic.

      c) Cut and remove sufficient asphalt pavement and concrete from the edges of the inlet frame or manhole to permit removal of the frame from the gully or manhole without damaging the reinforcing steel and cart away and dispose of the rubble in accordance with the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer.

      d) Position the frame of the inlet, manhole or other service facility at the proper elevation and cast it in place with Class C25 concrete using Type V Portland cement with additives approved by the Engineer to accelerate the set of the concrete. All concrete and reinforcement for the work shall comply with the requirements of Chapter 4, Concrete works, and Chapter 5, Reinforcing Steel, of these Standard Specifications.

      e) Paint the exposed concrete surface with bituminous emulsion after the initial set but never later than twenty minutes after placing the concrete. Curing period shall be as approved by the Engineer

      f) Clean the inside of the inlet or manhole and replace the inlet grate or manhole cover

2. Demolish and reconstruct existing inlets, manholes or service facilities to new pavement elevation: At locations where the level difference between the new pavement level and the covers for existing inlets, manholes or service facilities is beyond the scope of minor adjustments and requires major level adjustment, the contractor shall demolish and reconstruct these facilities to match the new pavement level and slopes. Respective utility

owner and the Engineer will determine, on site, the requirement to demolish and reconstruct the existing inlet, manhole or service facility. Contractor shall perform the work as follows:

i. Demolition of existing inlets, manholes or other service facilities shall meet the requirements of Section 2.3.2 of Chapter 2, Earthworks, of these Standard Specifications and as directed by the Engineer. New inlets, manholes, or other service facilities at these locations shall be similar to those demolished unless otherwise directed by the Engineer or required by the utility owner. Shop drawings for the construction of new inlets, manholes and service facilities shall include all details necessary to construct these proposed items. Shop drawings for utility manholes will be approved by applicable utility authority.

ii. Contractor shall reuse the removed cover and frame for the reconstruction work unless otherwise directed by the Engineer. If the Contractor is required to use a new cover and frame, separate measurement and payment will be made as specified herein under the items, remove and transport the existing cover and frame and replace with new cover and frame.

iii. Contractor shall construct the new inlets, manholes or service facilities in accordance with all applicable requirements as specified herein to adjust the top levels of these items including, but not limited to, the reuse of covers and frames, and the submittal of shop drawings indicating the proposed construction materials and procedures for approval by the utility owner.

3. Remove and transport existing covers and frames and replace with new covers and frames for inlets, manholes and service facilities in pedestrian areas. When covers and frames for existing inlets, manholes or service facilities in pedestrian areas, except for sewerage house connection chambers, require replacement with new covers and frames, the Contractor shall furnish new medium duty ductile iron covers and frames with appropriate service description. Engineer and the respective utility owner will determine, on site, the requirement to replace the existing covers and frames with new ones. When an existing sewerage house connection chamber used as a restaurant grease trap requires a new cover, the Contractor shall furnish a new lightweight ductile iron cover and inner GRP cover as shown on the Contract plans. Medium duty and light weight ductile iron covers and frames shall comply with the requirements of and be of the type as described in Section 12.3.2 of Chapter 12, Storm water Drainage, or as shown on the Contract plans or as directed by the Engineer. Contractor shall clean, load, transport unload and place in store yard where designated by the Engineer all removed covers and frames.

4. Remove and transport existing covers and frames and replace with new covers and frames for inlets, manholes and service facilities in traffic areas: When covers and frames for existing or reconstructed inlets, manholes or service facilities in traffic areas such as service roads parking areas and main roads, require replacement with new covers and frames, the Contractor shall furnish new heavy duty ductile iron covers and frames. Engineer and the respective utility owner will determine, on site, the requirement to replace the existing covers and frames with new ones. Heavy duty ductile iron covers and frames shall comply with the requirements of and be the type as described in Section 12.3.2 of Chapter 12, Storm water Drainage, or as shown on the drawings or as directed by the Engineer. Contractor shall clean, load, transport, unload and place all removed covers and frames in a store yard designated by the Engineer.

3.8 Portland Cement Concrete Pavement

3.8.1 Description

This Work shall consist of furnishing concrete mix, transporting, and constructing jointed plain concrete pavement on a prepared base course in accordance with the specifications, in conformity with the lines, grades, thickness and typical cross-sections shown on the plans or established by the Engineer and included in the bills of quantities.

This work also includes pavement rehabilitation consisting of full-depth, full-width removal and reconstruction of rigid pavement.

3.8.2 Materials

Concrete pavement shall meet the material requirements as specified herein. Concrete pavement shall meet the composition requirements shown in Table 3-49. All Portland cement concrete pavements shall incorporate 1000 g/m^3 of approved polypropylene fiber in the concrete mix to avoid the risk of shrinkage cracking.

Table 3-494: Rigid pavement composition

Water/cement ratio (maximum)	Temperature of concrete	Slump	Air content (%)	Aggregate size (AASHTO M 43)	28-day compressive strength (minimum)
0.45	20 ±10 º C	40 ±20 mm	2 max.	No. 57 or 67	45 mPa

3.8.2.1 Aggregates

Aggregates shall meet the applicable requirements of Section 4.3.7 of Chapter 4, Concrete Works, and the following:

a. Reactivity. Aggregate shall be free of substances that are deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of the concrete. Acceptable aggregate shall be based on satisfactory evidence furnished by the Contractor that the aggregate is free from such materials. This evidence shall include service records of concrete of comparable properties under similar conditions of exposure and/or certified records of tests by a testing laboratory that meets the requirements of ASTM C1077. Tests shall be made in accordance with ASTM C295 and ASTM C1260 as required to insure reactivity is not present.

b. Fine Aggregate. Fine aggregate shall conform to the requirements of ASTM C33 and with additional requirements as modified acceptance criteria specified in project specification. Gradation shall meet the requirements of Table 3-50 when tested in accordance with ASTM C136. Dust and other coating shall be removed from the aggregates by washing or suitable means.

Table 3-50: Gradation for fine aggregate

Sieve designation (square openings)	Percentage by weight passing sieves
9.5 mm	100
4.75 mm	95-100
2.36 mm	80-100
1.18 mm	50-85
600 µm	25-60
300 µm	10-30
150 µm)	2-10

c. Coarse aggregate:. Coarse aggregate shall conform to the requirements of ASTM C33. Gradation, within the separated size groups, shall meet the requirements of Table 3-51. when tested in accordance with ASTM C136. When the nominal maximum size of the aggregate is greater than 25 mm, the aggregates shall be furnished in two size groups.

i. Aggregates delivered to the mixer shall consist of crushed stone, crushed or uncrushed gravel, air-cooled blast furnace slag. Aggregate shall be composed of clean, hard, uncoated particles and shall meet the requirements for deleterious substances contained in ASTM C33, Class 4S and the additional requirements as modified acceptance criteria specified in project specification. Dust and other coating shall be removed from the aggregates by washing. Aggregate in any size group shall not contain more than 15 % by weight of flat or elongated pieces when tested in accordance with ASTM D4791. A flat or elongated particle is one having a ratio between the maximum and the minimum dimensions of a circumscribing rectangular prism exceeding 3 to 1.

ii. Percentage of wear shall be no more than 40 percent when tested in accordance with ASTM C131 or ASTM C535.

Table 3-51: Gradation for coarse aggregate per ASTM C33

Sieve Designations (square openings)	From 50.8 mm to 4.75 mm % by weight passing sieves	
Mm	**50.8 mm-25.4 mm**	**25.4 mm-4.75 mm**
63	---	---
50.8	90-100	---
38.1	35-70	100
25.0	0-15	95-100
19.0	---	---
12.5	0-5	25-60
9.5	---	---
4.75	---	0-10
2.36	---	0-5

d. Alternative gradation: Contractor may use the combined aggregate gradation specified in BS EN 12620. Contractor shall submit to the Engineer for approval the combined aggregate gradation, however , in no case shall materials passing 0.075 mm sieve exceed 3 % by weight of the combined aggregate. Changes from gradation to another shall not be made during progress of the work unless approved by the Engineer.

3.8.2.2 Cement and Cement Replacements

Cement and cement replacements shall comply the requirements of Section 4.3, of Chapter 4, Concrete Works, and with the following:

a. Ordinary portland cement (OPC)

1. Conform to ASTM C150 Type I. Do not use cement meeting the requirements of rapid hardening portland cement. Use OPC with the heat of hydration not exceeding 325 kJ per kg when tested in accordance with ASTM C186. Do not use OPC with the tricalcium-aluminate (C3A) content less than 4 % by weight as tested in accordance with ASTM C114.

2. If necessary because of potential silica reactivity concerns, use “low alkali” OPC as defined in ASTM C150

3. Supply the manufacturer's test certification with each delivery of cement that confirms the material complies with the above requirements and submit not later than the day of delivery. Engineer may call for tests on each delivery of cement if necessary to establish or confirm that the cement meets the above requirements.

b. Fly ash or pulverized-fuel ash (PFA):

1. Conform to ASTM C618, Class F requirements including the optional requirements for effectiveness of controlling alkali-silica reaction and sulfate expansion in high sulfate environments.

2. Supply the manufacturer's test certification with each delivery of PFA that confirms the material complies with the above requirements and submit not later than the day of delivery. Engineer may call for tests on each delivery of PFA if necessary to establish or confirm that the cement meets the above requirements.

c. Silica Fume (SF):

1. Conform to ASTM C1240 including the optional requirements for very high sulfate resistance and, if necessary, the optional requirements for reactivity with cement alkalis because of reactive aggregate concerns identified in the petrographic report.
2. Engineer shall have the right to call for tests on each delivery of SF if necessary to establish or confirm that the SF meets the above requirements. Engineer may call for tests on each delivery of SF if necessary to establish or confirm that the cement meets the above requirements.

3.8.2.3 Premolded Joint Filler

Premolded joint filler for expansion joints shall conform to the requirements of ASTM D1751 shall be punched to admit the dowels where called for on the plans. Filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the Engineer. When the use of more than one piece is required for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the Engineer.

3.8.2.4 Joint Sealer

Joint sealer for the joints in the concrete slab shall meet the requirements of Section 4.3.15 of Chapter 4, Concrete Works, of these Standrad Specifcations and shall be of the type(s) specified in the plans.

3.8.2.5 Steel Reinforcement

Reinforcing shall consist of plain or deformed steel bars meeting the requirements of Chapter 5 and conforming to the requirements of ASTM A615 Grade 60. Use epoxy coating conforming to the requirements of AASHTO M 254

3.8.2.6 Dowel and Tie Bars

Tie bars shall be deformed steel bars conforming to ASTM A615 Grade 60, unless noted otherwise.

Dowel bars shall be plain steel bars conforming to ASTM A615 or A616 and shall be free from burring or other deformation restricting slippage in the concrete. Use epoxy-coated steel dowels conforming to the requirements of AASHTO M 254.

Sleeves for dowel bars used in expansion joints shall be metal or other type of an approved design to cover 50 mm to 75 mm of the dowel, with a closed end and with a suitable stop to hold the end of the bar at least 25 mm from the closed end of the sleeve. Sleeves shall be of such design that they will not collapse during construction.

Dowel and tie bars shall conform to AASHTO M 284M and M 31M or M 42M. Dowels shall be free of loose, flaky rust and loose scale and shall be clean and straight.

3.8.2.7 Admixtures

Admixtures shall meet the requirements of Section 4.3.6 of Chapter 4, Concrete Works. Engineer shall approve the use of any material added to the concrete mix. Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the Engineer may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests may be made of samples taken by the Engineer from the supply of material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved. Contractor shall also comply with the following:

1. Do not use air-entraining admixtures.
2. Chemical admixtures. Water reducing, set retarding, and set accelerating admixtures shall meet the requirements of ASTM C494, including the flexural strength test.

3.8.2.8 Epoxy Resin

Epoxy-resin used to anchor dowels and tie bars in slabs shall conform to the requirements of ASTM C881, Type I, Grade 3, and Class C. Class A or B shall be used when the surface temperature of the hardened concrete is below 16º C.

3.8.2.9 Material Acceptance

All materials shall meet the applicable sampling and testing requirements per Section 4.3, of Chapter 4, Concrete Works, of these Standard Specifications.

3.8.2.10 Mix Design

All concrete mix design, testing and acceptance shall meet the applicable requirements of Section 4.3.10 of Chapter 4, Concrete Works, of these Standrad Specifications.

3.8.3 Construction Requirements

In addition to the requirements listed below, Contractor shall conform to the latest edition of FHWA Standard specifications for construction of roads and bridges.

3.8.3.1 Forms

Furnish straight, steel forms. For edge radii less than 60 m, furnish flexible or curved forms. Conform to all the following:

1. Depth equal to edge of pavement thickness
2. 3-meter minimum length
3. Stabilizing devices to withstand paving operations
4. Joint locks to join form lengths tightly together
5. Clean and oil before each use

3.8.3.2 Paving Equipment

Contractor shall furnish the paving and finishing equipment applicable to the type of construction as follows:

a. Slip form construction. Furnish slip form machines capable of spreading, consolidating, screeding, and float-finishing the freshly-placed concrete in one complete pass of the machine to provide a dense and homogeneous pavement with minimal hand finishing. Equip the paving machine with the following:

    1. Electronic controls to control line and grade from either or both sides of the machine

    2. Vibrators to vibrate the concrete for the full width and depth of the strip of pavement being placed

    3. A positive interlock system to stop all vibration and tamping elements when the forward motion of the machine is interrupted.

    Operate the paving machine with a continuous forward movement and coordinate mixing, delivering, and spreading concrete to provide uniform progress without stopping and starting the paving machine. Apply no tractive force to the machine except that which is controlled from the machine.

b. Side form construction. Furnish mechanical, self-propelled spreading and finishing machines capable of compacting and finishing the concrete with minimal hand finishing. Equip the machine with one 450 mm minimum width screed with compensating springs to minimize the effect of the screed's momentum on the side forms, or 2 independently-operated screeds.

   Coordinate the number of driving wheels, power of the motor, and the machine's mass to prevent slippage. Any machine that displaces the side forms will not be permitted.

c. Vibrators. Furnish internal immersed tube or multiple spud type vibrators for all paving more than 200 mm thick. Surface pan type vibrators are acceptable for full-width concrete consolidation of slabs 200 mm or less in thickness. Attach vibrators to the spreader or finishing machine or mount on a separate carriage. For construction of irregular areas, use hand-held vibrators.

d. Joint sealing: Furnish sealing equipment according to the sealant manufacturer's recommendations.

e. Joints and concrete removal: Furnish an adequate supply of concrete saws with sufficient power to saw full depth and complete the work with water-cooled, diamond-edged blades or abrasive wheels. Equip saws with blade guards and guides or devices to control alignment and depth. Furnish and maintain standby equipment and an adequate supply of replacement blades or wheels.

f. Concrete removal: Furnish concrete saws, drop hammers, hydro hammers, and jack hammers to break concrete. Concrete saws shall conform to 5 above. Ball drop breakers are not permitted. Furnish equipment that will not damage the subgrade, subbase, base, or existing concrete slabs designated to remain. If new or existing slabs not scheduled for replacement are chipped, spalled, or damaged during the removal operations, replace the damaged slabs.

3.8.3.3 Preparing Surface for Concrete Pavement

Place base course on top of prepare subgrade meeting the requirements of Section 2.6, of Chapter 2, Earthworks, for subgrade preparation. Type and thickness of base course should match the typical cross-sections on the plans. Uniformly dampen the base course before placing the concrete. If traffic is allowed to use the prepared roadbed, check and correct the surface immediately before the concrete is placed.

3.8.3.4 Placing Concrete

For storing, handling, batching, and mixing material and delivering concrete, conform to the requirements of Section 4.3.11 of Chapter 4, Concrete Works, of these Standard Specifications.

Where a paving machine is impractical, place concrete according to Article 3.8.3.5

When concrete is placed adjoining a previously-constructed lane of pavement, do not allow mechanical equipment to be operated on the existing lane until the lane has attained a minimum flexural strength of 3.8 mPa according to AASHTO T 97 or compressive strength of 24 mPa according to AASHTO T 22. Protect the previously constructed lane from damage by the paving equipment.

Install reinforcing steel according to the requirements of Section 5.5, of Chapter 5, Reinforcing Steel. Firmly position the reinforcement on acceptable supports before placing the concrete, or after spreading, mechanically place or vibrate the reinforcement to the required depth in the plastic concrete.

3.8.3.5 Construction of Irregular Areas

In irregular areas or areas inaccessible to paving equipment, construct the pavement using side forms. Strike-off, consolidate, float, and surface finish the concrete as follows:

1. Thoroughly and uniformly vibrate and compact the concrete during placement without segregating the material
2. Using templates or screeds, strike-off the concrete to shape it to the required cross-section between the forms. Carry a slight excess of concrete in front of the leading edge of the template or screed
3. Float the surface to the required grade and cross-section
4. Finish the surface according to Article 3.8.3.7

3.8.3.6 Joints

Do not vary longitudinal joints more than 13 mm and transverse joints more than 6 mm from the true alignment. When kerbs or medians are constructed integral with the pavement, construct transverse joints continuous through the ~~kerb~~ or median. Protect all joints from the intrusion of deleterious matter until sealed.

Form isolated joints at structures by placing 25 mm expansion joint filler around each structure that extends into or through the pavement before concrete is placed.

Remove and replace all newly-placed concrete pavements where uncontrolled cracking occurs.

a. Longitudinal Joints

Construct longitudinal joints by forming or sawing. Construct sawed longitudinal joints (with tie bars) when the concrete pavement placement width exceeds 4.5 m. Construct the longitudinal joint continuous with no gaps in either the transverse or longitudinal joints at intersections.

Place tie bars, as shown in the typical sections, perpendicular to the longitudinal joints with mechanical equipment or rigidly secured chairs without damaging or disrupting the concrete. Do not paint or coat tie bars with any material or enclose them in tubes or sleeves.

Where adjacent lanes of pavement are constructed separately, use slip form paving machines or steel side forms to form a keyway along the construction joint. Tie bars may be bent at right angles against the form of the first lane constructed and straightened into final position before placing concrete in the adjacent lane. Repair or replace broken or badly-damaged tie bars.

Threaded hook bolts may be used instead of tie bars. Fasten hook bolts to the form of the longitudinal construction joint. With slip form paving, tie bars may be hydraulically inserted through metal keyways.

1. Formed joints. Form joints with an approved nonmetallic or removable device while the concrete is plastic. When adjacent lanes are constructed separately, form the sealant reservoir in the lane placed last
2. Sawed joints. After placing concrete, saw joints as soon as equipment can be supported and before uncontrolled cracking occurs and it shall be performed within the sawing window. Do not ravel the joints while sawing. Saw longitudinal joints immediately after sawing transverse joints. Protect the sawed concrete faces from drying during the curing period. If necessary, continue sawing day and night, regardless of weather conditions. Clean the saw cut and adjacent concrete surface of slurry residue after sawing each joint.
   i. Do not saw a joint if a crack occurs at or near the joint location before sawing. Discontinue sawing when a crack develops ahead of the saw
   ii. If a crack develops in reinforced concrete pavement, remove and replace at least a 3 m long, full-width slab properly attached to adjacent slabs
   iii. If a full depth crack develops in plain concrete pavement, remove and replace a full slab properly attached to adjacent slabs.

b. Transverse Expansion Joints

Form transverse expansion joints where shown on the Contract plans or as directed by the Engineer. Place dowel bars through transverse joints. Hold dowels parallel to the surface and center line of the slab by a metal device that remains in the pavement.

Dowel placement implanters may be used while the concrete is plastic provided they conform to the dowel tolerance specified. Remove all concrete that leaks into the joint expansion space.

Install the preformed joint filler full-depth, perpendicular to the subgrade, and continuous across the full-pavement width. Do not use damaged or repaired joint filler. If joint filler is assembled in sections, construct without an offset between adjacent sections.

c. Transverse Contraction Joints

Place dowel bars per the details shown on the Contract plans. Dowel bar sleeves and finishing caps are not required. Saw joints according to Article 7.6.4.2 of Chapter 7, Incidental Construction, of these Standard Specifications. For adjacent lanes placed separately, construct joints continuously across full width of pavement.

Concrete edges adjacent to the joint may be rounded or beveled to a radius or length as approved. Re-saw or grind any joint having an insufficient opening. Where a joint is larger than required, furnish a larger size joint seal as approved.

d. Transverse Construction Joints

Unless an expansion joint occurs at the same location, construct a transverse construction joint at the end of each day's work or where concrete placement is interrupted for more than 30 minutes. Do not construct a transverse joint within 3 m of any parallel joint.

If sufficient concrete has not been mixed to form a slab at least 3 m long when an interruption occurs, remove and dispose of the excess concrete back to the last preceding joint.

Use a metal or wooden bulkhead to form the joint, shaped to the pavement cross-section, and designed to permit the installation of dowel bars.

Install dowel bars in all transverse construction joints whose location does not coincide with the location of a transverse expansion or contraction joint.

3.8.3.7 Finishing

Protect the surface from rain damage.

After floating, check the surface of the fresh concrete with a 3 m straightedge. Remove high areas indicated by the straightedge. Lap each successive check with the straightedge 1.5 m over the previous check path.

Correct pavement edge slump in excess of 6 mm in 3 m before the concrete has hardened. If edge slump exceeds 25 mm on any 0.3 m or greater length of hardened concrete, remove and replace the entire panel between the transverse and longitudinal joints.

Before the concrete has initially set, work the pavement edges on each side of transverse expansion joints, formed joints, transverse construction joints, and emergency construction joints to produce a 6 mm continuous radius and a smooth, dense mortar finish. Do not use mortar buildup to round edges.

In case fine cracks or hair checks appear in newly placed concrete before it is thoroughly set, apply water to the concrete surfacing, in the form of a fine fog mist until the finishing operations are completed and the curing is applied.

Apply the fog mist to the area between the finishing machine and the tining machine. If the combination of fogging and curing compound application are not, or will not be effective in preventing plastic shrinkage cracking, stop paving operations until environmental conditions improve substantially or until other preventative measures are approved in writing. Contractor shall use one of the following finishing methods, as shown on the Contract plans, included in the particular specifications or as directed by the Engineer:

1. Tining method: In advance of curing operations first texture the concrete pavement with a drag strip of burlap and then with a mechanical spring steel tine device which will form grooves parallel to the centerline. Do not perform tining too early, whereby the grooves may close up. Make tines of rectangular cross section and of sufficient thickness and resilience to result in grooves spaced 19 mm on center, 2 mm to 3 mm wide and 3 mm to 5 mm deep in the finished concrete pavement.

   Operate the tine machine at a speed which keeps up with paving operations. Leave a 25 mm gap between each tine strip to prevent overlapping the tined surface and producing a weak surface area.

   Tine the pavement within 75 mm but no closer than 50 mm of pavement edges.

   Do not tine the surface adjacent to longitudinal weakened plane joints. Untined area is to extend to no less than 19 mm nor more than 50 mm from the centerline of the longitudinal weakened plane joint.

   Omit tining at this location for a total width no less than 38 mm and no more than 100 mm uniformly throughout the Contract.

   Maintain the tining device clean and free of encrusted mortar and debris to ensure uniform groove dimensions.

   Do not tine pavement which has set, whereas the operation is lifting aggregate out of, tearing, or causing excessive roughness to the pavement surface. In such a case, groove the hardened pavement, as directed, at own expense.

2. Oscillating screed method: Provide free floating oscillating screed device attached to the slipform paver, behind the conforming pan, which is capable of performing final finishing on the concrete surface.

   Machine shall have a lightweight aluminum float 300 mm wide and a minimum of 3.6 m long, which oscillates fore and aft in the direction of traffic. Provide float able to traverse the entire concrete slab from edge to edge.

   Connect the float in such a way that it is driven (oscillated), yet it is free floating on the surface of the concrete.

   Adjust and set the movements of the float according to concrete surface conditions and forward speed of the paver.

3. Hand Float Method. Finish the surface of the concrete smooth and true to grade with 2 wooden floats 4.8 m long, 25 mm thick and 100 mm wide, rigidly ribbed and with adjusting screws between the rib and float bars at not more than 600 mm centers, to insure a true and flat surface on the underside at all times. Operate each float from the side of the pavement and with the float parallel with the centerline of the pavement. Use the edge of the float to cut down all high areas, and float the material so removed into the depressions until a true surface is obtained. Lap each successive passage of the float just over the previous path. Upon completion of the passage, bring the float back and the overlap between the 2 passages smoothed.

   Operate the floats as far back of the tamping machine as the concrete remains workable and use a number of passes sufficient to remove all irregularities.

   Make available at least one spare float in good condition at all times.

Final Finish: After the preliminary finishing has been completed, round the edges of an initial pavement lane to a 13 mm radius. Round transverse contact joints, expansion joints, and joints adjacent to an existing pavement to a 6 mm radius.

In advance of the curing operations, or as directed, texture the pavement with a drag strip of burlap or other device which will produce scoring parallel to the centerline. Burlap drag shall consist of one or more pieces of burlap fastened to a cross member riding on the subgrade or side forms by means of wheels or skids to form a continuous strip of burlap the full width of the pavement. Keep drags clean and free from encrusted mortar.

Discard drags that cannot be cleaned and substitute new drags. Grind or score completed concrete pavement, which does not have a satisfactory skid resistant surface texture, by abrasive means to provide a satisfactory surface texture.

3.8.3.8 Curing

Immediately after finishing and when marring will not occur, cure the concrete for a minimum of 72 hours. Do not leave the concrete exposed for more than one half hour during the curing period. Cure using one of the following methods:

a. Water Method

Entirely cover the surface of the pavement and the edges of the slab with water saturated mats. Extend mats at least twice the thickness of the pavement beyond the edges of the slab. Place the mats in complete contact with the surface. Use masses or other approved methods to maintain contact.

b. Liquid Membrane Curing Compound Method

Protect sawed joints from intrusion of foreign material into the joint before sealing. Repair damaged areas immediately with additional compound.

c. Waterproof Cover Method

Thoroughly wet the surface using a fog mist applicator. Cover the entire surface with a waterproof cover. Lap the cover at least 0.5 m. Extend the cover beyond the edges of the slab at least twice the thickness of the pavement. Place the cover in complete contact with the surface.

Contractor should use curing procedure that will not cause shrinkage. If excessive shrinkage cracking occurs, the Engineer will stop the work until the Contractor submits a revised plan for approval by the Engineer that can address shrinkage cracking

Remove forms when the concrete has hardened sufficiently to resist damage but no earlier than 12 hours after placing concrete. Protect the sides of the exposed slabs immediately with a curing method equal to that provided for the surface. Prevent erosion of the base course beneath the exposed pavement edges until shoulders are constructed.

3.8.3.9 Sealing Joints

Saw cut and seal joints before the pavement is opened to construction or public traffic. Do not saw sealant reservoirs within 72 hours after placing concrete.

Clean each joint of all foreign material, including membrane curing compound and concrete slurry, immediately after sawing the joint. Blow dry joints with compressed air. Do not apply sealing material unless the joint faces are clean and surface dry.

Use preformed joint seals, silicone sealant, or hot-poured sealant for expansion joints. Use silicone or hot-poured sealants for longitudinal and transverse Contraction joints.

a. Silicone or Hot-Poured Sealants

Install backer rod with a steel wheel to the depth required. Do not stretch or twist the backer rod during installation. Limit the length of backer rod installed to that which can be sealed during the same workday.

Place poured joint sealing material. Immediately remove any excess or spilled material, and clean the pavement surface. Do not use sand or similar material to cover the seal.

b. Preformed Joint Seals

Furnish the seal in one piece in the size specified for the joint opening. Install seals with a lubricant adhesive covering both sides of the concrete joint. Compress the seal to between 20 and 50 % of its nominal width. Install the top of the seal about 6 mm below the pavement surface.

Remove and replace seals that are damaged, twisted, improperly positioned, or stretched more than 3 %.

3.8.3.10 Pavement Smoothness/Roughness

Measure the smoothness/roughness of the final pavement surface after the concrete has sufficiently hardened and according to the designated type shown in the plans or approved by the Engineer.

a. Driveways and Alleys smoothness

Depend solely on surface tolerance levels.

b. Concrete Pavement roughness (International Roughness Index (IRI))

Engineer will direct and observe operation. Measure in the middle portion of each lane.

Areas of localized roughness will be identified using a 7.62 m moving average filter. The difference between the 7.62 m moving average and the reported relative elevation for every profile point will be determined. Deviations greater than 3.81 mm are areas of localized roughness.

An IRI value will be determined for each 0.1-lane kilometer of traveled way.

Defective areas are 0.1-lane kilometer segments with IRI values greater than 1.5 m/km or areas of localized roughness.

c. Straightedge Pavement Smoothness/Roughness

Use a 4 m metal straightedge to measure at right angles and parallel to the centerline. Defective areas are surface deviations in excess of 6 mm in 3 m between any two contacts of the straightedge with the surface.

d. Defective area correction

Correct defective areas from above. Obtain approval for the proposed method of correction. Re-measure corrected areas according to the specified type of pavement smoothness/roughness. Smoothness/roughness value obtained will replace the original.

3.8.3.11 Full-Depth, Full-Width Patching

Construct the pavement patch to provide a similar appearance to the existing pavement. Prepare test panels using the same materials proposed for the work.

Begin pavement work after the test panels have been inspected and approved for appearance and the concrete mix design 28-day compressive strength is verified.

a. Concrete removal:

   1. For mesh-reinforced, plain dowel, or plain jointed concrete pavement, saw cut slabs full depth leaving vertical edges at the limits of the patch.
   2. For continuously reinforced concrete pavement, saw cut the exterior transverse patch limits to a depth of 45 ±5 mm. Do not allow the saw cut to penetrate the steel reinforcement. Saw cut longitudinal limits full depth. Break up the concrete with a chipping hammer down to the steel.

      If replacement steel is welded, cut the existing reinforcing steel and leave 200 mm of steel exposed. If replacement steel is tied, cut the existing steel to leave the lap length plus 50 mm. Lap lengths are shown in the following table.

Table 3-52: Reinforcing steel splices

Bar size	Length of overlap (mm)
10 M	375
15 M	450
20 M	550

Remove the concrete by either or both of the following methods:

i. Break-up and clean-out method: Break up the concrete from the center of the patch area toward the end saw cuts. Remove the concrete pieces with equipment that will not damage the underlying surface or adjacent slab. .

ii. Lift-out method. Lift the slab in one or more pieces without disturbing the underlying surface. Clean out the area with hand tools.

Dispose of the concrete in a designated area outside the right-of-way. When directed, excavate the underlying material to a maximum depth of 300 mm, and replace with aggregate base as shown in the typical sections. Prevent adjacent concrete slabs from being undermined.

Repair all saw overcuts at the corner of repair areas and nicks to adjacent pavement outside the perimeter of the repair area with non-corrosive, non-shrink grout.

b. Replacing reinforcing steel. For concrete pavement patches, provide a 75 mm clearance between the ends of new reinforcing steel and the existing slab face. Match the number, type, and spacing of the new reinforcement to the existing pavement. Support reinforcing steel with bar chairs or other approved methods while placing concrete.

c. Joints. Construct joints according to Article 3.8.3.6. Field adjust locations and lengths of joints as directed at intersections, median openings, and other areas of odd-shaped slabs such that no joint is less than 460 millimeters long and no slab has an angle less than 60 degrees. Construct joints perpendicular to the edge of pavement.

Place dowels or tie bars into the existing slab. Drill the dowel or tie bar holes into the face at the required diameter with the drill rigidly supported. Completely fill the holes around the dowels and tie bars with an epoxy or nonshrink grout for a permanent fastening to the existing concrete. Furnish a plug or donut to prevent epoxy or grout loss.

Edge all transverse and longitudinal joints against forms or existing pavement. Transverse joints in a continuous lane pour or longitudinal joints in a continuous dual lane pour do not require edging.

Clean the exposed faces of joints and seal joints according to Article 7.6.4.2 of Chapter 7, Incidental Construction, of these Standard Specifications.

d. Concrete placement. Construct side forms to overlap the ends of the existing slab. Securely fasten side forms so they do not move when concrete is placed. To accommodate forms for the patch, excavate the adjacent shoulders a maximum width of 300 mm.

Cast each patch in one continuous full-depth operation. After removal of the forms, backfill, compact, and return the excavated shoulder area to its previous condition.

e. Finishing. Finish patches according to Article 3.8.3.8 to match the plane and texture of the contiguous pavement.

3.8.3.12 Opening to Traffic

Do not allow traffic on new concrete pavement earlier than 14 days after concrete placement unless concrete tests indicate one of the following conditions is obtained:

1. Flexural strength of 4 mPa according to AASHTO T 97; or
2. Compressive strength of 45 mPa according to AASHTO T 22.

Cure specimens according to AASHTO T 23, Curing, and curing for determining form removal time or when a structure may be put into service.

Do not allow traffic on the pavement when joint sealant is tacky and traffic debris would imbed into the sealant.

3.8.3.13 Adjustments

a. Volunteer Cracking

Repairing or removing and replacing slabs in which volunteer cracking occurs, for allowing traffic or equipment on the pavement have been satisfied, will not be measured for payment. Repairing or removing and replacing slabs in which volunteer cracking occurs after said requirements have been satisfied, will be measured for payment if it is determined that all specification requirements were fulfilled.

b. Compressive Strength

If concrete placed is shown by test to be below the specified 28 day compressive strength, a determination will be made as to whether the concrete shall be removed and replaced or allowed to remain in place. If after review, the concrete is allowed to remain in place, liquidated damages will be determined. Price adjustments for strength and thickness will be determined separately.

Appendix 1

A1.0 Steel Slag Aggregates (SSA) in Asphalt Concrete Paving Courses

All Asphalt Concrete Paving Courses shall be constructed in general accordance with latest version of the **Abu Dhabi Standard Construction Specifications Part 1 Roads, Chapter 3: Pavement**, as published by Abu Dhabi Quality and Conformity Council and as otherwise indicated in these Specifications. Steel Slag Aggregates shall meet the requirements of Chapter 3 and its Appendix 1 of these specifications and as specified in **ASTM D 5106, Standard Specification for Steel Slag Aggregates for Bituminous Paving Mixtures**.

A1.1 Steel Slag Fine Aggregate for Asphalt Concrete Paving Courses

Fine aggregate is that portion of the steel slag aggregate passing the No. 8 Sieve. Fine aggregate shall consist of crushed steel slag or mixture of crushed steel slag aggregates and natural crushed aggregates or sand and shall be of such gradation that when combined with other aggregates in proper proportions, the resultant mixture shall meet the required gradation. Steel slag fine aggregates shall not be thin, flaky or elongated. Sampling of fine aggregate shall be in accordance with AASHTO T002. Sieve analysis shall be in accordance with AASHTO T027 and AASHTO T011.

When natural crushed sand is included in the steel slag fine aggregate mixture, this material shall be fed to the dryer as a separate aggregate and the amount used shall be limited to 25% by weight. No rounded windblown or rounded water-deposited sand will be permitted.

Fine aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental materials. Individual stockpiles of steel slag fine aggregates when tested in accordance with AASHTO T176 shall have a sand equivalent of not less than 55. Individual stockpiles of aggregate containing more than 10 percent by weight of fine aggregate shall be tested for sand equivalent.

Steel slag fine aggregate shall have a maximum Sodium Sulfate Soundness of 10 percent and a maximum Magnesium Sulfate soundness of 12 percent when tested in accordance with AASHTO T104.

A1.2 Steel Slag Coarse Aggregate for Asphalt Concrete Paving Courses

Coarse aggregate is that portion of the steel slag aggregate retained on the No. 8 Sieve. Coarse aggregate shall consist of crushed steel slag aggregates. Crushed particles shall be cubic and angular in shape and shall not be thin, flaky or elongated. The gradation shall be such that when combined with other aggregate fractions in proper proportions, the resultant mixture shall meet the required gradation. Sampling of coarse aggregate shall be in accordance with AASHTO T002. Sieve analysis shall be in accordance with AASHTO T027 and AASHTO T011.

Coarse aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental material. The degree of crushing shall be such that at least 100 percent by weight of the material retained on the No. 8 Sieve has at least one fractured face and at least 70% shall be totally crushed. The flakiness index of each individual stockpile shall not exceed 30 percent for Base and Binder course materials and 20 percent for wearing course materials, when tested in accordance with BS 812.

Coarse aggregate shall have a maximum Sodium Sulfate Soundness of 10 percent when tested in accordance with AASHTO T104. The abrasion loss (AASHTO T096) for coarse aggregate used in asphalt mixtures shall not exceed 40 percent.

For guidance purposes, steel slag coarse aggregate for asphaltic wearing course shall have a Polished Stone Value (PSV) of 30 to 50 when tested in accordance with (AASHTO T278 and T279).

A1.3 Mineral Filler for Asphalt Concrete Paving Courses

Commercial mineral filler shall consist of finely ground particles of Slag Dust, limestone, cement, or hydrated lime in accordance with AASHTO M017. It shall be thoroughly dry and free from lumps and shall meet the gradation requirements of AASHTO M017. When hydrated lime is used as mineral filler, the hydrated lime shall comply with the requirements set forth in the latest version of the **Abu Dhabi Standard Construction Specifications Part 1 Roads, Chapter 3: Pavement**. When cement is used as mineral filler, it shall meet the requirements of Type I cement in accordance with ASTM C150.

A2.0 Hot Mix Asphalt Design Requirements

Asphaltic concrete mixes shall be designed using the Marshall Method of mix design (Asphalt Institute Manual Series MS-2), as per AD-QCC Standard Specifications, Part 1 – Section 3.3.2.5, except as modified or supplemented below. Use of steel slag aggregates shall be limited to asphalt wearing course and binder course.

A2.1 Gradation:

- For Steel Slag Binder Course: Use steel slag aggregate varying in proportion from approximately 50% to 100% (by weight) of total aggregate (fine plus coarse).
- For Steel Slag Wearing Course: Use steel slag aggregate by approximately 50% to 100% (by weight) of total aggregate (fine plus coarse).

A2.2 Marshall Stability:

- For Steel Slag Binder Course: Marshall Stability ≥ 1800 kg
- For Steel Slag Wearing Course: Marshall Stability ≥ 2000 kg

A2.3 Dynamic Modulus, |E*| Test (AASHTO T342-11)

Complex Modulus testing of asphalt materials shall be conducted using a uniaxial haversine loading waveform at 21.1ºC and 10 Hz. Loading Frequency and preparation of test specimens shall be according to AASHTO T 342. Dynamic Modulus values shall meet the following requirements:

- Steel Slag Binder Course ≥ 13,000 MPa
- Steel Slag Wearing Course ≥ 13,800 MPa

A2.4 Tri-axial Repeated Load Permanent Deformation (TRLPD) or Flow Number (FN) Test

TRLPD (or FN) tests shall be conducted at a testing temperature of 54.4 ºC and stress level of 200 KPa and meet the following requirements:

- Steel Slag Binder Course ≥ 2500 cycles (avg. of minimum 3 specimens)
- Steel Slag Wearing Course ≥ 4500 cycles (avg. of minimum 3 specimens)

A2.5 Indirect Tensile Strength Test (AASHTO T322)

Indirect tensile strength tests shall meet the following requirements:

- Steel Slag Binder Course: Tensile Strength ≥ 1700 KPa (avg. of minimum 3 specimens)
- Steel Slag Wearing Course: Tensile Strength ≥ 1700 KPa (avg. of minimum 3 specimens)

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STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 4 - CONCRETE WORKS

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 4: Concrete Works

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4 CONCRETE WORKS

4.1 Description

This work shall include, but not by way of limitation, the following activities as indicated on the Contract plans:

1. Preparing concrete, shotcrete, mortar, and grout mixes
2. Transporting and placing concrete on prepared surfaces or in prepared forms
3. Supplying, cutting, bending, and placing reinforcing steel
4. Placing, consolidating, and curing concrete
5. Supplying and installing precast structures or parts of structures, including bedding and jointing

This work consists of constructing concrete structures, and their component parts, made of cementitious material concrete, with or without reinforcement. Concrete structures may be either cast-in-situ or furnished and installed as precast units as shown on the Contract plans or as otherwise specified.

4.2 Reference Standards and Codes

Standards and codes shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Construction Specifications;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
ADQCC (TR-516)	Road Structures Design Manual;
ASTM	American Society for Testing and Materials;
ACI	American Concrete Institute;
ACI 301M-10	Specifications for Structural Concrete (Metric);
ACI 305.1-06	Specification for Hot Weather Concreting;
ACI 308.1-11	Specification for Curing Concrete;
ACI 318M -11	Building Code Requirements for Structural Concrete and Commentary (Metric);
AITC	Timber Construction Manual;
ANSI	American National Standards Institute;
ANSI/SDI C-2011	Standard for Composite Steel Floor Deck – Slabs;
SDI	Steel Deck Institute;
AISC	American Institute of Steel Construction;
APA	American Plywood Association - Design/Construction Guide for Concrete Forming;
PCI	Precast/Prestressed Concrete Institute;

BSI	British Standards Institution;
BS EN	European Standards;
BSI PD 6678	Guide to the specification of masonry mortar;
DIN	Deutsches Institut Fur Normung, German National Standard;
DIN 1048-5	Testing concrete; testing of hardened concrete (specimens prepared in mould);
FHWA	Federal Highway Administration;
TT-S-227e	Federal Specification.

Table 4-1 and Table 4-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for concrete works. It also includes designations and titles.

Table 4-1: Designations and titles for AASHTO and ASTM standards that apply to concrete works

AASHTO Designation	ASTM Designation	Title
	ASTM C150 / C150M - 12	*Standard Specification for Portland Cement.*
	ASTM C1157 / C1157M - 11	*Standard Performance Specification for Hydraulic Cement.*
	ASTM C227-10	*Standard Test Method for Potential Alkali Reactivity of Cement Aggregate Combinations (Mortar Bar Method)*
AASHTO T 131-2010		*Time of Setting of Hydraulic Cement by Vicat Needle.*
	ASTM C191 - 08	*Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle.*
AASHTO T 260-1997		*Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials.*
	ASTM C1218 / C1218M – 99 (2008)	*Standard Test Method for Water Soluble Chloride in Mortar and Concrete.*
	ASTM C465 - 2010	*Standard Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements.*
AASHTO M 240-2010		*Blended Hydraulic Cement.*
	ASTM C563 - 07	*Standard Test Method for Approximation of Optimum SO3 in Hydraulic Cement Using Compressive Strength.*
	ASTM C1038 / C1038M 2007	*Standard Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water.*
	ASTM C265 / 2008	*Standard Test Method for Water Extractable Sulfate in Hydrated Hydraulic Cement Mortar.*
AASHTO M 295-2007		*Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.*

AASHTO Designation	ASTM Designation	Title
	ASTM C618 - 2008	*Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.*
	ASTM C311 - 11a	*Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland Cement Concrete.*
AASHTO M 302-2006		*Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars.*
AASHTO M 307-2007		*Silica Fume Used in Cementitious Mixtures.*
AASHTO M 154-2006		*Air-Entraining Admixtures for Concrete.*
	ASTM C260 / C260M - 2010a	*Standard Specification for Air Entraining Admixtures for Concrete.*
	ASTM G109 - 07	*Standard Test Method for Determining Effects of Chemical Admixtures on Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments.*
AASHTO M 194M 06		*Chemical Admixtures for Concrete.*
	ASTM C494 / C494M - 2011	*Standard Specification for Chemical Admixtures for Concrete.*
	ASTM C457 / C457M - 2011	*Standard Test Method for Microscopical Determination of Parameters of the Air Void System in Hardened Concrete.*
	ASTM C642 / 2006	*Standard Test Method for Density, Absorption, and Voids in Hardened Concrete.*
AASHTO T 96-02		*Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
AASHTO T 160-09		*Length change hardened hydraulic cement Mortar and Concrete.*
AASHTO T 303-00		*Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars due to Alkali-Silica Reaction.*
	ASTM C1260 - 07	*Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar Bar Method).*
	ASTM C1293 - 08b	*Standard Test Method for Determination of Length Change of Concrete Due to Alkali Silica Reaction.*
AASHTO M 6-2008		*Fine Aggregate for Hydraulic Cement Concrete.*
AASHTO T 21 - 2005		*Organic Impurities in Fine Aggregates for Concrete.*
AASHTO T 71-2008		*Effect of Organic Impurities in Fine Aggregate on Strength of Mortar.*

AASHTO Designation	ASTM Designation	Title
AASHTO T 176-2008.		*Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.*
AASHTO M 80-2008		*Coarse Aggregate for Hydraulic Cement Concrete.*
AASHTO M 43-2005		*Sizes of Aggregate for Road and Bridge Construction.*
AASHTO T 335-2009		*Determining the Percentage of Fracture in Coarse Aggregate.*
AASHTO MP 16 / 2010		*Reclaimed Concrete Aggregate for Use as Coarse Aggregate in Hydraulic Cement Concrete.*
AASHTO T 27-06		*Sieve Analysis of Fine and Coarse Aggregates.*
AASHTO M 195- / 2006		*Lightweight Aggregates for Structural Concrete.*
	ASTM C1567 / C1567	*Standard Test Method for Determining the Potential Alkali Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar Bar Method).*
	ASTM C39 - C39M 2011	*Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.*
AASHTO T 22-10		*Compressive Strength of Cylindrical Concrete Specimens.*
	ASTM C40 / C40M 11	*Standard Test Method for Organic Impurities in Fine Aggregates for Concrete.*
	ASTM C87 / C87M - 2010	*Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar.*
	ASTM C88 /2005	*Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.*
AASHTO T 104-99		*Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.*
	ASTM C123 / C123M - 2011	*Standard Test Method for Lightweight Particles in Aggregate.*
AASHTO T 113-2006		*Lightweight Pieces in Aggregate.*
	ASTM C136 - 06	*Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.*
AASHTO T 26-79		*Quality of Water to be Used in Concrete.*
	ASTM D512 / 2010	*Standard Test Methods for Chloride Ion In Water.*
	ASTM D516 / 2011	*Standard Test Method for Sulfate Ion in Water.*

AASHTO Designation	ASTM Designation	Title
	ASTM D4191 / 2008	*Standard Test Method for Sodium in Water by Atomic Absorption Spectrophotometry*
	ASTM D4192 / 2008	*Standard Test Method for Potassium in Water by Atomic Absorption Spectrophotometry.*
	ASTM D4832 - 2010	*Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders.*
	ASTM D6023 - 2007	*Standard Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material (CLSM).*
AASHTO T 119M/T 119-10		*Slump of Hydraulic Cement Concrete.*
	ASTM C869 / C869M - 11	*Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete.*
	ASTM C144 /11	*Standard Specification for Aggregate for Masonry Mortar.*
AASHTO T 106M/T 106-09		*Compressive Strength of Hydraulic Cement Mortar (Using 50-mm or 2-in. Cube Specimens)*
	ASTM C476 / 2010	*Standard Specification for Grout for Masonry.*
	ASTM C404 - 2011	*Standard Specification for Aggregates for Masonry Grout.*
	ASTM C1019 - 2011	*Standard Test Method for Sampling and Testing Grout.*
	ASTM C143 / C143M - 10a	*Standard Test Method for Slump of Hydraulic Cement Concrete.*
	ASTM C270 / 12	*Standard Specification for Mortar for Unit Masonry.*
	ASTM C91 / 2005	*Standard Specification for Masonry Cement.*
	ASTM C207-06 / (11)	*Standard Specification for Hydrated Lime for Masonry Purposes.*
	ASTM C387 / C387M - 11b	*Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar.*
AASHTO M 157-06		*Ready-Mixed Concrete.*
AASHTO T 24M/T 24-2007		*Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.*
AASHTO T 141-2005		*Sampling Freshly Mixed Concrete.*
AASHTO T 309M/10		*Temperature of Freshly Mixed Hydraulic Cement Concrete.*
AASHTO T 152-10		*Air Content of Freshly Mixed Concrete by the Pressure Method*

AASHTO Designation	ASTM Designation	Title
AASHTO R 18-10		*Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories.*
AASHTO T 23-08		*Making and Curing Concrete Test Specimens in the Field.*
	ASTM C171 - 07	*Standard Specification for Sheet Materials for Curing Concrete.*
	ASTM C309 / 11	*Standard Specification for Liquid Membrane Forming Compounds for Curing Concrete.*
	ASTM C156 – 11	*Standard Test Method for Water Loss [from a Mortar Specimen] Through Liquid Membrane Forming Curing Compounds for Concrete.*
AASHTO M 182-05		*Burlap Cloth Made from Jute or Kenaf and Cotton Mats.*
AASHTO M 220 -1984		*Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements.*
	ASTM D2628 - 91(2011)	*Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements*
	ASTM D4070 - 2008	*Standard Specification for Adhesive Lubricant for Installation of Preformed Elastomeric Bridge Compression Seals in Concrete Structures.*
AASHTO M 33-99		*Preformed Expansion Joint Filler for Concrete (Bituminous Type).*
	ASTM D1751 - 04-08	*Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).*
AASHTO M 153-06		*Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.*
AASHTO M 213-01		*Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).*
	ASTM D1056 - 07	*Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber.*
	ASTM D5249 - 10	*Standard Specification for Backer Material for Use with Cold- and Hot-Applied Joint Sealants in Portland-Cement Concrete and Asphalt Joints.*
	ASTM C920 - 11	*Standard Specification for Elastomeric Joint Sealants.*
	ASTM D6690-07	*Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements.*
	ASTM D5329 - 09	*Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements*
AASHTO M 148-05		*Liquid Membrane forming compounds for curing concrete*

AASHTO Designation	ASTM Designation	Title
	ASTM D5167 - 10	*Standard Practice for Melting of Hot-Applied Joint and Crack Sealant and Filler for Evaluation.*
	ASTM C805 / C805M - 08.	*Standard Test Method for Rebound Number of Hardened Concrete.*
	ASTM E329 - 13b	*Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection*
	ASTM C33 / C33M - 13	*Standard Specification for Concrete Aggregates*
	ASTM C1602 / C1602M - 12	*Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*
	ASTM C1585 - 13	*Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes*
	ASTM C1017 / C1017M - 07	*Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete*
	ASTM C989 / C989M - 12a	*Standard Specification for Slag Cement for Use in Concrete and Mortars*
	ASTM C1240 - 12	*Standard Specification for Silica Fume Used in Cementitious Mixtures*
	ASTM C1116 / C1116M - 10a	*Standard Specification for Fiber-Reinforced Concrete*
	ASTM C1579 - 13	*Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (Using a Steel Form Insert)*
	ASTM C1609 / C1609M - 12	*Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)*
	ASTM C1550 - 12a	*Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)*
	ASTM A820 / A820M - 11	*Standard Specification for Steel Fibers for Fiber-Reinforced Concrete*
	ASTM C1611 / C1611M - 09be1	*Standard Test Method for Slump Flow of Self-Consolidating Concrete*
	ASTM C1621 / C1621M - 09b	*Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring*
	ASTM C1610 / C1610M - 10	*Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique*
	ASTM C94 / C94M - 13a	*Standard Specification for Ready-Mixed Concrete*
	ASTM C70 - 13	*Standard Test Method for Surface Moisture in Fine Aggregate*

AASHTO Designation	ASTM Designation	Title
	ASTM C566 - 13	*Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying*
	ASTM C172 / C172M - 10	*Standard Practice for Sampling Freshly Mixed Concrete*
	ASTM C231 / C231M - 10	*Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*
	ASTM C173 / C173M - 12	*Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*
	ASTM C138 / C138M - 13a	*Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*
	ASTM C1064 / C1064M - 12	*Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete*
	ASTM C31 / C31M - 12	*Standard Practice for Making and Curing Concrete Test Specimens in the Field*

Table 4-2: Designations and titles for BS and BS EN standards that apply to concrete works

BS Designation	BS EN Designation	Title
BS 1881-122:2011		*Testing concrete. Method for determination of water absorption.*
	BS EN 206-1.2000	*Concrete: Specification, performance, production & conformity.*
BS 8500-1-2006+A1:2012		*Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.*
	BS EN 998-1-2010	*Specification for mortar for masonry. Rendering and plastering mortar.*
BS EN 934-3 / 2003		*Admixtures for concrete, mortar and grout. Admixtures for masonry mortar. Definitions, requirements, conformity, marking and labelling.*
BS 1305 / 1974		*Specification for batch type concrete mixers (withdrawn)*
	BS EN 12390-1 / 12	*Testing hardened concrete. Shape, dimensions and other requirements for specimens and moulds*
	BS EN 12390-2 / 2009	*Testing hardened concrete. Making and curing specimens for strength tests*
	BS EN 12390-3 / 2009	*Testing hardened concrete. Compressive strength of test specimens*
BS 4978 2007+A1 2011		*Visual strength grading of softwood. Specification.*
	BS EN 338 /2009	*Structural timber. Strength classes.*

BS Designation	BS EN Designation	Title
BS 5756+A1/ 2011		*Visual strength grading of hardwood. Specification.*
	BS EN 14081 +A1 12	*Timber structures. Strength graded structural timber with rectangular cross section. Machine grading; additional requirements for initial type testing.*

4.3 Materials

All materials to be incorporated in the concrete work shall be as shown on the Contract plans, as specified herein, as may be specified in the Particular Specifications, and as approved by the Engineer.

Materials shall be delivered, stored, and handled so as to ensure the preservation of their quality and their fitness for the work. Materials, even though approved before storage or handling, may again be inspected and tested prior to use in the work. Stored materials shall be located so as to facilitate their prompt and easy inspection. All storage sites shall be restored to their original conditions at the Contractor's expense prior to acceptance of the work.

Materials that fail to comply with the requirements of these Standard Specifications will be rejected by the Engineer and shall be removed immediately from the site of the works, unless otherwise instructed by the Engineer.

Rejected or unapproved materials shall not be incorporated into the work.

4.3.1 Portland Cement

Unless otherwise specified in the project particular specifications or other sections of these specifications, cementitious materials shall be Portland cement conforming to the following requirements:

1. Type I as per ASTM C150 / C150M – 12 with the percentages of supplemental cementitious materials (GGBS or Fly Ash) as per table 4-16.
2. Where specified, Type II or Type V cement shall be as per ASTM C-150 /C150M and Type MS or Type HS (Moderate Sulphate Resistance or High Sulphate Resistance) as per ASTM C1157M.

The following exceptions apply:

a. Bags shall contain 50kg ±1%; barrels or containers shall contain multiples thereof
b. Tricalcium aluminate (C_3Al) shall not exceed 8% by weight, see Equation 1.
c. Alkalis shall not exceed 0.75% by weight, see Equation 2. If the content of alkali is greater than 0.60% in Type V cement, tests shall be carried out according to ASTM C227 with the aggregates to be used

Tricalcium aluminate (C_3Al) shall be calculated per Equation 1.

$$C_3Al = 2.650Al_2O_3 - 1.692Fe_2O_3$$

Equation 1: Tricalcium alumninate calculation

Alkalis shall be calculated per Equation 2.

$$Alkalis = Na_2O + 0.658K_2O$$

Equation 2: Alikalis calculation

Time of setting shall be determined by the Vicat test method, AASHTO T 131 or ASTM C191.

One brand of cement, as approved by the Engineer, shall be used for all concrete works throughout the project unless otherwise authorised in writing by the Engineer. Cement of different types or brands shall not be intermingled or used in the same batch. Sacked or bulk cement may be used; however, the use of fractional bags of sacked cement shall not be permitted unless the Contractor elects to weigh the cement into each batch.

Cement entering the mixers shall not have a temperature that exceeds 45° C.

Water-soluble chloride ion (Cl^-) content totals within the mixed concrete shall not exceed 0.06 % by weight of cementitious material for prestressed concrete or 0.10 % by weight of cementitious material for reinforced concrete. An initial evaluation may be obtained by testing individual concrete ingredients for total chloride ion content per AASHTO T 260 and totalling these to determine the total water-soluble chloride ion (Cl^-) or the total water-soluble chloride ion (Cl^-) in accordance with ASTM C1218M.

Processing addition amounts used shall comply with ASTM C465, and shall not exceed 1 % of the weight of Portland cement clinker and 3 % cement kiln dust by mass of the cement.

In addition to ASTM C150 / C150M - 12, requirements of ASTM C465 shall be met when the following actions are taken:

1. Adding 1 % to 5 % of an inorganic processing addition, such as fly ash or ground granulated blast-furnace slag. Control cement shall be CC1 or CC2
2. Adding 1 % to 5 % inorganic processing addition and 1 % to 5 % limestone addition. Control cement shall be CC1

When adding 1 % to 5 % limestone to a cement already containing an inorganic processing addition that meets ASTM C465, the blended cement shall meet ASTM C465 mortar/paste testing requirements, but it is not required to pass the fineness tolerances. Control cement shall be composed of either CC1 or CC2.

Control cement types shall be defined as follows:

a. CC1: Clinker + organic grinding aid that meets ASTM C465 + gypsum,

b. CC2: Clinker + organic grinding aid that meets ASTM C465 + gypsum + limestone that meets ASTM C465 mortar/paste requirements

c. CC3: Clinker + organic grinding aid that meets ASTM C465 + gypsum + inorganic processing addition that meets ASTM C465

For cements with limestone additions, corrected percent limestone shall be reported to accurately reflect the total amount of limestone added. Difference between background or baseline loss on ignition (pre-limestone addition) and the total loss on ignition (after limestone addition) shall be reported as the corrected percent limestone.

4.3.1.1 Low-alkali Cement

When the Particular Specifications require low-alkali cement, the percentage of alkalis in the cement, calculated per Equation 2, shall not exceed 0.60 % by weight. This limitation shall apply to all types of Portland cement.

4.3.1.2 Blended Hydraulic Cement

Blended hydraulic cement may be used where shown in the Particular Specifications, or shown on the Contract plans. Blended hydraulic cement may also be used as an option in limited applications by the Contractor, if the Contractor's usage proposal is specifically approved by the Engineer. As an alternative to the use of fly ash, ground granulated blast-furnace slag (GGBS) and cement as separate components, a blended hydraulic cementitious material may be used.

When both GGBS and fly ash are included in the concrete mix, the total weight of both these materials is limited to 35 % by weight of the total cementitious material.

Blended hydraulic cement shall provide either moderate sulphate resistance (MS) or high sulfate resistance (HS) and conform to AASHTO M 240, or ASTM C1157, except that the content of alkalis, calculated per Equation 2, shall not exceed 0.75 % by weight, and except that the content of tricalcium aluminate, calculated per Equation 1, shall not exceed 8 % by weight. Source and weight of the fly ash or GGBS shall be certified on the cement mill test certificate and shall be reported as a percentage by weight of the total cementitious material. Fly ash or GGBS constituent content in the finished cement shall not vary more than ± 5 % by weight of the finished cement from the certified value.

4.3.1.3 Packaging and Marking

Cementitious material shall be delivered to the site of the works in sealed bags or water-tight barrels bearing the manufacturer's name, cement type, date of manufacture, and mill test report number.

4.3.1.4 Sampling, Testing, and Acceptance

Representative samples of each material, at least 1 kg in size of each colour and type of cementitious material with corresponding mill certificates and material safety data sheets (MSDS) shall be submitted by the Contractor for laboratory testing and evaluation and to the Engineer for approval.

Each mixing facility or plant using Portland cement shall be equipped with a suitable means or device for obtaining a representative sample of the cementitious material. This device shall enable the sample to be readily taken in proximity to the cementitious material weigh hopper and from a container or conveyor holding only cementitious material.

Cementitious material shall be sampled by the Engineer during the course of a project to ensure continued compliance. Sample material may be taken by the Engineer from the plant, terminal, transportation containers, concrete plants, and the site of the works to verify compliance with these Standard Specifications. Sampling, testing, and processing costs shall be borne by the Contractor.

Cementitious material shall be accepted on the basis of the Engineer’s approval of the Contractor’s material submittal. A part or the whole of any consignment of cementitious materials may be rejected by the Engineer if the Engineer considers it unsuitable for use in the works.

Cementitious material sources shall be subject to the Engineer's approval, which shall be based upon the following items, furnished by the Contractor for all cementitious material batches delivered to site:

1. Manufacturer's mill test report number indicating full conformance to these Standard Specifications
2. Date of manufacture, certified by an independent agency in the country of origin.

All shipments of cementitious material shall be identified by the applicable mill test report number.

Contractor shall submit to the Engineer for acceptance monthly samples for all certified cementitious materials. Monthly samples shall be received by the 15th of each month. Random sampling of materials for testing and random audits of test reports may be conducted by the Engineer. For each type of cementitious material, the Contractor shall submit the following to the Engineer:

a. Monthly mill certificate that shows the following:
    1. Cementitious material meets the requirements of this specification
    2. Minimum, maximum, and average values for equivalent alkalis obtained from quality control tests or a calculated value for maximum total alkali, based on a 95 % confidence level
    3. Average tricalcium aluminate (C_3Al) content for Type III (MS) cementitious material meets the requirements of ASTM C150 / C150M – 12 Table 2
b. Written notification of changes in clinker source or other major production changes
c. Annual test reports, if applicable, for the following:
    1. ASTM C563

2. ASTM C1038M
3. ASTM C265
4. ASTM C1157

d. Test reports, if applicable, for processing additions using ASTM C465

4.3.1.5 Storage

During transport and storage, the cementitious material shall be fully protected from rain and dampness.

Cementitious material shall be stored on the site of the works in a manner that permits easy access for inspection and identification. Storage areas and associated facilities shall be:

a. Perfectly dry and waterproof, to provide constant protection from rain, high-humidity atmosphere, and other factors that may promote deterioration of the cementitious material
b. Provided with temperature and humidity control devices
c. Large enough to hold the amount of cementitious material required for the largest unit to be cast
d. Erected with the floors raised well above the ground
e. Used exclusively for the storage of cementitious material
f. On or near the site of the works
g. Stacked with bags of cementitious material in piles not more than eight bags high
h. Easy to access, with free passage of at least 1 m between the cementitious material and the side walls and access ways between containers, such that every container is visible.
i. Organised such that each consignment of cementitious material is stored separately
    1. Consignments shall be used in the order in which they are delivered
    2. Each type, colour, and brand of cementitious material shall be located in a separate storage silo
    3. Conveying equipment shall be required for each type and/or colour of cementitious material
j. Permanently equipped with Contractor-provided weighing machines that shall be for checking the weight of the cementitious material containers
k. Accessible by the Engineer at all times
l. Be dismantled and removed, the foundations broken up, and the site restored to its original condition by the Contractor
m. Remain the property of the Contractor at the completion of the works

Cementitious material that, in the opinion of the Engineer, contains lumps that shall not be pulverised in the mixer shall be rejected and removed from the site at the Contractor’s own expense. Type II Portland cement stored by the Contractor for longer than 60 days shall be held for retest. If tests show the cement has lost strength during the period of storage, the cement may be rejected, or sufficient additional cement, as determined by the Engineer, shall be added to the mix at the Contractor’s expense to overcome such loss.

Cementitious material delivered by bulk carriers shall be stored in silos made for cementitious material storage, and be suitable for the climatic conditions of the Emirate. Cementitious material shall be handled in bulk by use of air-veyors, augerscrew conveyors, enclosed bucket, or enclosed belt conveyors. All operations for the handling of bulk cementitious material shall be by methods that prevent contamination of the cementitious material. Cementitious material storage silos with interior moisture control devices that keep the cementitious material dry and prevent premature hydration in the silos shall be provided. Silos with access ladders and entry ways so that samples can be extracted from various levels of each silo for testing purposes shall be provided.

4.3.2 Fly Ash

Fly ash, if used, shall not exceed 30 % by weight of the total cementitious material in any given concrete mix design. Fly ash shall conform to the requirements of AASHTO M 295 Class C or Class F, including optional chemical requirements as set forth in Table 2 of the standard, and with a further limitation that the loss on ignition shall be a maximum of 1.5 %. Fly ash and cement shall be added separately to the concrete mix at the batch plant. The cement used shall be Type I Portland cement unless otherwise specified.

4.3.2.1 Class C and Class F

Classification of the fly ash shall be based on chemical composition. Both classes of fly ash shall meet all the physical and chemical requirements of both ASTM C 618 and the following Table 4-3:

Table 4-3: Supplementary Class C and Class F specification requirements

Item	Limit
Calcium oxide (CaO) variation in percentage points of CaO from the average of the last 10 samples (or less, if 10 have not been tested) must not exceed	± 4.0
Moisture content, maximum	2.0 %
Loss on ignition, maximum	3.0 %
Increase of drying shrinkage of mortar bars at 28 days, maximum	0.03 %

4.3.2.2 Ultra-fine

Ultra-fine fly ash shall conform to the requirements listed above for Class F fly ash, with the exceptions and additions listed in Table 4-4.

Table 4-4: Additional ultra-fine specification requirements

Item	Limit
Pozzolanic activity index • 7-day, minimum • 28-day, minimum	 85 % of control 95 % of control
Particle size distribution, as measured by laser particle size analyzer • particles less than 3.25 microns, minimum • particles less than 8.50 microns, minimum	 50.0 % 90.0 %
Fineness, amount retained when wet-sieved on 45-µm sieve, maximum	6.0 %
Moisture content, maximum	1.0 %
Loss on ignition, maximum	2.0 %

4.3.2.3 Modified F

Modified F fly ash shall consist of Class F fly ash blended by grinding with no more than 10 % cementitious material, with or without approved accelerating and water-reducing admixtures, and conforming to the requirements listed above for Class F fly ash, with the exceptions and additions listed in Table 4-5.

Table 4-5: Additional Modified F specification requirements

Item	Limit
Pozzolanic activity index • 3-day, minimum • 28-day, minimum	 70 % of control 95 % of control
Alkali content, maximum	1.5 %

4.3.2.4 Sampling, Testing, and Acceptance

Representative samples, measuring at least 1 kg in size, of each colour and type of material shall be submitted by the Contractor for laboratory testing and evaluation, with accompanying material safety data sheet (MSDS) information. Sampling shall be per ASTM C311.

Fly ash shall be sampled by the Engineer during the course of a project to ensure continued compliance. Material from the plant, terminal, transportation containers, and the site of the works may be sampled by the Engineer to verify compliance with these standard specifications.

Producers shall submit monthly samples for all types of fly ash. Monthly samples shall be received by the 15th of each month. Engineer reserves the right to conduct random sampling of the materials for testing and to perform random audits of test reports. Sampling, testing, and processing costs shall be borne by the source owner.

Fly ash shall be accepted on the basis of the Engineer’s approval of a request for approval of materials. A part or the whole of any consignment of fly ash may be rejected by the Engineer if the Engineer considers it unsuitable for use in the works. Fly ash sources shall be subject to the Engineer’s approval and based upon the following items furnished by the Contractor at all times:

1. Name, address, and contact information of the supplier
2. Name and location of the power plant
3. Coal origin and classification being used by the plant
4. Class of fly ash being collected

Fly ash shall conform to ASTM C618 and these Standard Specifications.

For each type of fly ash, monthly composite samples shall be submitted to the Engineer. Monthly samples shall be received by the 15th of each month. Engineer reserves the right to conduct random sampling of materials for testing and to perform random audits of test reports. Contractor shall submit the following to the Engineer:

a. Monthly mill certificate showing that the fly ash complies with these Standard Specifications
b. Monthly test report with the following information:
    1. coal origin
    2. test date
    3. results of all specified physical and chemical requirements, except available alkalis, but including “supplementary specification requirements” in the referenced standards
c. Monthly split sample from the same material used to generate the monthly test report

Contractor shall notify the Engineer when a change in production occurs. This includes, but is not limited to, changes in a coal source or the major alteration of plant operations.

4.3.2.5 Storage on the Site of the Works

Fly ash shall be stored in compliance with Article 4.3.1.5 of these Standard Specifications.

4.3.3 Ground Granulated Blast-furnace Slag

When used, ground granulated blast-furnace slag (GGBS) shall be 65 % by weight of the total cementitious material in any given concrete mix design. GGBS grades and the source and type of manufacturing facility shall be certified on the GGBS mill test certificate. Cement and GGBS shall be added to the mix separately at the batch plant. The cement used shall be Type I Portland cement unless otherwise specified. The Alumina content (AL_2O_3) of GGBS shall not exceed 14%.

4.3.3.1 Sampling, Testing, and Acceptance

Sampling shall meet the requirements for sampling fly ash in Article 4.3.2.4, except that 2 samples, each at least 1 kg in size, shall be required.

GGBS shall be accepted on the basis of the Engineer's approval of a request for approval of materials. GGBS shall meet the requirements of AASHTO M 302, Grade 100 or Grade 120, and reporting requirements shall consist of the producer providing the following:

1. Monthly mill certificate certifying that the GGBS meets the requirements of AASHTO M 302, Grade 100 or Grade 120
2. Written notification of any major production change

4.3.3.2 Storage on the Site of the Works

GGBS shall be stored in compliance with Article 4.3.14.3.1.5.

4.3.4 Microsilica Fume

When used, the microsilica fume shall be 5% by weight of the total cementitious material in any given concrete mix design.

Microsilica fume is a hazardous substance. To avoid inhalation of the dust, microsilica fume shall only be accepted on the site of the works, stored, and used in the form of a slurry, called slurried microsilica fume.

Slurried microsilica fume shall conform to the requirements of AASHTO M 307. An optional physical requirement for reactivity with cement alkalis set forth in Table 3 of the standard shall be required when slurried microsilica fume is being used as an alkali silica reaction (ASR) mitigation measure. ASR is an expansion mechanism that occurs over time in which the alkaline cement paste reacts with silica in the aggregate or other concrete constituents causing spalling, loss of strength, and even failure of the concrete.

4.3.4.1 Sampling, Testing, and Acceptance

Sampling shall meet the requirements for sampling fly ash, per Article 4.3.2.4, except that 2 samples, each at least 1 kg in size, shall be required.

Slurried microsilica fume will be accepted on the basis of the Engineer's approval of the Contractor's material submittal. Slurried microsilica fume shall meet the requirements of AASHTO M 307, and no additional reporting shall be required after qualification, except that the producer shall inform the Engineer in writing of any major change in operations.

4.3.4.2 Storage on the Site of the Works

Silica fume shall be stored in compliance with Article 4.3.14.3.1.5.

4.3.5 Metakaolin

Metakaolin may be used as an alternative for slurried microsilica fume.

4.3.5.1 Sampling, Testing, and Acceptance

Sampling shall meet the requirements for sampling fly ash, per Article 4.3.2.4, except that 2 samples, each at least 1 kg in size, shall be required.

Metakaolin shall meet the requirements of ASTM C311 and ASTM C618, Class N, with the modifications listed in Table 4-6.

Table 4-6: Modified metakaolin specification requirements

Item	Limit
Silicon dioxide (SiO_2) + aluminium oxide (Al_2O_3) + iron oxide (Fe_2O_3), minimum	85.0 %
Available alkalis, maximum	1.0 %
Loss on Ignition, maximum	3.0 %
Fineness: amount retained when wet-sieved on 45-µm sieve, maximum	1.0 %
Strength activity index, at 7 days	85 % of control
Increase of drying shrinkage of mortar bars at 28 days, maximum	0.03 %
Density variation in percentage points of density from the average of the last 10 samples (or less, if 10 have not been tested) must not exceed	± 5

Tests and acceptance shall be per Article 4.3.2.4 except that metakaolin shall meet the requirements of ASTM C311 and these Standard Specifications, and no additional reporting shall be required after qualification, except that the Contractor shall inform the Engineer in writing of any major change in operations.

4.3.5.2 Storage on the Site of the Works

Metakaolin shall be stored in compliance with Article 4.3.1.5.

4.3.6 Admixtures

Admixtures are part of the mix design. All tests, including tests for compressive strength, shall be carried out for all concrete with admixtures. Any change to the brand or type of cementitious material shall require retesting of the concrete mix to ensure compliance with these Standard Specifications. Admixtures for use in concrete shall meet the specifications described in Table 4-7 and Table 4-8. Accelerators shall not be used, except as noted in Table 4-7.

Table 4-7: Requirements for admixtures for concrete

Admixture	Specification (meet AASHTO or ASTM requirements)	
Air-entrainer	AASHTO M 154	ASTM C260M
Corrosion inhibitor		ASTM G109
Water reducer	AASHTO M 194M Type A	ASTM C494M Type A
Set retarder	AASHTO M 194M Type B	ASTM C494M Type B
*Accelerator	AASHTO M 194M Type C	ASTM C494M Type C
Water reducer/set retarder	AASHTO M 194M Type D	ASTM C494M Type D
*Water reducer/accelerator	AASHTO M 194M Type E	ASTM C494M Type E

Admixture	Specification (meet AASHTO or ASTM requirements)	
High range water reducer	AASHTO M 194M Type F and G	ASTM C494M Type F and G
*Only non-chloride accelerating admixtures shall be used. Accelerating admixtures are only allowed for use in the following applications: in controlled-density fill, in accordance with Article 4.3.10.3 and in Portland cement concrete pavement in accordance with Section 3.8.		

Table 4-8: Latex additive requirements

Property	Value
Total solids, minimum	47 %
pH	9.0 to 11.0
Brookfield viscosity (#No. 1 spindle @ 10rpm), maximum	60 MPa·s
Butadiene content	30 % to 40 %
Freeze-thaw stability, 2 cycles, maximum	0.1

Concrete admixtures shall be added to the concrete mix at the time of batching the concrete or in accordance with the manufacturer's written procedure and as approved by the Engineer. Modified procedures shall not be used to add admixtures to the concrete until the Engineer has approved the modifications in writing.

Use of admixtures shall conform to these additional requirements:

1. Admixtures shall contain less than 1 % chloride ion (Cl^-) by weight of admixture
2. Air-entrained cement shall not be used to air-entrain concrete
3. Retarders shall not be used together with other admixtures in the same mix, unless approved by the Engineer
4. Retarders used by the Contractor and approved by the Engineer shall comply with the requirements of Type D, as specified in ASTM C494M
5. Any approved retarder in use shall be the responsibility of the Contractor, in strict accordance with the manufacturer's instructions
6. Fluid content of admixtures shall be considered in the determination of water-to-cement ratios

Materials shall be delivered to the site of the works in sealed containers labelled with the manufacturer's name, the trade name of the product, the lot number, and shelf life of product, and the mix ratio if applicable. Containers shall be kept tightly closed when not in use.

4.3.6.1 Sampling, Testing, and Acceptance

A 0.5 litre sample shall be submitted to the Engineer for testing and approval, with accompanying material safety data sheets, at least 10 days prior to use.

Random sampling of approved certified materials for testing and performing random audits of test reports is the right of the Engineer, who may sample material from the manufacturing plant, the site of the works, and the warehouse. Sampling, testing, and processing costs shall be borne by the source owner.

Acceptance of admixtures shall be based on the manufacturer's certificate of compliance demonstrating conformance to these standard specifications and the fulfilment of the requirements of Table 4-9. Prior to the use of any admixture, the Contractor shall submit to the Engineer for approval evidence that all admixtures are compatible and will not adversely affect the air void system of the hardened concrete when the Contractor is proposing to use admixtures from different manufacturers. If the concrete requires air entrainment, the Contractor shall also submit evidence to the Engineer that the admixture shall not adversely affect the air void system of the hardened concrete. Test results complying with ASTM C457M shall be provided as evidence to satisfy this requirement.

Testing samples to verify compliance with this specification is the right of the Engineer. In cases of variance, the Engineer's tests shall govern.

Concrete made with waterproofing admixtures shall have a percent absorption after immersion and boiling of less than 5.0 % at seven days and a volume of permeable voids less than 11.0 % at seven days, per ASTM C642.

Table 4-9: Submittal for approval requirements for admixtures

Requirement	For materials except latex	For latex
Name and information of company contact personnel	●	●
Product name	●	●
Polymer description		●
Chloride content of the product with a statement that no chloride has been added during its manufacture	●	
Copy of the manufacturer's written procedure	●	●
Any proposed deviations from the manufacturer's written procedures	●	●
Completed ASTM C494M or ASTM C260M test report from a certified independent laboratory	●	
Specification targets and production tolerances for the following properties:		
Viscosity (including test method and temperature reference)		●
Percent solids	●	●
pH	●	●
Specific gravity	●	●
Colour and appearance	●	
Infrared spectrophotometry scan	●	
Styrene/butadiene ratio		●

To maintain approval status, the Contractor shall submit to the Engineer for approval:

- Semi-annual notarised certifications in June and December stating that there has been no chemical alteration of the product since its original submittal for approval
- Any change in formulation or manufacturing process, which requires re-approval

4.3.6.2 Storage on the Site of the Works

Admixtures shall be stored in accordance with manufacturer's recommendations. Admixtures shall not be stored in direct sunlight, and they shall be prevented from freezing.

4.3.7 Aggregates for Cementitious Material Concrete

4.3.7.1 General

Aggregates shall consist of tough, hard, durable, and uncoated particles. All aggregates shall meet the requirements as specified herein or in the project particular specifications.

To permit samples to be taken in the presence of an Engineer and Contractor representative, the Contractor shall advise the Engineer of sources of aggregates sufficiently in advance of work. Samples of the aggregates shall be tested and approved by the representative prior to delivery to the site of the works. Approval of aggregate quality and gradation shall not waive the responsibility of the Contractor to fabricate concrete to the strength specified.

Cementitious material concrete aggregates shall be manufactured from ledge rock, talus, or sand and gravel in accordance with these Standard Specifications. Material from which concrete aggregate is manufactured shall meet the Los Angeles wear requirements for 500 revolutions, 35 % max per AASHTO T 96.

A certificate from an approved laboratory shall be submitted by the Contractor to show the shrinkage characteristics of the aggregate. Drying shrinkage of concrete samples made from each of the required three concrete mixtures for preparing the compressive- and flexural-strength samples shall not exceed 0.04 %. Shrinkage per AASHTO T 160 shall not exceed shrinkage of the reference aggregate by more than:

1. 130 % for prestressed concrete, concrete bridge decks, and slender columns;
2. 150 % for other reinforced concrete members; and
3. 200 % for mass concrete substructures, unreinforced concrete head walls, and wing walls.

Aggregates tested in accordance with AASHTO T 303 or ASTM C1260, with expansion greater than 0.20 % undergo an alkali silica reaction (ASR) and shall require mitigating measures described in Article 4.3.7.7 below. Aggregates tested in accordance with ASTM C1293, with expansion greater than 0.04 %, are ASR and shall require mitigating measures as described in Article 4.3.7.7. ASR is an expansion mechanism that occurs over time in which the alkaline cement paste reacts with silica in the aggregate or other concrete constituents causing spalling, loss of strength, and even failure of the concrete.

4.3.7.2 Fine Aggregate

Fine aggregate shall consist of natural sand or other inert materials, or combinations thereof, having hard, strong, durable particles and conforming to AASHTO M 6, except as otherwise indicated in these Standard Specifications. Fine aggregates shall be washed with fresh potable water. They shall be free from extraneous materials, clay balls, organic matter, or other deleterious material in accordance with AASHTO M 6, Class B, including the reactive aggregate supplementary requirement, and these additional limitations:

1. Quantity of clay lumps shall not exceed 1.0 % by weight
2. Combined chlorides and sulphates shall not exceed 1,000 ppm by weight
3. Organic matter shall not be darker than the reference standard colour (organic plate No. 3) per AASHTO T 21, unless a darker colour is proved to be harmless per AASHTO T 71 and the compressive strength of the mortar at 7 and 28 days is at least 90 % that of a mortar prepared in the same manner with the same Type II cement and graded Ottawa sand having a fineness modulus of 2.40 ± 0.10

Fine aggregate grading shall conform to the following requirements shown in Table 4-10:

Table 4-10: Fine aggregate gradation, percent passing by weight

Sieve size (square mm)	Type 1 fine aggregate	Type 2 fine aggregate

	Allowable range	**Allowable range**
9.5	100[a] minimum	100 minimum
4.75	95 to 100[a]	95 to 100
2.36	68 to 86[a]	-
1.18	47 to 65[a]	45 to 80
0.600	27 to 42[a]	-
0.300	9 to 20[b]	10 to 30
0.150	0 to 7[b]	2 to 10
0.075	0 to 2.5[b]	0 to 2.5

[a]Variation of 2 % under the minimum or over the maximum permitted on individual tests, provided the average of three consecutive tests is within specified limits.

[b]Variation of 0.5 % under the minimum or over the maximum permitted on individual tests, provided the average of three consecutive tests is within specified limits.

Fine aggregate shall also be evaluated for the following:

- Fineness: per AASHTO M 6
- Soundness: per AASHTO M 6, using sodium sulphate
- Sand equivalency: per AASHTO T 176, shall be at least 75

4.3.7.3 Coarse Aggregate

Coarse aggregate shall be gravel, crushed stone, or other inert material or combinations thereof, having hard, strong, durable pieces free from adherent coatings. Coarse aggregate shall be homogeneous, clean, and free from organic matter, mesh, alkaline, and extraneous or detrimental material. Mesh material often appears with natural occurring aggregates. Orders to wash the coarse aggregate may be made by the Engineer to remove deleterious material; or the Engineer may reject material that does not comply with these Standard Specifications.

Coarse aggregates shall meet the requirements of AASHTO M 80, Class A, including the supplementary reactive aggregate requirement and except as otherwise indicated in these Standard Specifications. Coarse aggregate for cementitious material concrete shall conform to one or more of the standard size grading shown in Table 4-11, whose source is Table 1 in AASHTO M 43.

Table 4-11: Grading of coarse aggregate for cementitious material concrete, allowable range, percent by mass

	Nominal Maximum Aggregate Size (mm)				
Sieve size (square mm)	**37.5**	**25**	**19**	**12.5**	**9.5**
50	100	-	-	-	-
37.5	95 to 100	100		-	-
25.0	-	95 to 100	100	-	-
19.0	35 to 70	-	90 to 100	100	-
12.5	-	25 to 60	-	90 to 100	-

	Nominal Maximum Aggregate Size (mm)				
Sieve size (square mm)	**37.5**	**25**	**19**	**12.5**	**9.5**
9.5	10 to 30	-	20 to 55	40 to 70	85 to 100
4.75	0 to 5	0 to 10	0 to 10	0 to 15	10 to 30
2.36	-	0 to 5	0 to 5	0 to 5	0 to 10
1.18	-	-	-	-	0 to 5
In individual tests, a variation of 4 percentage points under the minimum or over the maximum shall be allowed if the average of 3 consecutive tests is within the required limits.					

Coarse aggregate shall contain no piece greater than 2 times the maximum sieve size for the specified grading measured along the line of greatest dimension.

If the Engineer approves, coarse aggregate may be blended from other sizes under the following conditions:

a. Resulting aggregate meets all requirements for the approved grading
b. Each size used makes up at least 5 % of the blend
c. Contractor supplies to the Engineer grading and proportions for the proposed sizes

Amount of deleterious substances in coarse aggregate shall not exceed the limits given in AASHTO M 80 for Class A, with the following modifications:

1. Clay lumps shall not exceed 0.25 % by mass
2. For coarse aggregate with a single-face fracture content of at least 25 % by mass, material finer than the 0.075 mm sieve may increase to 1.5 % by mass. Fracture requirement shall be at least one fractured face and shall apply to the combined aggregate retained on the 4.75 mm sieve per AASHTO T 335
3. Pieces with specific gravity less than 1.95 shall not exceed 2.0 % by mass

With the approval of the Engineer, reclaimed concrete aggregate may be used as coarse aggregate for hydraulic cement concrete in accordance with AASHTO MP 16.

4.3.7.4 Combined Aggregate Gradation for Cementitious Material Concrete

As an option to using coarse- and fine-graded aggregates for cementitious material concrete, a combined gradation may be used. Combined aggregates shall consist of sand, gravel, crushed stone, or other inert material or combinations thereof, having hard, strong durable particles free from adherent coatings. Aggregates shall be washed to remove clay, loam, alkali, organic matter, silt, bark, sticks, or other deleterious matter.

Deleterious substances shall be limited to the amounts shown in Table 4-12.

Table 4-12: Allowable combined aggregate contamination

Substance	Percent by mass
Clay lumps	0.3
Material finer than a 0.075 mm sieve	2.0
Pieces of specific gravity less than 1.95	2.0

Shale	1.0
Organic matter, by colourimetric test, shall not be darker than the reference standard colour (organic plate No. 3) AASHTO T 21 unless other tests prove a darker colour to be harmless.	
Los Angeles wear for material retained on the 4.75 mm sieve shall not exceed 35% after 500 revolutions, per AASHTO T 96.	

Nominal maximum aggregate size is defined as the largest sieve size to retain between zero and 10 % of the aggregate by mass. If a nominal maximum aggregate size is not specified, the Contractor shall determine the nominal maximum aggregate size. In no case shall the maximum aggregate size exceed:

1. One-fifth of the narrowest dimension between sides of the forms
2. One-third the depth of slabs
3. Three-fourths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pre-tensioning strands.

Combined aggregate shall conform to the requirements of Table 4-13, based upon the nominal maximum aggregate size.

Table 4-13: Combined aggregate gradation based on nominal maximum aggregate size, percent by mass passing

Sieve size (square mm)	Nominal maximum aggregate size (mm)					
	37.5	**25.0**	**19.0**	**12.5**	**9.5**	**4.75**
50	100	-	-	-	-	-
37.5	87 to 100*	100	-	-	-	-
25.0	-	82 to 100*	100	-	-	-
19.0	62 to 88	-	87 to 100*	100	-	-
12.5	-	57 to 83	-	81 to 100*	100	-
9.5	43 to 64	-	60 to 88	-	86 to 100*	100
4.75	29 to 47	34 to 54	41 to 64	48 to 73	-	68 to 100*
2.36	19 to 34	22 to 39	27 to 47	31 to 54	39 to 73	-
1.18	12 to 25	14 to 29	17 to 34	20 to 39	24 to 54	28 to 73
600 µm	7 to 18	8 to 21	9 to 25	11 to 29	13 to 39	16 to 54
300 µm	3 to 14	3 to 15	4 to 18	5 to 21	6 to 29	7 to 39
150 µm	0 to 10	0 to 11	0 to 14	0 to 15	0 to 21	0 to 29
75 µm	0 to 2.0	0 to 2.0	0 to 2.0	0 to 2.0	0 to 2.0	0 to 2.0
* = Nominal maximum size						

Each component aggregate may be sampled by the Engineer prior to introduction to the weigh batcher. Each component shall be sieve analysed alone per AASHTO T 27. All material components shall be mathematically re-combined by proportions in a weighted average and supplied by the Contractor.

4.3.7.5 Lightweight Aggregate

Lightweight aggregate shall conform to AASHTO M 195.

4.3.7.6 Aggregate for Kerb and Barrier

Fine aggregates for kerb and barrier shall be uniformly graded up to a maximum size of 9.5 mm and shall contain sufficient fines to create the required surface finish. Coarse aggregates shall meet the requirements for Size 67 in Table 4-11.

4.3.7.7 Mitigation for Alkali Silica Reactive (ASR) Aggregate

Alkali silica reaction (ASR) is an expansion mechanism that occurs over time in which the alkaline cement paste reacts with silica in the aggregate or other concrete constituents causing spalling, loss of strength, and even failure of the concrete. Mitigating measures for aggregates with expansions from 0.21 % to 0.45 %, when tested in accordance with AASHTO T 303 or ASTM C1260, may be accomplished by using low-alkali cement as per Article 4.3.1.1 above or by using 25 % Class F fly ash by total weight of the cementitious materials. Alternative mitigating measures may be submitted by the Contractor to the Engineer for approval test results per ASTM C1567 that demonstrate the mitigation, when used with the proposed aggregate, controls expansion to 0.20 % or less. To verify its effectiveness, the Engineer may test the proposed ASR mitigation measure. In the event of a dispute, the Engineer’s results shall prevail.

Mitigating measures for aggregates with expansions greater than 0.45 % when tested in accordance with AASHTO T 303 or ASTM C1260 shall include the use of low-alkali cement per Article 4.3.1.1 and may include the use of fly ash, lithium compound admixtures, ground granulated blast-furnace slag, or other material, as approved by the Engineer. Contractor shall submit evidence in the form of test results from ASTM C1567 to the Engineer that demonstrate the proposed mitigation, when used with the aggregates proposed, will control the potential expansion to 0.20 % or less before the aggregate source may be used in concrete. Engineer may test the proposed ASR mitigation measure to verify its effectiveness. In the event of a dispute, the Engineer’s results shall prevail.

ASTM C1293 sampling and testing must be coordinated through the Engineer. Cost of sampling, testing, and processing shall be borne by the Contractor.

4.3.7.8 Tests and Acceptance

Aggregates for use in hydraulic cement concrete shall be tested per the following standards:

Table 4-14: Acceptance tests for coarse and fine aggregate

Material attribute	Standard
Compressive strength	ASTM C39M or AASHTO T 22
Organic impurities	ASTM C40M or AASHTO T 21
Mortar strength	ASTM C87M or AASHTO T 71
Soundness	ASTM C88 or AASHTO T 104 [1]
Coal and lignite	ASTM C123M or AASHTO T 113
Sieve analysis	ASTM C136 or AASHTO T 27
Coarse aggregate shall withstand at least five cycles of immersion and drying in both sodium sulfate and magnesium sulfate solutions, as prescribed in the soundness test, and shall show an average weight loss of not more than 12 %.	

Previously approved materials may be rejected if subsequent tests do not reflect compliance with the requirements of the specified standards.

4.3.7.9 Storage on the Site of the Works

Aggregates of different nominal sizes shall be stored separately and in such a manner as to prevent segregation, contamination, and intermixing of different materials. Aggregates from different sources shall not be mixed nor stored in the same pile.

Aggregate stockpiles shall be on hard, clean surfaces with not more than 5 % slope. Stockpiles shall be built and removed in layers not exceeding 1 m in thickness and the centre of the storage area shall be free of excess moisture. Aggregate that has become segregated or contaminated with foreign matter during storage or handling shall be rejected, removed, and reprocessed or replaced with material of acceptable quality. Aggregates shall be stored in sufficient quantity to ensure that no interruption of concreting work occurs.

Aggregates exposed in coastal regions with marine salty air shall be covered to protect them from salt contamination.

4.3.8 Water for Concrete Mixing and Curing

Unless otherwise authorised in writing by the Engineer, only water from a municipal potable water supply system shall be used for mixing concrete and other products containing cementitious material. Similarly, only potable water may be used for curing concrete and cementitious material products during the first 24 hours after pouring. Later, fresh water, Sulaibiyah, including recycled sanitary-effluent water, or other water containing not more than 4,000 ppm dissolved solids, of which not more than 1,200 ppm may be chlorides, may be used for curing. All water for use with cementitious material shall be free from detrimental concentrations of acids, alkalis, salts, sugar, and other organic or chemical substances that could impair the durability and strength of the concrete or the imbedded steel.

Water shall enter the mixers at as low a temperature as possible. Every effort shall be made to protect water pipes and tanks from the sun, such as burying, shading, insulating, or painting pipes white.

4.3.8.1 Tests and Acceptance

Water used shall be sampled, tested, and in compliance with AASHTO T 26. If the water contains substances that cause discolouration, unusual or objectionable smell or taste, or other suspicious content, the Engineer may require that the Contractor provide test results that document the acceptability of the water per these Standard Specifications and requirements of Table 4-15.

Water used in concrete works shall have a pH between 5.0 and 8.0.

Table 4-15: Chemical limits for mix water

Contaminant	Test method	Maximum concentration (ppm)
Chloride (Cl)	ASTM D512	
Prestressed concrete		500
Bridge decks and superstructure		500
All other concrete		1,000
Sulfate (SO_4)	ASTM D516	1,000
Alkalis ($Na_2O + 0.658K_2O$)	ASTM D4191 and ASTM D4192	600
Total solids	AASHTO T 26	50,000

Water used to mix and cure white hydraulic cement shall be free of iron and impurities that may cause staining or discolouration.

4.3.9 Classification of Concrete

Concrete classes used shall be as noted in the Contract plans, the particular specifications, and as described in these Standard Specifications. Concrete classifications shall be per BS EN 206-1 and BS 8500-1 and as modified by the following definitions.

a. Compressive strength class of a concrete mix will be designated as ”Xyy/zz” on the Contract plans and in these Standard Specifications, where:

   1. Prefix: ‘X’ = ‘C’ for normal-weight and heavyweight concrete or ‘LC’ for lightweight concrete
   2. ‘yy’ = Minimum 28-day cube strength in N/mm^2
   3. ’zz’ = nominal maximum size of aggregate in mm

b. Class of concrete may be abbreviated by omitting the aggregate size, e.g. C20 in place of C20/20.

   The compressive strength classes are in N/mm^2 (MPa). Typical concrete classes include:

   - Normal Concretes: C15, C20, C25, C30, C35, C40, C45, C50, C60
   - Lightweight Concretes: LC15, LC20, LC25, LC30, LC35, LC40, LC45, LC50, LC60

Table 4-16: Typical concrete classes

Concrete Class	Characteristic* 28-day cube Strength** (N/mm^2)	Max Free Water to Cementitious Material Ratio (kg per kg)	Minimum Weight of Cementitious Material (kg/m^3)	Max. Agg. Size (mm)	Proportions of GGBS or Fly Ash by Weight of Total Cementitious Content (%)	
					GGBS	Fly ash
C60/20	60	0.4	450	20	65	30
C50/20	50	0.4	445	20	65	30
C45/20	45	0.4	435	20	65	30
C40/20	40	0.4	425	20	65	30
C40/20W***	40	0.4	425	20	65	30
C35/20	35	0.4	400	20	65	30
C30/20	30	0.4	350	20	65	30
C25/20	25	0.4	300	20	65	30
C20/20	20	0.5	250	20	65	30
C15/20	15	0.5	220	20	65	30
*The Preliminary (Design Target) Cube Strength shall be 33.3% higher than the characteristic strength and in accordance with BS 8500-1- 2006+A1:2012. **Refer to Article 4.3.12.3** C40/20W: Concrete to be placed under water and concrete for piles.						

c. Letter designations following the class of concrete may sometimes be used to identify the following specific uses:

   1. P for piling applications
   2. W for underwater applications

3. D for deck applications
4. A for bridge approach slab applications

d. Letter designations following the use of concrete may sometimes be used to identify the following specific slumps (for workability) as shown in Table 4-17:

Table 4-17: Concrete slump classifications

Slump classification	Slump (mm)[a]	Tolerance (mm)
X	> 180	-
Y	180	± 40
Z	120	± 40
[a] Maximum slump should not exceed the requirements of Article 4.3.12.6 unless otherwise approved by the Engineer.		

Design of the concrete mix and the proportions of the constituent materials necessary to produce concrete that complies with these specifications shall be the responsibility of the Contractor. Typically, classes of concrete C10, C15, and C20 are used for mass concrete or non-structural applications, while classes C25, C30, C35, C40, and higher strength concretes are used for structural applications. All concrete classes shall be used as shown in the Contract plans and the Particular Specifications.

Requests may be made by the Contractor, in writing, for permission to use a different class of concrete than specified in the Contract plans or these Standard Specifications or the Particular Specifications with either the same or a higher compressive strength than specified. Substitute concrete shall be evaluated for acceptance based on the specified class of concrete. Responses shall be received from the Engineer in writing. Added costs that result from the change shall be borne by the Contractor.

Testing for acceptance of concrete shall be conducted in accordance with Section 4.3.12.

Before starting any concrete work, the Contractor shall submit the following for approval by the Engineer:

- Samples of the constituent materials of the concrete
- Statement of the mix proportions proposed for each class of concrete
- Evidence establishing that concrete made from the materials in the proposed proportions shall have the required properties established in these standard specifications, the project particular specifications, and the drawing
- Evidence that the mix designs and the concrete comply with these standard specifications

Any change in material source, aggregate size, or any component of the concrete requires resubmittal of the above items and approval by the Engineer. Approval of mix design shall not relieve the Contractor’s responsibility to produce concrete with the specified properties.

4.3.10 Contractor’s Proposed Concrete Mix Design

Before batching concrete, the Contractor shall submit, in writing, the proposed concrete mix design, including all admixtures and all ingredient properties as confirmed with a Lab trial, for approval by the Engineer. No concrete shall be placed until the Engineer has reviewed it and provided written approval of the mix design based on a Plant trial to the Contractor. Arrangements for obtaining approval of the mix design shall be made by the Contractor as early as possible. No Claims for delay or compensation shall be considered on account of waiting for the Engineer's written approval or instructions. Mix design submittals from the Contractor shall include the information in Table 4-18.

Table 4-18: Contractor's mix design submittal requirements

Names of Contract, Contractor, and the individual submitting mix design	For each cementitious material: • Mass per cubic metre • Proposed source • Type, class, or grade • Specific gravity • Material certification
Date of submittal	
Contract number	
Unique identification for each mix design	
Description of use for the particular mix design on the specific project	
Concrete class	For each admixture: • Manufacturer • Product name • Type • Estimated range (ml/m3) • Material certification
Concrete supplier, plant location, and plant number	
Gradation of aggregate	
Maximum water-to-cement ratio	
Mass of mixing water per cubic metre of concrete	
Indication of use of recycled or reclaimed water	
Mix design density (kg/m^3)	For each aggregate component: • Pit number • ASR results • Grading • Percent of total aggregate • Specific gravity • Saturated surface dry mass per cubic metre • Material certification
Test results and the calculated average for 28-day compressive strength (MPa)	
Test results and the calculated average for 14-day flexural strength (MPa)	
Fineness modulus	
Proposed ASR mitigation method	

Required average 28-day compressive strength shall be selected per the American Concrete Institute (ACI) 318M, Chapter 5, Section 5.3.2. In addition to the requirements set out in these specifications, ACI 211.1 and ACI 318M shall be consulted to determine proportions. Fine, coarse, and combined aggregate shall conform to the applicable requirements of Section 4.3.7.

All preliminary trial batches and testing necessary to substantiate the proposed mix designs and demonstrate that the mix design conforms to specification requirements shall be performed by the Contractor. All trial batches and testing shall incorporate admixtures per the concrete mix design. Concrete place-ability, workability, and strength shall be the responsibility of the Contractor. Contractor shall notify the Engineer in writing of any proposed mix design modifications. No concrete of the revised mix design shall be placed until the Engineer has reviewed and provided written approval of the revised mix design to the Contractor. Any delay due to such changes shall be entirely the responsibility of the Contractor and no Claims for delay or compensation shall be considered, except as follows:

1. When coloured concrete is required, the Contractor shall submit preliminary samples of the coloured concrete.
2. Samples shall be a 1 m by 1 m by 100 mm panel for each mix to be coloured.
3. Panels shall be finished and cured in the same manner as the concrete in the works.

Concrete may be sampled at any time during the work by the Engineer to check compliance with the approved mix design.

4.3.10.1 Proportioning of Materials

Proportioning of materials in the concrete mix shall be selected by the Contractor based on the specified performance criteria. Cementitious material and other additive quantities used in the mixing shall be approved by the Engineer on the basis of preliminary tests and trial mixes. Mix guidelines for specific classes of concrete are included in Table 4-16.

Proportioning of materials for concrete shall produce a plastic mixture that shall work readily into all angles and corners of the forms, around all reinforcing steel, prestressing steel, and items that must be built into the concrete, without segregation of materials or excess water collecting on the surface.

Unless otherwise specified, the Contractor shall use Type I, II, or V Portland cement in all concrete as defined in Section 4.3.1. Type of cement shall be as shown on the Contract plans, as may be included in the Particular Specifications and as otherwise required in these Standard Specifications. In general, Types I and II shall be used for superstructure only and Type V for substructures in contact with the earth.

Use of fly ash and ground granulated blast-furnace slag (GGBS) shall be used if required in the Particular Specifications, shown on the Contract plans or approved by the Engineer for all classes of concrete. Class C fly ash shall not be used in sulfate-resistant concrete.

Fly ash, if used, shall not exceed 30% by weight of the total cementitious material and shall conform to Section 4.3.2. GGBS, if used, shall be 65% by weight of the total cementitious material, and shall conform to Section 4.3.3. When both ground GGBS and fly ash are included in the concrete mix, the total weight of both these materials is limited to 35% by weight of the total cementitious material.

As an alternative to the use of fly ash, GGBS and cement as separate components, a blended hydraulic cement that meets the requirements of Article 4.3.1.2 may be used if specifically approved by the Engineer.

Supplementary cementing materials shall not be used when white hydraulic cement is specified. Light-coloured aggregates shall be used when white hydraulic cement is required.

Use of recycled crushed hydraulic cement concrete as a coarse or fine aggregate shall be limited to Classes C15 and C25 concrete. Recycled crushed concrete as a fine aggregate shall not exceed 20% of the fine aggregate. Use of recycled crushed hydraulic cement concrete shall only be used if specifically approved by the Engineer.

Prior to starting concrete work, the Contractor shall submit approval samples of all concrete work materials to the Engineer for testing. No materials forming any part of the concrete mix shall be delivered to the site of the works before the Contractor receives written approval of such material by the Engineer.

4.3.10.2 Water-to-cement Ratio

Water-to-cement ratios used in the concrete mix shall be selected by the Contractor based on the specified performance criteria. Water quantities used in the mixing shall be approved by the Engineer on the basis of preliminary tests and trial mixes. Water-to-cement ratios shall be calculated on the total weight of cementitious material. Cementitious materials are Portland cement, fly ash, ground granulated blast-furnace slag, and microsilica.

Approved mixes shall be the least amount that shall produce a workable homogeneous plastic mixture that can be worked into the forms and around the reinforcement. In no circumstances shall the consistency of the concrete be such as to permit a separation of the aggregate from the mortar during handling. Excess water shall not be permitted and any batch containing such excess shall be rejected.

In measuring water for each batch of concrete, an allowance shall be made for the water contained in the aggregates and the water contained in any admixtures. Total water in the batch shall be deemed to consist of the water carried by the aggregates plus the fluid content of admixtures plus the water added.

Maximum water-to-cement ratios should not exceed the general mix requirements of Table 4-16 and if not otherwise specified, the applicable requirements of Table 4.3.1 of ACI 318M, unless otherwise approved by the Engineer.

4.3.10.3 Controlled Density Fill (CDF) Concrete

Controlled density fill (CDF) concrete is a self-compacting, cementitious, flowable material requiring no subsequent vibration or tamping to achieve consolidation. Mix designs shall be provided, in writing, by the Contractor to the Engineer for approval with ACI 229 used as a guide to develop the CDF mix design. No CDF shall be placed until the Engineer has approved the mix design. CDF shall be designed to have a minimum 28-day strength of 0.35 MPa and a maximum 28-day strength of not more than 2.0 MPa. CDF consistency shall be flow-able with an approximate slump of 70 mm to 250 mm.

To develop the CDF mix design, the Contractor shall use the following test methods:

1. For 28-day compressive strength – ASTM D4832
2. For unit weight, yield, and air content – ASTM D6023
3. For slump – AASHTO T 119M.

Water-to-cement ratios shall be calculated on the total weight of cementitious material. Cementitious materials are Portland cement, fly ash, GGBS, and slurried microsilica fume. Water calculation shall account for the moisture content of the microsilica fume slurry.

Admixtures used in CDF shall meet the requirements of Section 4.3.6. Foaming agents, if used, shall meet the requirements of ASTM C869M. Admixtures shall be used in accordance with the manufacturer's recommendations and non-chloride accelerating admixtures may be used to accelerate the hardening of CDF.

CDF shall meet the requirements of Article 4.3.12.2 and shall be accepted based on a certificate of compliance provided by the Contractor for each truckload of CDF, in accordance with Article 4.3.12.1.

4.3.10.4 Mortar and Grout

Grout shall be a pumpable mixture of cement, sand, admixtures, and water, with constituent materials that meet the following requirements:

1. Portland cement, water, and admixtures shall meet the requirements of their respective subsections of Section 4.3
2. Ground granulated blast furnace slag shall not be used
3. Sand shall conform to ASTM C144 and have a gradation and colouring suitable for the intended use
4. Minimum compressive strengths shall meet the requirements of Table 4-19, as determined per AASHTO T 106M
5. Grout for masonry shall conform to the requirements of ASTM C476. Aggregate for masonry grout shall meet the requirements of ASTM C404 with a maximum coarse aggregate size of 9.5 mm

Grout shall be a workable mix with flowability suitable for the intended application. Grout cube testing shall be required for permanent ground anchor installations if admixtures are used or irregularities occur in anchor testing.

Table 4-19: Minimum required grout strengths

Application	Minimum Required Strength (MPa) per AASHTO T 106		
	3 days	7 days	28 days
Soil nails	10.5		21
Ground anchors		27.6	
Masonry grout*			17.5

*Masonry grout shall be tested for strength in accordance with ASTM C1019.

Grout mix shall be proportioned by weight per Table 4-20, or as directed by the Engineer or shown in the Contract plans.

Table 4-20: Nominal grout mix proportions by weight

Class	Cement*	Sand	Pulverised fuel ash (PFA)*
G1	1	1	-
G2	1	2	
G3	1	3	-
G4	1	10	-
G5	1	-	10
G6	1	-	4
G7	1	-	½
*Sulphate-resisting cement shall not be a constituent of grouts containing PFA.			

Grout and mortar shall be mixed to the required proportions using the minimum quantity of water to ensure the necessary fluidity and to render it capable of penetrating the work. Any work constructed with improperly mixed material shall be removed and reconstructed at the Contractor's expense. To mix properly, the Contractor shall:

a. Thoroughly mix ingredients in quantities needed for immediate use
b. Use mechanical mixers
c. Maintain sand uniformly damp immediately before the mixing process
d. Provide uniformity of mix and colouration
e. Re-temper only within 2 hours of mixing if water is lost to evaporation
f. Not re-temper more than 2 hours after mixing
g. Not use anti-freeze compounds
h. Never mix in contact with the ground.

Grout shall be used within one hour of mixing, unless it contains a retardant admixture.

Sampling requirement for mortar and grout shall be 2 strength samples for each 460 m^2 of masonry wall surface for each type of grout or mortar placed each day. Contractor shall also submit to the Engineer for approval 2 samples to illustrate colour range.

Grout sampling and testing shall be carried out in accordance with ASTM C 1019. During the first 48 hours, samples shall be protected from loss of moisture by covering with wet cloth and keeping moist. Contractor shall record maximum and minimum temperatures by using a max/min thermometer. After 48 hours, samples shall be transported to laboratory for testing. Samples shall be protected from vibration, freezing, and moisture loss during transportation. Compressive strength shall be the average of the 2 samples.

Coarse grout shall be used when grout space is equal to or greater than 100 mm in both directions. Fine grout shall be used when grout space is smaller than 100 mm in any dimension. Air-entrainment admixtures shall not be used.

Grout for anchor bolts shall be either:

1. A pre-packaged grout, mixed, placed, cured as recommended by the manufacturer; or

2. Produced using Type I or II Portland cement, fine aggregate Class 1 or Class 2, and water, in accordance with these Specifications.

For grout for anchor bolts, the Contractor shall submit to the Engineer laboratory test data from an independent testing laboratory for approval with the request for approval of material as well as:

- A material sample, if using a pre-packaged grout.
- Mix proportions, if using a cement-aggregate-admixtures grout.

Field grout samples shall be made for either pre-packaged grout or a Contractor provided mix when requested by the Engineer, but not less than 1 per day.

Before placing grout, the concrete on which it is to be placed shall be thoroughly cleaned, roughened, and wetted with water to ensure proper bonding. Grout pad shall be cured as recommended by the manufacturer or kept continuously wet with water for 3 days. Grout pad may be loaded when a minimum of 27.6 MPa compressive strength is attained.

Latex-Portland cement grout shall meet the requirements of ANSI A 118.6 for materials. Factory-prepared, dry-grout mixture shall consist of Portland cement; dry, redispersible, ethylene vinyl acetate additive; and ingredients necessary to produce:

1. Unsanded grout mixture for joints 3.2 mm and narrower.
2. Sanded grout mixture for joints 3.2 mm and wider.

Dry-set grout shall comply with ANSI A 118.6 for materials for joints 3.2 mm and narrower, and the latex additive shall be acrylic resin.

Mortar strength tests shall be conducted as followings:

a. Spread mortar on the masonry units 12 mm to 16 mm thick
b. Allow mortar to stand for one minute
c. Remove mortar and place in a 50 mm by 100 mm cylinder in 2 layers, compressing the mortar into the cylinder using a flat-end stick or fingers. Lightly tap mould on opposite sides, level off and immediately cover molds and keep them damp.
d. After 48 hours' set, have remove molds and place specimens in the fog room until tested in damp condition
e. Compressive strength shall be at least 13.8 MPa at 28 days, in accordance with ASTM C1019
f. Slump shall be 200 mm to 250 mm, taken in accordance with ASTM C143M.

Mortar mix shall be designed in accordance with the proportion specification of ASTM C270, Types M or S only, and required environmental conditions. The Contractor shall submit to the Engineer:

1. Test results demonstrating conformance to the proportion specification of ASTM C270, Type M or Type S
2. Test and evaluation reports per ASTM C780
3. Mmanufacturer’s certificate that products meet or exceed specified requirements

Portland cement shall be Type I or Type II meeting the requirements of Section 4.3.1 and shall be gray in colour. Fly ash, GGBS, and pozzolans shall not be permitted as substitutes for Portland cement. Masonry cement shall meet the requirements of ASTM C91.

Mortar aggregate shall meet the requirements of ASTM C144 for standard masonry type. Sand for mortar and ready-to-use retarded mortar shall comply with the relevant provisions of BS EN 998-1. Aggregate shall be kept clean, dry, protected against dampness and contamination by foreign matter. Contractor shall store sand for mortar on plastic sheeting to prevent contamination by extraneous chemicals in earth beneath.

Mortar and grout shall not contain admixtures or other chemicals with any of the following:

- Thiocyanates
- Chlorides
- Fluorides
- Sulfites
- Nitrates

Hydrated lime shall meet the requirements of ASTM C207, Type S.

Water shall meet the requirements of Section 4.3.8.

Masonry cement shall comply with ASTM C91, Type II and have colouring suitable for the type of masonry and as approved by the Engineer.

Admixtures shall not be used unless approved by the Engineer prior to construction. Plasticising and set-retarding mortar admixtures shall comply with BS EN 934-3 and shall be supplied with instructions for use.

Mortar mixes shall be proportioned by volume per Table 4-21, or as directed by the Engineer or shown in the Contract plans. Cement for mortar used for finishing shall be the same brand as the cement in the concrete work being finished.

Table 4-21: Nominal mortar mixes by volume

Class*	Cement: lime putty: sand	Cement: sand with plasticizer	Masonry cement: sand
M1	1 : (0 to ¼) : 3	1 : (2½ to 3)	
M2	1 : ½ : (4 to 4½)	1 : (3 to 4)	
M3	1 : 1 : (5 to 6)	1 : (5 to 6)	
M4	1 : 2 : (8 to 9)	1 : (7 to 8)	
M5			1 : 1
M6			1 : (2 to 2½)
M7			1 : (2½ to 3½)
M8			1 : (4 to 5)
M9			1 : (5½ to 6½)
*For pointing mortar, the Contractor shall duplicate the original mortar proportions, then add aluminium tristearate, calcium stearate, or ammonium stearate equal to 2 % of cement.			

Mixing of components on-site is acceptable. Mixing on-site water and packaged dry blended mix for mortar meeting ASTM C387M that contains no masonry cement, is acceptable.

High bond mortar mixture shall consist of, by volume, 1-part Portland cement, 3-part sand with addition of water and liquid acrylic resin. It shall demonstrate the following properties when tested in accordance with the relevant provisions of BSI PD 6678:

1. Compressive strength: ≥ 20 MPa, using 50 mm x 50 mm x 50 mm cubes
2. Tensile strength: ≥ 4 MPa, using the 25 mm x 25 mm x 25 mm briquettes
3. Flexural strength: ≥ 6 MPa, using flexural bar
4. Brick bond strength: ≥ 3 MPa, using crossed brick

Mortar colour shall be as designated in the Contract plans, as directed by the Engineer, and matching the masonry concrete block colour unless otherwise required.

All mortar shall be conveyed fresh to the site of the works as required for use. Mortar which has begun to set or which has been site-mixed for a period of more than one hour in the cases of Classes M1, M2, M5 and M6, and two hours in the case of classes M3, M4, M7 and M8 shall not be used.

4.3.10.5 Shotcrete

Shotcrete, also called pneumatically placed concrete, shall be proportioned to produce a nominal 30 MPa compressive strength at 28-days. Shotcrete mix design and evidence that the proposed design will produce the required compressive strength shall be submitted to the Engineer for approval. Constituent materials shall meet the following requirements of these Standard Specifications:

1. Cement – Section 4.3.1: Low-alkali cement in cases where the aggregates are reactive with the alkalies in cement. Type V cement in cases where the shotcrete will be exposed to sulfates, such as used in the coastal areas. Type III cement in cases where high early strength is required.
2. Admixtures – Section 4.3.6: Per approval of the Engineer.
3. Fine aggregate – Type 2 per Table 4-10
4. Coarse aggregate – Size 8 per Table 4-11

Admixtures shall be used only with written approval of the Engineer. If admixtures are used to increase workability, to reduce water-to-cement ratio, to retard or accelerate setting time, or to accelerate the development of strength, the admixtures shall be used at the rate specified by the manufacturer and approved by the Engineer.

Shotcrete for reinforced concrete slope protection, shall be 1-part cement to 4.5 parts sand. Fine aggregate moisture content at time of use shall be 3 % to 6 % by weight.

Two test cubes shall be made for each full day's operation. Test cubes shall be tested as required in Article 4.3.12.3. Cubes shall develop a minimum compressive strength of 28 MPa at 28 days.

Shotcrete facing shall conform to the requirements of Section 7.3.3 of Chapter 7, Incidental Construction.

4.3.10.6 Permeable Concrete

High porosity is attained by a highly interconnected void content. Typically, permeable concrete has little or no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles, while preserving the interconnectivity of the voids.

Permeable concrete mix design shall be submitted to the Engineer for approval with evidence that the proposed design will produce the required compressive strength per ASTM C39M, void space, and initial permeability. Contractor shall prepare trial pavement sections for inspection of the in-situ concrete properties, as well as a demonstration of the Contractor's proposed installation methods, for approval by the Engineer. Constituent materials shall meet the following requirements:

1. Cement – Section 4.3.1: Utilize Type V in coastal areas and Type I or II for inland areas
2. Admixtures – Section 4.3.6
3. Aggregate – Section 4.3.7

Table 4-22: Typical permeable concrete mix design

Material	Typical value
Cement (any type)	224 kg to 388 kg
Coarse aggregate	1,431 kg to 1,670 kg
Water-to-cement ratio	0.27 to 0.38
Admixtures	Retarders

Flexural strength of the cured pavement can range from 3.5 MPa to 5.0 MPa.

Mixes shall be designed in accordance with the ACI Design Guide 211, Appendix 6. Due to the relatively low water content of the concrete mix, an admixture is required to retard the concrete set time.

Permeable pavement shall have an in-place void space of at least 15 %, which allows rapid percolation of stormwater through pavements. Initial permeability of cured pavements, in clean conditions, shall be at least 5 m/hr.

4.3.10.7 Contents of Chlorides and Sulphates

Total water soluble chloride ion (Cl^-) content of the mixed concrete shall not exceed 0.06 % by weight of cementitious material for prestressed concrete nor 0.10 % by weight of cementitious material for reinforced concrete. An initial evaluation may be obtained by testing individual concrete ingredients for total chloride ion content per AASHTO T 260 and totalling these to determine the total water soluble chloride ion or the total water soluble chloride ion in accordance with ASTM C1218M.

Sulphate in the concrete shall not exceed 800 ppm when calculated on the total concrete mass, or 5,000 ppm when calculated on the amount of the cement in the actual mix.

Total sulphate content of the concrete mix, expressed as SO_3, shall not exceed 4 % (m/m) of the cementitious binder content of the mix per ASTM C265. Sulphate content shall be calculated as the total from the various constituents of the mix.

4.3.11 Concrete Batching Requirements

All concrete shall be batched in a prequalified manual, semi-automatic, or automatic plant as described in this section of these Standard Specifications. Delays to the Contractor due to problems in getting the plant certified shall not be the responsibility of the Engineer.

4.3.11.1 Batching Plant

Concrete batch plant shall be suitable in type, capacity and design for its purpose and acceptable to the Engineer. Batch plants shall meet the requirements specified herein and per the applicable requirements of Article 4.3.11.3.

Continuous mixers shall not be permitted. Mixers for designed mixes shall be of the pan type. Mixers and their accessories shall be to an internationally recognised standard such as BS 1305, and shall be in good condition. Performance of the batch plant and its disposition shall be adequate for the Contractor's work programme and acceptable to the Engineer. Mixers shall operate at the speeds and mix for at least the length of time recommended by the manufacturer. Mixing time shall be increased if necessary to achieve a uniform distribution of materials in the mix and a uniform colour.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed. Unless otherwise agreed by the Engineer, a small first batch shall be used to coat the mixer, and this coating batch shall not be incorporated in the works.

Standby mixing capacity shall be provided by the Contractor (sufficient to ensure continuity of concreting in the event of breakdowns of mixing plant) and shall be maintained ready for immediate use during the course of all concrete pours.

Precautions shall be taken to avoid the loss of cementitious material during windy conditions. The batching plant shall have separate balances for cementitious materials and aggregates unless otherwise agreed by the Engineer. Weighing and water dispensing mechanisms shall be maintained in good order, and their accuracy shall be maintained to ensure batch weights within the tolerances required by the AASHTO LRFD specification. Facilities shall be provided for calibration of all weighing equipment, gauges and meters for use in the manufacture of concrete. Calibration checks shall be carried out jointly with the Engineer at monthly intervals.

Automatic recording equipment shall maintain a record of each material used, including quantity, number of batches mixed and classification of mix, and dates and times of operations. Form of data output shall be acceptable to the Engineer.

At all times when concreting is being carried out, the Contractor shall have available sufficient standby plant to cover the operations of mixing, transporting, placing and compaction of concrete in the event of plant breakdowns.

A plant appraisal has to be conducted and approved by the Engineer prior to any approval of concrete mix and batching commencement.

4.3.11.2 Transporting and Placing

Contractor shall arrange his methods for transporting and placing concrete so that:

1. Contamination, segregation or loss of constituents does not occur;
2. Concreting shall proceed continuously for the whole of a pour without interruption by meal breaks, change of shift, movements of placing positions, and the like;
3. Transport of concrete from mixer to placing equipment shall be only by means of purpose made agitating trucks operated at the manufacturer's recommended agitating and discharge speeds, operating continuously from commencement of the pour and discharging within the time specified in Table 4-27 from the introduction of cement into the mixer. Time of such introduction shall be recorded on the delivery note together with the weight of the constituents of each mix;
4. Concrete shall be compacted in its final position within 15 minutes of its discharge from the mixer or from the agitator truck.

Before concreting is commenced, the reinforcement and other embedded items shall be cleaned of all deleterious matter including concrete 'splash' from previous concreting operations. All forms and falsework shall be carefully examined and the space to be occupied by the concrete thoroughly cleaned out.

Adequate notice must be given to the Engineer that areas are ready for concreting to enable the Engineer to attend and make necessary tests, inspections and checks.

Concrete shall not be placed in any part of the works until the Engineer's consent has been given. If concreting is not started within 24 hours of consent being given, consent shall again be obtained from the Engineer. Concreting shall then proceed continuously over the area between construction joints.

All concrete shall be placed in the positions and to the sequences indicated on the Contract plans, in the Specification or as directed by the Engineer and by such means as shall prevent contamination, segregation or loss of constituent materials.

When deposited, concrete shall not have a temperature of more than 32^{o} C.

Concrete shall be deposited as nearly as possible in its final position and shall be brought up in horizontal layers not exceeding 300mm in compacted depth. Where lateral spreading of concrete in the forms is necessary it shall be carried out by approved means and not by the use of vibrators. Concrete shall not be allowed to freely fall more than 1.2 m.

Where chutes are used in the placing of concrete they shall be of an accepted design and shall be used at slopes acceptable to the Engineer. Concrete shall not be pumped or discharged through aluminium alloy conduits.

Where concrete is placed by pumping, the Contractor shall take all precautions necessary to regulate the velocity of discharge in order to prevent segregation of the concrete or damage and distortion to the reinforcement and other embedded items and formwork.

During the placing of concrete for reinforced work a competent steel-fixer and carpenter shall be in constant attendance to adjust or correct the position of reinforcement and formwork as necessary.

Time-table for a pour of concrete is to be so arranged that no face of concrete shall be left more than 20 minutes before fresh concrete is deposited against it or more than 90 minutes after the mixing of the concrete forming the face, whichever is the less.

All concrete shall be compacted using internal (immersion) mechanical vibrators unless otherwise specified or ordered. Vibrating shall be carried out to a plan acceptable to the Engineer and no workmen shall be allowed to be operators without having received special training. Vibrators shall be of approved pattern and arrangement, and care shall be taken to avoid segregation and to ensure adequate.

A sufficient number of vibrators in serviceable condition shall be on site to ensure that spare equipment is always available in the event of breakdowns.

Vibration shall not be applied by way of the reinforcement. Where vibrators of the immersion type are used, contact with reinforcement and all inserts shall be avoided as far as is practicable.

4.3.11.3 Qualification of Concrete Suppliers

All commercially available concrete shall be batched in a prequalified manual, semi-automatic, or automatic plant as described in this section of these Standard Specifications and per the applicable requirements of Article 4.3.11.1. Delays to the Contractor due to problems in getting the plant certified shall not be the responsibility of the Engineer.

Batch plant qualification shall be obtained through a National Ready Mixed Concrete Association (NRMCA) certified batch plant inspector using the NRMCA batch plant checklist or an equivalent method as approved by the Engineer. Copies of the following documentation shall be provided by the Contractor to the Engineer:

1. Current certificate of conformance
2. Concrete mix designs
3. Truck list
4. Batch plant scale certification
5. Admixture dispensing certification
6. Volumetric water batching devices, including water metres and verification

Requirements for central-mixed concrete include the following:

a. Mixers shall be equipped with a timer that prevents the batch from discharging until the batch has been mixed for the prescribed mixing time.

b. Concrete shall be mixed for at least 1 minute after all materials and water have been introduced into the drum. Shorter mixing time may be allowed if the mixer performance is tested in accordance with AASHTO M 157 Annex A1, Concrete Uniformity Requirements.

c. Concrete transported by truck mixer/agitator shall not undergo more than 250-revolutions before beginning discharging. To remain below this limit, the supplier may agitate the concrete intermittently within the prescribed time limit. When water or admixtures are added after the load is initially mixed, an additional 30-revolutions shall be required at the recommended mixing speed.

d. Tests shall be conducted by either:

    1. The project site lab
    2. An approved independent lab certified by ADQCC

e. Flow of water into the mixer shall be uniform with a portion of the water entering in advance of the cementitious material and aggregates and all of the water entering within the first 15 seconds of the mixing time.

Requirements for shrink-mixed concrete include the following:

- Mixing time in the stationary mixer shall be at least 30 seconds or until the ingredients have been thoroughly blended.
- Mixing time in the transit mixer shall be at least 70 revolutions at the mixing speed designated by the manufacturer of the mixer.
- Following mixing, the concrete in the transit mixer may be agitated at the manufacturer's designated agitation speed.
- A maximum of 320 revolutions total for mixing and agitation shall be permitted prior to discharge.

Requirements for transit-mixed concrete include the following:

1. Mixers and agitators shall always operate within the capacity and speed-of-rotation limits set by the manufacturer.
2. Any fully loaded mixer shall keep the concrete uniformly mixed.
3. All mixers and agitators shall be capable of discharging the concrete at a steady rate.
4. In transit-mixing, mixing shall begin within 30 seconds after the cementitious material is added to the aggregates.
5. Water used for cleaning the mixer shall be discharged prior to further batching.

Only those transit mixers that meet the following requirements shall be allowed to deliver concrete:

a. Operational revolution counter

b. Functional device for measurement of water added

c. Mixing drums free of concrete build-up

d. Mixing blades that meet the minimum specifications of the drum manufacturer

e. Metal data plates attached to each mixer and agitator that clearly display:

   1. Maximum concrete capacity of the drum or container for mixing and agitating; and
   2. Rotation speed of the drum or blades for both the agitation and mixing speeds

f. A copy of the manufacturer's blade dimensions and configuration on file at the concrete producer's office

g. No components made of aluminium or magnesium alloys that contact plastic concrete during mixing and transporting

h. Smooth, mortar-tight, metal bodies capable of discharging the concrete at a satisfactory controlled rate without segregation. If discharge of concrete is accomplished by tilting the body, the surface of the load shall be retarded by a suitable baffle.

For each project, the plant manager shall examine mixers and agitators to check for any build-up of hardened concrete or worn blades biannually, or as required. If this examination reveals a problem, or if the Engineer wishes to test the quality of the concrete, slump tests may be performed with samples taken at approximately the one-quarter and three-quarter points as the batch is discharged. Maximum allowable slump difference shall be as follows:

- If the average of the 2 slump tests is <100 mm, the difference shall be <25 mm; or
- If the average of the 2 slump tests is >100 mm, the difference shall be <37 mm

If the slump difference exceeds these limits, the equipment shall not be used until the faulty condition is corrected. However, the equipment may continue in use if longer mixing times or smaller loads produce batches that pass the slump uniformity tests. All concrete production facilities shall be subject to verification inspections at the discretion of the Engineer. Verification inspections are a check for current scale certifications, accuracy of water metering devices, accuracy of the batching process, and verification of coarse aggregate quality. If the concrete producer fails to pass the verification inspection, the following actions shall be taken:

1. For the first violation, a written warning shall be provided.
2. For the second violation, the Engineer shall give written notification and assess a price reduction equal to 15% of the invoice cost of the concrete that is supplied from the time of the infraction until the deficient condition is corrected.
3. For the third violation, the Contractor is suspended from providing concrete until all deficiencies causing the violation have been permanently corrected and the plant and equipment have been re-inspected and meet all the prequalification requirements.

4.3.11.4 Batching and Delivering Permeable Concrete

Batching of permeable concrete requires special attention. Batch plant shall ensure that aggregate has been triple washed to remove fines and stored in a no-fines silo. Trucks to be used in delivering and mixing the material shall have their drums thoroughly flushed and cleaned prior to loading.

4.3.12 Acceptance of Concrete

All concrete shall be accepted based on the approved qualifications of the materials, mix and the testing of the as-delivered mixed concrete to the jobsite. All concrete shall be accepted based on adherence to the requirements of these standard specifications for temperature, slump, air content, and compressive strength at 28 days, as tested and determined by the Engineer.

A sublot is defined as the material represented by an individual strength test. An individual strength test is the average compressive strength of cubes from the same sample of material.

Each sublot shall be deemed to have met the specified compressive strength requirement when both of the following conditions are met:

a. Individual strength tests do not fall below the specified strength by more than 12.5 % or 3.5 MPa, whichever is least.
b. An individual strength test averaged with the 2 preceding individual strength tests meets or exceeds specified strength for the same class and exact mix number of concrete on the same Contract.

When compressive strengths fail to satisfy one or both of the above requirements, the Contractor may request acceptance of in-place concrete strength based on core results. This method shall not be used if the Engineer determines coring would be harmful to the integrity of the structure. If allowed, the Contractor shall obtain the cores in accordance with AASHTO T 24M and deliver them to the Engineer for testing in accordance with AASHTO T 22. If the concrete in the structure will be dry under service conditions, the core will be air dried at a temperature of between 15^{o} C and 27^{o} C and at a relative humidity of less than 60 % for 7 days before testing, and shall be tested air dry.

Acceptance for each sublot by the core method requires that the average compressive strength of 3 cores be at least 85 % of the specified strength with not 1 core less than 75 % of the specified strength. When the Contractor requests strength analysis by coring, the results obtained shall be accepted by both parties as conclusive and supersede all other strength data for the concrete sublot.

If the Contractor elects to core, cores shall be obtained no later than 50 days after initial concrete placement. Engineer must concur in the locations to be cored. Repair of cored areas shall be the responsibility of the Contractor. Cost incurred in coring and testing, including repair of core locations, shall be borne by the Contractor.

4.3.12.1 Certification of Compliance

Commercial suppliers shall provide a certificate of compliance for each truckload of concrete. Certificate of compliance shall verify that the delivered concrete is in compliance with the mix design and a responsible representative of the concrete producer shall sign it, affirming the accuracy of the information provided. For ready-mix concrete, the certificate of compliance shall include as a minimum the batching facility, date, and quantity batched per load. Certificates of compliance shall include the information given in Table 4-23, and may be machine-produced records or printed forms filled in by hand. Ready-mix commercial concrete shall be subject to the Engineer's acceptance testing of the as-delivered product as specified in Section 4.3.12.

Table 4-23: Certificate of compliance requirements for each truckload of concrete

1. Manufacturer plant or batching facility 2. Contracting agency Contract number 3. Date 4. Time batched 5. Truck number 6. Initial revolution counter reading 7. Quantity batched this load 8. Type of concrete by class and producer design mix number 9. Cementitious material producer, type, and mill certification number. Mill test number as required by Section Packaging and Marking is the basis for acceptance of cementitious material 10. Fly ash, if used, brand and type 11. Mix design weight per cubic metre and actual batched weights for: 12. Cementitious material 13. Fly ash, if used 14. Coarse aggregate and moisture content for each size[1] 15. Fine aggregate and moisture content[1] 16. Water, including free moisture in aggregates 17. Admixtures brand and total quantity batched 18. Air-entraining admixture 19. Water reducing admixture 20. Other admixtures 21. Approved aggregate gradation designation
22. For concretes that use combined aggregate gradation, the certificate of compliance shall include the aggregate components and moisture contents for each size in lieu of the aggregate information described above.

4.3.12.2 Conformance to Mix Design

Cementitious materials and coarse and fine aggregate weights shall be within the following tolerances of the mix design:

Table 4-24: Conformance to mix design in production

Condition:	Batch Volume ≤ 4 m^3	Batch Volume > 4 m^3	Cementitious materials in mix
Cement	+5 % -1 %	+5 % -1 %	+5 % -1 %
Aggregate	+10 % -2 %	+2 % -2 %	
Fly ash			+5 % -1 %
Ground granulated blast-furnace slag			+5 % -1 %
Microsilica			±10 %

Water shall allow for moisture content of aggregates, volume of liquid admixtures, and shall not exceed the maximum water specified in the mix design.

4.3.12.3 Sampling and Testing Methods

Concrete properties shall be determined from concrete as delivered to the project and as accepted by the Contractor for placement. It shall be the Contractor's responsibility to provide adequate and representative samples of the fresh concrete to a location designated by the Engineer for the testing of concrete properties and making of specimens. Sampling and testing methods for acceptance of concrete for slump, temperature, and air content, if applicable, shall be completed by the Contractor and Engineer as follows:

Table 4-25: Sampling and testing methods for acceptance of concrete

Concrete Property or Process	Test Method
Sampling freshly mixed concrete	AASHTO T 141
Slump of hydraulic cement concrete	AASHTO T 119M
Temperature of freshly mixed cementitious material concrete	AASHTO T 309M
Air content of freshly mixed concrete by the pressure method	AASHTO T 152
Making and curing of concrete cube test specimens	BS EN 12390-1, BS EN 12390-2
Compressive strength testing of cube test specimens	BS EN 12390-3

Sampling and testing shall be performed as follows:

a. Before concrete placement from the first truck load.
b. For each load until 2 successive loads meet all applicable acceptance test requirements.
c. On 1 for every 5 truckloads, after 2 successive tests indicate that the concrete is within specified limits.
d. When the results for any subsequent acceptance test indicate that the concrete, as delivered and approved by the Contractor for placement, does not conform to the specified limits, the sampling and testing frequency shall be resumed for each truck load. Whenever 2 successive subsequent tests indicate that the concrete is within the specified limits, the random sampling and testing frequency of 1 for every 5 truckloads may resume.

Except for the first load of concrete, up to 0.5 m^3 may be placed prior to testing for acceptance. Loads to be sampled shall be selected per a random selection process.

Sampling and testing for a placement of one class of concrete consisting of 50 m^3 or less shall be as listed above, except that sampling and testing shall continue until 1 load meets all of the applicable acceptance requirements. After 1 set of tests indicate that the concrete is within specified limits, the remaining concrete to be placed may be accepted by visual inspection.

Contractor performed testing shall be performed by a testing laboratory whose equipment has been calibrated within 1 year prior to testing, and testers shall be either ACI certified or qualified in accordance with AASHTO R 18.

Concrete shall be tested for compressive strength per BS EN 12390-3 at the same frequency as the acceptance tests for temperature, consistency, and air content. Six test cubes shall be taken at each time, numbered consecutively and marked with the date, the section of work from which it was taken and any other information required. Cubes shall then be dispatched to the approved laboratory for curing and testing for compressive strength.

Contractor shall provide and maintain cure boxes for curing concrete test cubes and shall provide, maintain, and operate all necessary power sources and connections needed to operate the curing box. Concrete cubes shall be cured in a cure box in accordance with AASHTO T 23. Cure boxes shall maintain a temperature between 16^{o}C and 27^{o}C for concrete with specified strengths less than 40 MPa and between 20^{o}C and 26° C for concrete with specified strengths of 40 MPa and higher. A minimum/maximum thermometer shall be installed to measure the internal temperature of the cure box. Thermometer shall be readable from outside of the box and be capable of recording the high and low temperatures in a 24-hour period. Cure boxes shall create an environment that prevents moisture loss from the concrete specimens. Box tops shall have a working lock and the interior shall be rustproof.

A moisture-proof seal shall be provided between the lid and the box. Each cure box shall be the appropriate size to accommodate the number of concrete acceptance cubes necessary or the Contractor shall provide additional cure boxes. Once concrete cubes are placed in the cure box, the box shall not be moved until the cubes have been cured in accordance with these Standard Specifications. When concrete is placed at multiple locations simultaneously, multiple cure boxes shall be provided.

Concrete cubes shall be protected within the cure boxes from excessive vibration and shock waves during the curing period.

4.3.12.4 Point of Acceptance

Determination of concrete properties for acceptance shall be made based on samples taken at the discharge of the placement system, or otherwise at the truck discharge.

Once the Contractor has turned over the concrete for acceptance testing, no more mix adjustment shall be allowed, and the concrete shall be accepted or rejected.

Concrete shall not be placed until tests for slump, temperature, and entrained air, if applicable, have been completed by the Engineer, and the results indicate that the concrete is within acceptable limits.

Test cubes Nos. 1, 3 and 5 (from an individual sample as required in Article 4.3.12.3) shall be tested after 7 days.

If the average of the three 7-day test cubes is below the minimum requirement, the Contractor shall immediately stop all concreting until the material and equipment are checked and any deficiencies are corrected. If the Contractor elects to remove and replace the defective concrete without waiting for the results of the 28-day test, concreting can then continue entirely at the responsibility of the Contractor. Cube numbers 2, 4, and 6, shall be considered three individual samples or sets and after 28 days of curing shall be tested as specified above. If any cube in any set shows definite evidence, other than low strength, of improper sampling, moulding, handling, curing, or testing, it shall be discarded and the strength of the remaining cube shall then be considered the test result for that set.

Final acceptance of the concrete works is based on 28 days of compressive strength testing on the cubes. Work is considered in compliance if the average of the compressive strength tests equals or exceeds the minimum specified for the class of concrete being placed, and if the average of the three cubes in any one set does not fall below the specified minimum strength by more than 3.5 MPa.

If the results of the 28-day testing are unsatisfactory, the Contractor, in accordance with the instructions of the Engineer, shall conduct tests in the suspect parts of the structure. Concrete may be test loaded in situ or cylindrical test cores may be drilled out and tested in accordance with AASHTO T 22. Should the tests prove that the concrete is unsatisfactory or below the standards specified, the Engineer may order the removal and replacement of existing concrete with concrete of the specified quality or accept it at a reduced payment. All the above shall be at the expense and responsibility of the Contractor.

4.3.12.5 Water-to-cement Ratio Conformance

Actual water-to-cement ratio shall be determined from the certified proportions of the mix. No water shall be added after acceptance testing or after placement has begun. Excess water shall not be permitted and any batch containing such excess will be rejected.

For slip-formed concrete, water may be added during placement but shall not exceed the maximum water cement ratio in the mix design, and shall meet the requirements for consistency as described in Article 4.3.12.6. If water is added in concrete used in slip forming, an air and temperature test shall be taken prior to resuming placement to ensure that specification conformance has been maintained.

Frequent tests, including the slump test, shall be carried out to ensure that consistent water content is maintained.

4.3.12.6 Consistency

Slump shall not exceed the allowable range identified herein. Slump tests shall be performed in accordance with AASHTO T 119M or ASTM C143M. Maximum slump for concrete should be as indicated in Table 4-26, unless otherwise approved by the engineer.

Table 4-26: Maximum slump for concrete

Condition	Maximum Slump	Maximum Slump with a High-Range Water Reducer
Vibrated Class C25 or stronger concrete	90 mm	140 mm*
All other vibrated concrete	115 mm	165 mm
Non-vibrated concrete	180 mm	230 mm
Pipe and utility bedding and cases where water reducer is used per Section 4.3.6	230 mm	NA
Concrete placed in kerbs, gutters, and sidewalks	140 mm	190 mm
*Some mixes with combinations of mineral/chemical additives may produce slumps higher than this value while meeting the other specified performance values. Approval for this case will be based on review and acceptance of trial mixes.		

Concrete transport and placement equipment shall be shaded or wrapped, as necessary, to prevent loss of slump and workability during high temperature conditions.

4.3.12.7 Temperature and Time for Placement of Concrete

Temperature and time for placement of concrete shall meet the requirements of Table 4-27.

Table 4-27: Acceptable time and temperature limits for placement of concrete

Time to Completely Discharge Batch of Concrete (Measured from time cement added to concrete mixture)	Allowable Concrete Temperature Range
0 to 1.5 hours maximum	12° C to 32° C
1.5 hours to 1.75 hours maximum	12° C to 24° C
1.75 hours to 2 hours maximum with the Engineer’s approval	12° C to 24° C

Time to discharge may be extended upon written request from the Contractor. This time extension shall be considered on a case-by-case basis and requires the use of specific retardation admixtures and the approval of the Engineer.

When conditions are such that the concrete may experience an accelerated initial set, the Engineer may require a shorter time to discharge.

Precast concrete that is heat-cured per Article 4.4.84.4.8.3 shall remain between 10° C and 32° C while being placed.

4.3.12.8 Rejecting Fresh Concrete

Prior to sampling, the Engineer may reject any batch or load of concrete that appears defective in composition without testing. This includes cement content or aggregate proportions. Rejected material shall not be incorporated in the structure.

4.3.12.9 Concrete with Nonconforming Strength

Concrete with tested compressive strengths (refer to Section 4.3.12) that fail to meet acceptance level requirements will be rejected. Rejected concrete and the associated work shall be removed and replaced at the Contractors expense. Removal and replacement limits will be evaluated and approved by the Engineer prior to start of the Contractor's removal work.

4.3.13 Curing Materials

All concrete curing compounds and concrete evaporation retardants must demonstrate conformance to the requirements of these Standard Specifications. Each lot of the material shall be sampled at the site of the works and tested for acceptance.

Material that fails to meet the requirements of these Standard Specifications shall not be used.

4.3.13.1 Sheet Materials for Curing Concrete

Sheet materials for curing concrete shall meet the requirements of ASTM C171, "Sheet Materials for Curing Concrete," except that only the white, reflective type shall be used.

4.3.13.2 Liquid Membrane-forming Concrete Curing Compounds

Liquid membrane-forming compounds used for curing concrete shall conform to ASTM C309, Type 1D or 2, Class A or B, requirements; except that the loss of water within 72 hours shall not exceed 0.40 kg/m^2 for all applications, per ASTM C156.

4.3.13.3 Burlap Cloth

Burlap cloth shall meet the requirements of AASHTO M 182, Class 4.

4.3.13.4 Sampling

A product sample shall be submitted for each material under consideration, with the request for approval of material. Sample sizes shall be per the applicable testing standard as described in the subsections of Section 4.3.13, specifically:

- Sheet materials: ASTM C171
- Liquid membrane-forming compounds: ASTM C309
- Burlap cloth: AASHTO M 182

Sample containers for liquid membrane-forming concrete curing compound shall be standard friction seal 500 ml cans, lined to prevent rusting. Cans for sampling at the manufacturing site shall be provided by the manufacturer.

Sampling of liquid membrane-forming concrete curing compound shall comply with the following procedures, as applicable:

For production sampling, the following should occur:

1. Select 3 samples during actual transfer, or filling, operations to the shipping containers.
2. Take the first sample from the fill stream after 15 %, but before 30 %, of material has been transferred or filled. Label the sample No. 1 and indicate the approximate number of drums filled.

3. Take the second sample from the fill stream after 40 %, but before 60 %, of material has been transferred or filled. Label the sample No. 2 and indicate the approximate number of drums filled.
4. Take the third sample from the fill stream after 70 %, but before 90 %, of material has been transferred or filled. Label the sample No. 3 and indicate the approximate number of drums filled.

For sampling drums, the following should occur:

a. Select three drums, at random, for each identifiable lot or batch.

b. Thoroughly disperse material in each drum with a mechanical mixer.

c. Check each drum for complete dispersion by scraping a 25 mm by 25 mm slat, or similar object, along the drum bottom.

   1. Remove the slat and examine the end for settlement and material along the length for uniform appearance.

d. Secure a sample, using a 25 mm diameter tube or pipe, for each of the three drums.

   1. Insert the tube or pipe to within approximately 150 mm of the bottom of the drum, place the palm of the hand over the open end of the tube or pipe to form a seal and withdraw the tube over the sample can and discharge sufficient material to fill the can.
   2. Discharge the remainder of material back into the drum.

e. Allow material in the tube to drain down to a drip and wipe material from the exterior of the tube before sampling another drum.

When drums cannot be identified by lot or batch, segregate into groups of no more than 20 drums each. Assign a lot or batch number to each group and sample according to the drum sampling procedure. If there are 3 drums or less, sample each drum.

For bulk storage sampling, the following should occur:

a. Bulk storage tanks must be designed for recirculation; therefore, have fixed stirrers or use portable stirrers to insure complete mixing prior to discharge or use of material.

b. Ensure complete mixing as described in Step 3 of the drum sampling procedure, prior to sampling.

c. Bulk storage tanks with re-circulating systems may be sampled from a re-circulating line or from the discharge line. Discharge approximately 19 l into a clean container before securing sample.

   1. Circulate for 3 to 5 minutes, discharge approximately 19 l and secure a second sample. Repeat the circulation and discharge. Secure a third sample. Number the samples in the order taken.
   2. Discharged material may be returned to the storage tank if clean containers have been used.

d. Bulk storage tanks using mixers may be sampled in the same manner as drums, using a tube.

   1. Secure three samples: 1 from the top third of the tank, 1 from the middle third, and 1 from the bottom third.

Under no conditions shall two or more portions of material be blended or mixed to form a composite sample.

Samples of liquid membrane-forming compounds for curing concrete must be labelled with the batch number; the part of the batch represented, i.e., the first, middle, or last third; the total batch quantity represented; and the producer, material type, date of sampling, date of manufacture, and sampler's name.

Cost of sampling, testing, and processing shall be borne by the Contractor.

4.3.13.5 Tests and Acceptance

Material shall be accepted based on the Engineer's approval of a request for approval of materials, which shall include the following information:

1. Company name
2. Physical and mailing addresses
3. Type of material
4. Laboratory test report for each material with test data showing compliance with these standard specifications
5. Contact person and telephone number

4.3.14 Steel Reinforcing Bar

Concrete reinforcement shall meet the requirements of Chapter 5.

4.3.15 Joint Sealing Materials

Use of joint fillers, pads, waterstops, proprietary or custom-built expansion-joint assemblies, or other incidental materials used in forming, constructing, and sealing permanent joints, shall be subject to the approval of the Engineer. Joint filler and sealants shall conform to drawing requirements. When not specified, one of the joint fillers identified in these specifications may be used.

Samples for each lot taken by, or in the presence of, the Engineer shall be submitted by the Contractor to the Engineer for approval. Samples must be submitted for testing 14 days prior to use in the works.

Each lot of the joint filler or sealant shall be identified with the batch and lot number, material, the batch quantity, the date and time of manufacture, and the name and address of the manufacturer; and shall be accompanied by the manufacturer's certification attesting compliance with this specification. When required by the Engineer, the Contractor shall submit test certificates issued by an approved, independent testing authority to confirm that the respective materials comply with the specified requirements, or a certificate by the patent holder or designer certifying that the manufactured item complies in all respects with relevant product specifications.

4.3.15.1 Fixed-joint Seal

Joint sealer shall repel the intrusion of stones, dirt, and other material into the joint or into the material itself. Joint sealer shall be neoprene, preformed or extruded type, of the size and shape indicated on the Contract plans. Preformed joint sealer material shall comply with the requirements of AASHTO M 220 or ASTM D2628. Lubricant adhesive, for use with the preformed sealer, shall conform to ASTM D4070.

Shape, width, and depth of the sealer shall meet the following requirements:

1. Such that it is compressed to the point of being substantially solid with a minimum of air spaces when installed at the minimum joint opening.
2. Such that the top centre of the exposed surface is depressed below the surface of the sealer edges when compressed.
3. Approved by the Engineer prior to being furnished.

Sealer shall be flexible and pliable and retain its elasticity at temperatures from -28° C to 54° C. Sealer shall not develop appreciable permanent set after full compression of the approved joint shape for the full effective life of the material. It shall be compatible with the material of which the joint surfaces are composed and be relatively unaffected by the normal moisture in the material. Joint sealer shall not be field spliced, except when specifically permitted by the Engineer.

Each lot of the adhesive shall be delivered in containers plainly marked with the manufacturer's certification attesting compliance with this specification.

4.3.15.2 Preformed Joint Fillers

Preformed joint fillers shall be furnished in a single piece for the depth and width required for the joint with a thickness not less than 13 mm.

Table 4-28: Joint fillers

Type	Specification
Preformed expansion joint filler (bituminous type)	AASHTO M 33 or ASTM D1751
Preformed sponge-rubber and cork expansion joint fillers	AASHTO M 153* Type I – sponge-rubber Type II – cork Type III – self-expanding cork
Preformed expansion joint fillers (nonextruding and resilient bituminous types)	AASHTO M 213
Flexible cellular joint filler	ASTM D1056, Type 2, Grade 4 or 5
*Compression test specimen shall recover to at least 65 % of its thickness before testing. Compressive strength shall be at least 0.07 MPa.	

4.3.15.3 Backer Rod

Backer rod, or backing material, shall conform to the requirements of ASTM D5249. Sealant shall be a compatible sealant as recommended by the rod manufacture. Backer rod sizes shall conform to Table 4-29.

Table 4-29: Backer rod sizes

Joint width after preparation	Rod diameter
8 mm	9 mm
9 mm	13 mm
13 mm	16 mm
16 mm	19 mm
19 mm	25 mm
25 mm	32 mm
32 mm	38 mm
38 mm	50 mm

Material containing bitumen or solvents shall not be used with thermosetting chemically curing sealants.

4.3.15.4 Joint Sealants

Sealers for joints not coming in contact with bituminous materials shall be a 2-component, cold-curing polysulphide liquid polymer meeting Federal Specification, TT-S-227e, Type II, Class A, or as approved by the Engineer or as shown in the Contract plans. Sealer shall be gun grade, or Type II, suitable for both horizontal and vertical joints. Where a primer is to be used in conjunction with the sealant, it shall be of the prescribed proprietary material.

For proprietary asphalt-rubber products, the Contractor shall furnish the following:

1. Source and grade of asphalt binder
2. Total granulated rubber content and mass, as percent of the asphalt-rubber mixture
3. Granulated rubber types and content of each type, if blend
4. Mass as a percent of combined rubber
5. Gradation of granulated rubber
6. Type of asphalt modifier, if any
7. Quantity of asphalt modifier and mass as a percent of asphalt binder
8. Heating and application temperatures
9. Manufacturer's recommended application procedures
10. Other additives

Thermosetting chemically curing sealants shall comply with the requirements of ASTM C920. Final international rubber hardness degree (IRHD) hardness of the sealant shall be 20 +5. Silicone sealants shall comply with the requirements of the project particular specifications. Other sealants may be used, if approved by the Engineer, after the Contractor has furnished the Engineer with full information and specifications.

4.3.15.5 Hot-poured Joint Sealants

Hot-poured joint sealants shall meet the requirements of ASTM D6690 and be sampled and tested per ASTM D5167 and ASTM D5329. In addition, the sealant shall have a flash point per AASHTO T 48 of 205° C minimum.

Physical properties of the joint sealer, when mixed in accordance with the manufacturer’s recommendations, shall be per Table 4-30.

Table 4-30: Poured rubber joint sealer

Property	Criteria
Colour	Gray or black
Viscosity[1]	Pourable and self-levelling at 10ºC
Application life[1]	≥ 3 hours at 22º C and 50 % relative humidity
Set to touch	≤ 24 hours at 22º C and 50 % relative humidity
Curing time	≤ 96 hours at 22º C and 50 % relative humidity
Non-volatile content	≥ 92 %
Hardness rating (durometer “Shore A”)	5 to 35
Resiliency	≥ 80 %
Bond test methods	In accordance with this section of the standard specifications
Note 1: Viscosity and application life may be waived if the material is mixed and placed by a pump and mixer approved by the Engineer. Suitable primer, if required by the manufacturer, shall be furnished with each joint sealer. Primer shall be suitable for brush or spray application at 10ºC or higher and shall cure sufficiently at 10º C to pour the joint within 24 hours. It shall be considered	

Property	Criteria
as an integral part of the sealer system. Any failure of the sealer in the test described herein, attributable to the primer, shall be grounds for rejection or re-testing.	

Acceptance of joint sealing compound for use on a project shall be on the basis of laboratory tests of samples representative of each batch of material to be used on the job. A period of at least two weeks shall be allowed for completion of tests. Each container of the compound shall be clearly identified by its batch number.

Bond test for joint sealants shall be made per the following procedure:

a. Scope: This method covers the bond test for joint sealers.

b. Bond test apparatuses include the following:

   1. Bond extension apparatus shall consist of an extension machine, similar to that described in federal specifications, SS-R-406, so designed that the specimen can be extended for four hours at a uniform rate of approximately 3.175mm per hour. It shall consist essentially of one or more screws rotated by an electric motor through suitable gear reductions. Self-aligning plates or grips, one fixed and the other carried by the rotating screw or screws, shall be provided for holding the test specimen in position during testing. Machines must be capable of reversing themselves for the recompression cycle. Bond extension machine shall be housed in a refrigeration unit capable of maintaining a temperature of -18° C ±2° C.

   2. Concrete blocks shall measure 25.4 mm by 76.2 mm by 50.8 mm.

   3. Spacers made of brass or steel shall measure:

      i. 152.4 mm by 25.4 mm by 12.7 mm, or

      ii. 50.8 mm by 25.4 mm by 12.7 mm

   4. Release agents shall consist of 50 % talc, 35 % glycerine, and 15 % water-soluble medical lubricant blended into a smooth paste, where percentages are by weight.

c. Bond test preparation includes the following:

   1. Prior to use, the cured blocks shall be removed from storage in 98 % relative humidity, and acid etched with hydrochloric acid. Blocks shall be rinsed with water, wiped and allowed to surface dry before using. Three prepared blocks shall then be placed on a glass plate and a spacer 152.4 mm by 25.4 mm by 12.7 mm placed between them. At each end of the spacer block, a spacer block 50.8 mm by 25.4 mm by 12.7 mm shall be placed on end. Prior to using, the spacer blocks shall be coated with a release agent. When the blocks are pushed together and secured with rubber bands, a joint that measures 152.4 mm by 25.4 mm by 12.7 mm in size is formed. Hot-poured joint sealer, prepared as per ASTM D 5167, is poured in the formed joint to the top of the spacer blocks. Test specimens shall be allowed to cool at standard conditions at least 2 hours; they shall be flush with the top and bottom of the block; and shall be trimmed using a heated metal knife. Test specimens shall be placed in a freezer or extension chamber to equilibrate to testing temperature for at least 4 hours prior to first extension.

   2. Two component joint sealers shall be prepared according the manufacturer's recommendations and poured in the formed joint to the top of the spacer blocks. Allow to cure for 96 hours.

   3. Three samples are required for each test.

d. Bond test procedures consist of the following:

   1. Remove the spacers and insert the test specimens in the clamps of the extension machine. Bond extension machines must be at -18° C ±2° C. Blocks shall then be extended to 12.7 mm in approximately 4 hours. Specimen shall be removed within 30 minutes post extension and immediately inspected for obvious separations. Spacer strips shall be replaced and the

blocks allowed to recompress at room temperature for 2 hours. This completes one cycle. Specimens shall be returned to the freezer for at least 4 hours prior to the next extension. This cycle shall be repeated 2more times for 3 total test cycles. Immediately following final extension cycle, the Contractor shall determine conformance to respective material specifications.

2. Development of any crack, separation, or other opening in the joint sealer or between the joint sealer and the block shall be considered as a failure to pass the bond extension test.

4.3.15.6 Joint Mortar

A completed mortar joint shall be formed with a bead on the outside and finished smooth on the inside of the sections and cured per the manufacturer’s recommendations. Masonry mortar shall be proportioned to meet the requirements of Article 4.3.10.4.

4.3.15.7 Bond Breakers

Bond breaker shall be a nonstaining type which will provide positive bond prevention. Polyethylene tape-coated paper, metal foil, or similar material may be used where bond breakers are required.

4.3.16 Waterstops

Waterstops shall be of the type, size, and shape specified in the Contract documents. They shall conform to the requirements of Article 21.9.1.6 of Chapter 21, Concrete Structures, of theses standard specifications.

4.4 Construction Requirements

The concrete construction shall be as indicated on the Contract plans, as specified herein and as directed by the Engineer.

4.4.1 Placing Concrete

Prior to the start of concrete placement of any element of the work, the Contractor shall review his concrete placement methodology and program with the Engineer, unless this review requirement is otherwise waived by the Engineer. Contractor’s concrete placement methodology and program shall be included in his program of works submittal, which shall meet the requirements of Section 1.6.2. This program of works may need to be updated by the Contractor for any specific concrete placement, if directed by the Engineer.

Concrete shall be placed immediately after mixing by the Contractor. Contractor shall provide sufficient capacity in the concrete producing plant and concrete transporting arrangements to avoid cold joints. Cold joints are defined as locations where one concrete pour ends and becomes non-plastic before the next concrete pour begins.

Transport of concrete from the mixers to the place of final deposit shall be by methods that prevent the separation, loss, or contamination of any of the ingredients. Any method using pipes or chutes for transporting concrete will not be permitted, except with the written approval of the Engineer. Engineer may require that all structural concrete mixing, placement, and curing be accomplished in shaded areas. Concrete shall not be placed in locations where nearby vibrations could harm the concrete’s initial set or strength.

Concrete shall always be plastic and workable. Maximum time to discharge beyond the requirements of Article 4.3.12.7 may be reduced by the Engineer to ensure plasticity and workability.

Methods for placing and consolidating concrete shall:

1. Deposit concrete as near its final position as possible
2. Place each layer of concrete before the previous layer commences to set

3. Produce a compact, dense, homogeneous, and impervious concrete with smooth faces on exposed surfaces substantially free from water and air pockets, or honeycombs
4. Work the concrete around the reinforcement steel, ducts, embedded fittings, and into the corners of the formwork

Methods for placing and consolidating concrete shall not:

a. Leave a line of separation between layers
b. Segregate materials or aggregates
c. Displace reinforcing steel
d. Cause water to collect at the ends, corners, or along the faces of the forms
e. Move concrete over long distances
f. Allow surface water, such as rain, to affect or damage surface mortar quality or cause a flow or wash the concrete surface
g. Allow concrete to free fall more than 1 m

To convey the concrete as near as possible to its final position, drop chutes of rubber or metal conforming to the chutes, troughs, and conveyor belts requirements in Article 4.4.1.1 shall be used for small sections and bottom dump buckets or other suitable vessels for large sections. All vibration, consolidation, and finishing operations shall occur immediately after concrete is placed in its final position. Plastering is not permitted.

Prior to concrete placement for any part of the works, the Engineer shall evaluate and approve the following:

1. Placement of reinforcement steel
2. Method and sequence of placing concrete
3. Formwork
4. Depth and character of foundation

Immediately prior to concrete placement for any part of the works, the conditions of forms and foundations shall be:

a. Thoroughly clean, with no dirt, shavings, loose stones, or other debris
b. Free from material that might adhere to or discolour the concrete
c. Free from standing water. Contractor shall remove standing water by pumping, if necessary.
d. Saturated with water, for foundations, excavations, and absorbent form materials such as timber
e. Treated with a non-staining material to prevent adherence to the concrete, for exposed surfaces

After acceptance, concrete shall not be modified by the addition of water or in any other manner to facilitate handling or for any other reason.

Thickness of the layers shall be:

1. 150 mm to 300 mm for reinforced concrete
2. Up to 450 mm for unreinforced concrete
3. As instructed by the Engineer, dependent on the width of forms, amount of reinforcement and the necessity of placing each layer before the previous one commences to set

To protect the initial set of the concrete, the Contractor shall provide the following protections for freshly placed concrete for at least 72 hours after the time of placing and until the Engineer determines the concrete is not vulnerable to these factors. Contractor shall:

a. Prevent jarring of the forms
b. Prevent strain on the ends of projecting reinforcement steel
c. Install fencing or otherwise prevent persons from walking or placing articles on the concrete
d. Protect the concrete from rain, dust storms, chemical attack, and the harmful effects of sun, heat, wind, flowing water, vibrations, and shocks.

Concrete washout water shall be collected and disposed of in accordance with all applicable regulations. In no case shall washout water be allowed to enter any storm drains or other surface waters.

If a concrete pump is used as the placing system, the pump priming slurry shall be discarded before placement. Initial acceptance testing may be delayed until the pump priming slurry has been eliminated. Eliminating the priming slurry from the concrete may require that several cubic metres of concrete are discharged through the pumping system and discarded. Use of a concrete pump requires a reserve pump or other backup equipment at the site. When concrete pumps are used for placement, a Contractor's representative shall, prior to use on the first placement of each day, visually inspect the pumps' water chamber for water leakage. Pumps that allow free water to flow past the piston shall not be used by the Contractor.

Any section of defective concrete shall be removed at the Contractor's expense.

4.4.1.1 Chutes, Troughs, and Conveyor Belts

All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. Water used for flushing shall not be discharged into the works. No aluminium chutes, tremies, troughs, or conduits shall be used to pump or place concrete.

Chute lengths and slopes shall not cause segregation. Where steep slopes are required, chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of movement. Spouts and baffles shall be provided at the lower end to minimise segregation.

If the concrete will drop more than 1 m, it shall be deposited through a sheet metal or other approved conduit. If the form slopes, the concrete shall be lowered through approved conduit to keep it from sliding down one side of the form.

To prevent segregation, the maximum length of any conveyor belt used to transport concrete shall be 90 m. If concrete requires protection from the sun or rain, the Contractor shall cover the belt.

4.4.1.2 Continuity of Concrete Work

Casting of concrete shall not commence until a sufficient quantity of approved material is at hand to ensure continuity of operation, nor shall work commence until there is sufficient equipment in reserve in case of breakdown.

Concreting in any one part or section of the work shall be carried out in one continuous operation and no interruption of concreting work longer than 30 minutes shall be allowed unless the Engineer approves a longer time. Each layer shall be placed and consolidated before the preceding layer takes initial set.

Fresh concrete shall not be placed against concrete that has been in position for more than 30 minutes unless a construction joint has been formed. If a longer interruption is allowed, no fresh concrete shall be deposited on or against the concrete placed before the interruption until the latter is sufficiently set to resist injury, at least one hour. Same shall apply to adjacent pours at abrupt changes in sections. Particular care shall be taken to ensure that partially set concrete shall not be damaged by shock or any other cause whatsoever.

If directed by the Engineer, required in the Particular Specifications, or shown in the Contract plans, the Contractor shall place concrete in any particular section of the works without any interruption whatsoever from the beginning to the end of the operation.

4.4.1.3 Hot Weather Protection and Temperature Limits

When the shade air temperature is 32° C and rising, the Contractor shall take special precautions during all concrete operations to prevent the concrete temperature from exceeding 32° C prior to placement. Concrete that fails to conform to the maximum temperature requirement prior to placement shall be rejected.

Fresh concrete placed at air temperatures exceeding 32° C shall be shaded from the direct rays of the sun to the satisfaction of the Engineer. Concrete is not to be mixed or placed without special protection and precautions, as approved by the Engineer, when the shade air temperature is 40° C or above.

To maintain a concrete placement temperature less than 32° C, the Contractor may implement any combination of the following methods:

a. Shade or cool the aggregate stockpiles
   1. Sprinkle coarse aggregate with water
      i. Monitor the pile's moisture content and the mixing water to account for the free water in the aggregate
      ii. Remove from at least 300 mm above the bottom of the piles
   2. Sprinkling of fine aggregate piles with water shall not be allowed
b. Shade the concrete mixing plant
c. Cool the mixing water
   1. By refrigeration
   2. By liquid nitrogen
   3. By substituting well-crushed ice of a size that will melt completely during mixing for part of the mix water on a kg-for-kg basis
d. Screen and cover concrete in transit, concrete placement, and concrete curing to protect it from wind and sun
e. Sprinkle forms, subgrade, and reinforcing steel with cool water just prior to placement of concrete to cool all concrete-contact surfaces to less than 32°C before placement.

In hot weather, the Contractor shall minimise the time between mixing and placing and shall not permit mixer trucks to remain in the sun while waiting to discharge concrete. Chutes, conveyors, and pump lines shall be shaded. Curing shall commence immediately after concrete has been placed.

If the evaporation rate at the concreting site is 0.5 kg/m^2 of surface per hour or more, the Contractor shall surround the fresh concrete with an enclosure to protect the concrete from wind blowing across its surface until the curing compound is applied.

4.4.1.4 Concrete Exposed to Seawater

All concrete placement shall be done in the dry where the completed structure will be in contact with seawater or brackish ground water. Prior to removing dewatering and cofferdams, all exterior surfaces of concrete exposed to seawater or brackish ground water shall be cured and water proofing or protection coatings applied, as required in the Contract plans or Particular Specifications.

4.4.1.5 Concrete Exposed to Alkaline Soils or Water

Requirements for concrete in seawater shall also apply to concrete in alkaline soils or water. In addition, the Contractor shall:

1. Let the concrete set at least 30 days, longer if possible, before allowing soil or water to contact it directly

2. Vibrate each batch of concrete immediately after it has been placed into the forms, using enough vibrating tampers to do this effectively, and
3. Hand tamp, if necessary, to produce smooth, dense outside surfaces

4.4.1.6 Vibration of Concrete

Unless otherwise permitted by the Engineer, concrete shall be compacted by means of vibrators. Enough vibrators shall be supplied by the Contractor to consolidate the concrete, according to the requirements of this section. Standby vibrators shall also be made available by the Contractor in case of breakdowns. At least 2 vibrators shall be available at locations in which more than 25 m^3 of concrete is to be placed. The placement of the vibrators shall be strictly vertical to avoid air entrapment in the concrete. The size of the vibrators shall be for the intended purpose and approved by the Engineer as per the method statement or Inspection and Testing Plan (ITP).

Each vibrator shall meet the following requirements:

a. Be designed to operate while submerged in the concrete
b. Vibrate at a rate of at least 7,000 pulses per minute
c. Be of a diameter that is compatible with the spacing of the reinforcement, and
d. Receive the Engineer’s approval on its type and method of use.

Immediately after the concrete is placed, vibration shall be applied in the fresh batch at the point of deposit. Care shall be taken not to displace reinforcement nor to disturb or affect partially set concrete. In vibrating the concrete, the Contractor shall:

1. Space the vibrators evenly, no farther apart than 10 times the diameter of the vibrator
2. Ensure that vibration intensity is great enough to visibly affect a weight of 25 mm slump concrete across a radius of at least 460 mm
3. Insert the vibrators slowly to a depth that will effectively vibrate the full depth of each layer, penetrating into the previous layer so that the fresh concrete will be worked into the previously placed layer on multilayer pours
4. Protect partially hardened, or non-plastic, concrete by preventing the vibrator from penetrating it or making direct contact with steel that extends into it. Vibrators shall not penetrate non-plastic concrete when only the vibrator’s own weight is applied
5. Continue each immersion in one place until shortly after air bubbles cease to appear on the surface of the concrete, and not long enough to form pools of grout
6. Continue vibration long enough to consolidate the concrete thoroughly, but not so long as to segregate it
7. Withdraw the vibrator slowly, gradually, and vertically when the process is complete to ensure no air pockets are formed
8. Not use vibrators to move concrete from one point to another in the forms, and
9. Avoid vibrator contact with reinforcement and formwork shall.

When vibrating and finishing top surfaces that shall be exposed to weather or wear the Contractor shall not draw water or laitance to the surface. In high lifts, the top layer shall be shallow and made up of a concrete mix as stiff as can be effectively vibrated and finished.

To produce a smooth, dense finish on outside surfaces, the Contractor shall hand-tamp the concrete.

Vibration shall be applied by experienced labourers. Previously completed concrete pours shall not be subjected to disturbance by vibration within 4 to 24 hours of having been compacted. Vibrators shall not be attached to reinforcement in any circumstance.

4.4.1.7 Underwater Concrete

Placing concrete under water shall be allowed only in circumstances where it is not feasible to dewater the location before the concrete is placed. No concrete shall be placed in running water. Placement of concrete underwater shall be done using the methodology required in Section 21.7.4 of Chapter 21, Concrete Structures, of these Standard Specifications.

4.4.2 Curing Concrete

All newly placed concrete shall be cured, which shall begin immediately after finishing. Concrete surfaces shall receive continuous moisture for at least 7 days. When continuous moisture or wet curing is required, the Contractor shall keep the concrete surfaces wet with water during curing.

Curing shall be performed so that moisture is always present. Improperly cured concrete shall be considered defective and evaluated for rejection and reduced payment. Placing operations shall be stopped by the Engineer until the Contractor can put proper curing procedures into effect.

Adopted curing method shall be subject to the Engineer's approval and shall not cause staining, contamination, or marring of the surface of the concrete. Method A shall be used for curing exposed concrete surfaces, unless otherwise approved by the Engineer. When permitted in writing by the Engineer, the Contractor may use one of the following methods of curing exposed concrete surfaces.

4.4.2.1 Method A: Supplying Continuous Moisture

Continuous moisture shall be provided by the Contractor by watering a covering of heavy-quilted blankets or burlap and covering with white reflective type sheeting, or by wetting the outside surfaces of wood forms. Either approach shall be executed such that concrete surfaces remain wet with water continuously. Watering shall include supplying additional moisture by ponding, sprinkling, or fogging. Sawdust or coverings that cause unsightly discolouration of concrete shall not be used by the Contractor. Coverings shall be placed as soon as possible after finishing operations have been completed and there is no danger of surface damage. Coverings shall be kept continuously moist; any method that results in the concrete being alternately wet and dry shall be considered an improper curing procedure.

4.4.2.2 Method B: Preventing Moisture Loss

This method shall consist of preventing moisture loss from the concrete. It may be done with a combination of waterproof paper, white reflective plastic sheeting, or liquid membrane-forming curing compound. Paper and sheeting shall be securely anchored at the edges so as to effectively minimise moisture loss.

If a formed surface is to be rubbed, the concrete shall be kept moist before and during the rubbing, and the curing shall be initiated immediately following the first rub while the concrete surface is still moist.

Runoff water shall be collected and disposed of in accordance with all applicable regulations. In no case shall runoff water be allowed to enter any lakes, streams, or other surface waters.

Steam curing concrete is acceptable for precast units.

a. Waterproof Paper

Waterproof paper shall be the widest practicable width and adjacent sheets shall overlap a minimum of 150 mm and shall be tightly sealed with a pressure sensitive tape, mastic, glue, or other approved methods to form a complete waterproof cover of the entire concrete surface. Paper shall be secured so that wind shall not displace it. If any portion of the sheets is broken or damaged before expiration of the curing period, the Contractor shall repair the broken or damaged area immediately. Sections that have lost their waterproof qualities shall not be used.

b. White Reflective Plastic Sheeting

White reflective plastic sheeting shall be used in the same manner as required for waterproof paper and shall comply with Section 4.3.134.3.13.1.

c. Curing Compounds

Only Type 2 liquid membrane-forming curing compounds complying with AASHTO M 148 may be used, when approved by the Engineer, as the initial and final curing agents on concrete, subject to the following limitations:

1. If the membrane film is broken or damaged at any time during the curing period, the area or areas shall be recoated to the original requirements
2. Curing compounds shall be applied to unformed surfaces as soon as the water sheen has practically disappeared from the concrete, or as soon as the forms have been removed from surfaces not to be rubbed
3. Curing compounds shall not be used on areas receiving a rubbed finish
4. If there is to be any delay in applying curing compound, the surface shall receive moist curing until the compound can be applied
5. Curing compounds shall be applied with equipment that shall produce a fine spray, and all compounds shall be thoroughly agitated just prior to use. Surfaces shall be sprayed again immediately at right angles to the first application with a rate for each application at not less than 1 litre for each 3.6 m^2 of surface. Care shall be taken to prevent application to joints where concrete bond is required to reinforcement steel, and to joints where joint sealer is to be placed
6. No curing compound shall be used on fixed-form concrete barriers

Timber formwork covering the concrete shall be moistened with water at frequent intervals to keep it from drying during the curing period. Metal formwork exposed to the sun must be shaded from its direct rays, painted white, or otherwise protected during the curing period. When forms are removed before the end of the curing period, specified curing procedures shall be implemented by the Contractor and continued until the end of the specified curing period.

4.4.2.3 Method C: Curing Compound

Under the curing compound method, the Contractor shall:

a. Spray 2 coats of clear curing compound, Type 1D, on the concrete surface after the free water has disappeared. Coverage of combined coats shall be at least 4 L/15 m^2.

b. Cover the structure with white, reflective sheeting for at least 10 days, beginning no later than the morning after applying the curing compound.

c. After the 10-day curing period, remove the curing compound as necessary by light sandblasting or by spraying with a high-pressure water jet to produce an even surface appearance. Water jet equipment shall use clean fresh water and shall produce at least 175 kg/cm^2 at the nozzle with a discharge of at least 15 l/minute. Nozzles shall have a 25^o tip and shall be held no more than 250 mm from the surface being cleaned. Curing compounds or concrete sealers proposals, made by the Contractor, shall be evaluated by the Engineer and approvals shall be made in writing. As a minimum, the Contractor’s proposal shall include the following:

    1. Product identity
    2. Manufacturer’s recommended application rate
    3. Method of application and necessary equipment
    4. Material safety data sheet (MSDS)
    5. Sample of the material for testing

Contractor shall allow 14 working days for evaluating the proposal and testing the material.

4.4.2.4 Method D: Wet Blankets

Under the wet-cure method, the Contractor shall:

1. Provide an initial cure period by continuous fogging or mist spraying for at least the first 24 hours.
2. After the initial cure period, cover the structure with a heavy quilted blanket.
3. Keep the blankets continuously wet for at least 10 days. No additional finishing is required at the end of the curing period.

In the event any member or portion of the work prove, after removal of the formwork, to be of inferior workmanship or to be in any way whatsoever defective, or should crushing tests on samples taken from the work show that the concrete used therein is of inferior quality, such work shall, at the discretion of the Engineer, be cut out and replaced.

4.4.2.5 Curing Slip-form Construction

Slip-form construction shall be finished by the Contractor by:

1. Steel trowelling to close all surface pockmarks and holes; and
2. For plain surfaces, lightly brushing the front and back face with vertical strokes and the top surface with transverse strokes.

After finishing, the Contractor shall cure the slip-form construction by using either Method C, curing compound, or Method D, wet blankets, as described below.

Where slip-form work was performed, the concrete shall be protected against the weather and rapid drying out by means of a 4 m wide skirt attached to the lower perimeter of the formwork and hanging over the working platform. Skirts shall consist of hessian in the summer months and of canvas or other suitable material in winter and shall be weighted at the bottom to prevent flapping in windy conditions. To wet the concrete, the Contractor shall use a fixed spraybar, which shall be connected to a suitable high-pressure water supply, along the full-length of the sliding formwork.

4.4.2.6 Insulated Curing

The insulated curing method shall allow for a waterproof cover with a 1000 gauge polyethelene sheet and then insulated with 50mm rigid closed cells extruded polystyrene thermal board insulation. Over the polystyrene thermal board, a 1000 gauge polyethelene sheet is again placed to avoid moisture ingress into the Styrofoam/thermal board. The whole system is to be wrapped properly to avoid displacements during the curing period (normally 10 days for pozzolanic concrete).

4.4.3 Concrete Finishing

All concrete shall show a smooth, dense, uniform surface after the forms are removed. If it is porous, the Contractor shall bear the cost of repairing it. Contractor shall clean and refinish any stained or discoloured surfaces that may have resulted from their work or from construction delays.

Surfaces that are specified in the Contract documents to be “troweled” shall after the concrete is partially set, finished to a smooth surface by troweling with a steel trowel until a slick surface free of bleed water is produced. Surface shall then be brushed with a fine brush using parallel strokes.

Surface finishes for formed concrete surfaces shall be classified as follows:

- Class 1: Ordinary surface finish
- Class 2: Rubbed finish
- Class 3: Tooled finish
- Class 4: Sandblast finish

- Class 5: Wire brush or scrubbed finish

Requirements for Class 1 to 5 surface finishes shall be in accordance with Section 21.12 of Chapter 21, Concrete Structures, of these standard specifications.

All concrete shall be given a Class 1, Ordinary Surface Finish, and if further finishing is required, such other type of finish as is specified. If not otherwise specified in the Contract documents, exposed surfaces shall be given a Class 2, Rubbed Finish. Class 3, 4, or 5 finishes shall be applied only where specified in the Contract documents. Surfaces covered with fill do not require a surface finish.

All surfaces of concrete that are not placed against forms shall be finished in accordance with Section 21.10 of Chapter 21, Concrete Structures, of these standard specifications.

4.4.4 Construction and Expansion Joints

Construction joints shall be installed:

1. To the positions, dimensions, and types shown in the Contract plans.
2. As specified herein.
3. As approved by the Engineer, including additions, deletions, or relocations from the information shown in the Contract plans.
4. As requested in writing by the Contractor, accompanied by a drawing that depicts them, and approved by the Engineer.
5. In response to breakdowns or other unforeseen and unavoidable delays, with the Engineer’s approval and with the Engineer’s designation of bonded or unbonded.

Any added costs that result from Contractor-initiated changes shall be borne by the Contractor.

Concreting shall be carried out continuously at construction joints, which shall be formed at right angles to the axis of the member. Construction joints shall be formed neatly with grade strips or other approved methods. Irregular or wavy pour lines will not be accepted by the Engineer. Wire mesh forming material shall not be used. All joints shall be horizontal, vertical, or perpendicular to the main reinforcement. An edger shall not be used on any construction joint, and the Contractor shall remove any lip or edging before making the adjacent pour. Face edges of all joints that are exposed to view shall be carefully finished true to line and elevation.

Construction joints in abutment walls, wing walls, and barrels of box culverts shall be placed at intervals not exceeding 9 m, except as otherwise indicated on the Contract plans or approved by the Engineer.

For definitions of the various types of joints refer to the AASHTO Load and resistance factor design (LRFD) Bridge design specifications.

Waterstops shall be installed in all joints where the Engineer determines that ingress or egress of water is detrimental regardless of whether such waterstops are shown on the Contract plans.

If the Contract plans require a roughened surface on the joint, the Contractor shall strike it off to leave grooves at right angles to the length of the member. Grooves shall be 12 mm to 25 mm wide, 6 mm to 12 mm deep, and spaced equally at twice the width of the groove. If the first strike-off does not produce the required roughness, the Contractor shall repeat the process before the concrete reaches initial set. Final surface shall be clean and without laitance or loose material.

If the Contract plans do not require a roughened surface, the Contractor shall include shear keys at all construction joints. These keys shall provide a positive, mechanical bond. Shear keys shall be formed depressions and the forms shall not be removed until the concrete has been in place at least 12 hr. Forms shall be slightly bevelled to ensure ready removal. Raised shear keys are not allowed.

Shear keys for the tops of beams, at tops and bottoms of boxed girder webs, in diaphragms, and in crossbeams shall:

1. Be formed with 50 mm by 200 mm wood blocks
2. Measure 200 mm lengthwise along the beam or girder stem
3. Measure 100 mm less than the width of the stem, beam, crossbeam, or other adjacent element as measured transverse to the stem
4. Be spaced at 400 mm centre-to-centre.

Unless the Contract plans show otherwise, in locations not named above, shear keys shall equal approximately one-third of the joint area and shall be approximately 40 mm deep. Before placing new concrete against cured concrete, the Contractor shall thoroughly clean and roughen the cured face and wet it with water. Before placing the reinforcing mat for footings on seals, the Contractor shall:

a. Remove all scum, laitance, and loose gravel and sediment
b. Clean the construction joint at the top of the seals
c. Chip off any high spots on the seals that would prevent the footing steel from being placed in the position required by the Contract plans.

Shear keys formed into, or out from, the surface of the previously placed concrete, or steel dowels, shall be used where required. Shear keys formed into the concrete shall be formed by the insertion and subsequent removal of bevelled wood strips that shall be thoroughly saturated with water prior to insertion. Steel dowels may, at the discretion of the Engineer, be used in lieu of keys. Size and spacing of the keys and dowels shall be as shown in the Contract plans, or as directed by the Engineer.

4.4.4.1 Preparing the Surfaces

When the concrete has set and while it is still green, the surface film and all loose material shall be removed without disturbing the aggregate by means of a water jet assisted by light brushing to expose the aggregate and leave a sound, irregular surface. Where this is not possible, the surface film shall be removed after the concrete has hardened, by mechanical means appropriate to the degree of hardness of the concrete so as to expose the aggregate and leave a sound, irregular surface. Roughened surfaces shall be washed with clean water to remove all laitance, dirt, and loose particles.

Surface retarding agents may be used only with the Engineer’s approval.

4.4.4.2 Placing Fresh Concrete at Construction Joints

Where fresh concrete is placed on the same day as when the construction joint was formed, the fresh concrete shall be cast directly against the face of the construction joint.

When concreting recommences a day or more after the construction joint has been formed, the Contractor shall abide by the following procedure:

1. Construction joints shall be kept constantly wet for at least 6 hours. Surface shall be in a saturated, surface dry condition when concreting begins again.
2. Any dirt, excess water, and loose particles shall be removed prior to re-concreting.
3. For horizontal construction joints a 25 mm thick concrete layer of the same grade of concrete made richer by reducing the coarse aggregate content by 25 % shall be placed on the joint plane immediately before concreting.
4. For vertical construction joints the fresh concrete shall be placed against a surface prepared as described above to a saturated, surface-dry condition.

4.4.4.3 Bonded Construction Joint

Epoxy resins specially designed for bonding old concrete to new shall be used at construction joints where so specified and shown in the Contract plans. This epoxy shall consist of a 2-component liquid polysulphide polymer epoxy resin concrete adhesive.

Preparation of the construction joint surface and the application of the epoxy resin shall be strictly in accordance with the manufacturer's recommendations and the Engineer's instructions. Brand and type of resin used shall be subject to the Engineer's approval.

The epoxy resin shall be applied strictly in accordance with the manufacturer's recommendations to avoid premature setting and forming a de-bonding film.

Bonded construction joints shall be made using the following procedures, unless otherwise specified:

1. After the concrete has hardened so that the header board or form can be removed without damage to the concrete, it shall be removed and the cement paste removed from the surface by washing with water under pressure or by sandblasting to expose clean, well-bonded aggregate.
2. To facilitate the removal of the cement paste, the surface of the header board or form that shall be in contact with the first pour may be thoroughly covered with a retarder consisting of a ready-to-use liquid compound that delays the set of the surface concrete approved by the Engineer prior to beginning the work. Retarder shall produce results satisfactory to the Engineer and shall be evaluated on the basis of the manufacturer's data and recommendations. When the retarder is used, washing with water under pressure shall be used to expose clean, well-bonded aggregate.
3. Prepared surface of the concrete shall be kept saturated with water until the new concrete is placed, or it shall be saturated for a period of 4 hours before placing the new concrete.
4. Immediately prior to placing the new concrete, the forms shall be drawn tight against the concrete already in place and the surface shall be covered with a thin coat of Class M6 mortar.
5. After the header board or form is removed and the concrete has cured, the second pour shall be bonded to the first pour by the applying to the concrete joint surface a 2-component liquid polysulphide polymer epoxy resin concrete adhesive.
6. Surface on which the adhesive is to be applied shall be free of oil, dirt, and loose concrete. Unsound concrete shall be removed until a base of strong, undamaged concrete is exposed on which to apply the adhesive. Deposits of dirt or oil products shall be removed by wire brushing or sandblasting. Surfaces shall be free of moisture and dry before application of the adhesive, which shall not be applied to newly placed concrete before the normal curing period has elapsed.
7. Immediately before application, the two adhesive components shall be combined in the proportions specified by the adhesive manufacturer. Components shall be intimately blended by hand or with a slow speed motor drive mixing device. Next, the mixture shall be thinned by adding and blending the solvent into the adhesive. Adhesives amounts mixed at one time shall be limited to the quantity that can be conveniently applied within the pot life of the adhesive.
8. Two components and solvent shall not be mixed more than 30 minutes prior to use.
9. Adhesive shall be brushed onto the concrete in a layer 1 mm to 2 mm thick.
10. After the adhesive has been applied, concrete shall not be placed against it until the solvent has evaporated: 30 min to 60 min, depending on weather conditions.
11. Adhesives shall be tacky and not dry at the time of concrete application. If an area becomes dry, it shall be recoated before placing the concrete.

Because of toxicity of the materials, including the solvents, safety and health hazards exist in the handling and use of the materials, and may cause serious rash in persons sensitive to the materials.

Further, in the use of solvents as cleaning aids there exists a fire and flash hazard. Contractor shall obtain from the material formulator complete instructions for safety, health, and handling precautions with respect to the materials in use, and as to the procedure that shall be followed in the event that workmen come in contact with the material. Before they are permitted to proceed with the work, the workers shall be instructed as to the hazards to which they shall be exposed, the necessary safety precautions and the procedure to be followed in the event of accidental contact with the materials.

4.4.4.4 Unbonded Construction Joints

Unbonded construction joints shall be made by forcing or striking off the previously placed concrete to a true and even surface and allowing it to set. After the concrete has set, a bond breaker material (refer to Article 4.3.15.7) shall be placed and secured on the old concrete. New concrete shall be placed and thoroughly compacted to secure a close contact between the old and new concrete at all points, separated only by the bond breaker material, with no attempt to secure a bonding of the new concrete to the old work.

4.4.4.5 Expansion Joints

Expansion joints shall be located and formed as detailed in the Contract plans and specified herein. Expansion joints shall be installed per the Contract plans or the Particular Specifications. Materials meeting the requirements in Section 4.3.15 may be used, unless otherwise specified.

Expansion joints shall incorporate adequate protection against the entry of debris or other material that may interfere with the closing of the joints in their construction.

Joint filler shall be cut to the same shape as that of the surfaces being jointed and shall be firmly fixed against the surface of the concrete already in place in such a manner that it will not be displaced when concrete is deposited against it. Immediately after form removal, the expansion joints shall be carefully inspected, and any concrete or mortar that has sealed across the joint shall be neatly cut and removed.

Application of approved sealers per Section 4.3.15 shall be in accordance with the manufacturer's instructions.

Care shall be taken to prevent application of curing compound to locations where joint sealer is to be placed.

Open joints shall be formed with a template made of wood, metal, or other suitable material. Insertion and removal of the template shall be done without chipping or breaking the edges or otherwise injuring the concrete.

Any part of an expansion joint running parallel to the direction of expansion shall provide a clearance of at least 12 mm, produced by inserting and removing a spacer strip, between the two surfaces. To prevent any wedging from expansion and Contraction, the Contractor shall ensure that the surfaces are precisely parallel.

4.4.4.6 Installation of Fixed-joint Seals

Sealers shall be installed by the Contractor using suitable hand or machine tools and thoroughly secured in place with an approved adhesive that shall cover both sides of the sealer over the full area in contact with the sides of the joint. Adhesive may be applied to the sides of the joint or the sealer or both. Sealers shall be installed in a compressed condition and shall at all times be below the level of the surface by approximately the amount shown on the Contract plans. Sealers shall be in one continuous piece for the full width of transverse joint prior to being installed in the joint and shall have not more than 1 butt splice within its length, which shall be a manufacturer's splice. If this splice is torn or damaged it shall be repaired, prior to installation, using the manufacturer's recommended adhesive. In longitudinal joints the sealer shall be in practical lengths. Any joints in the sealer material shall be adequately sealed with additional adhesive.

Any leakage of the joint shall be cause for rejection.

Sealers shall be installed by the Contractor immediately after the removal of the curing cover, using an adhesive that is compatible with the sealer and the material of which the joint surfaces are composed. Temperature limitations of the adhesive, as guaranteed by the manufacturer, shall be observed. Joints shall be clean and free of foreign material immediately prior to the installation of the sealer.

No shipment of materials shall be accepted for use unless the material complies with the requirements of Article 4.3.154.3.15.1.

Materials shall not be used until the Contractor has been notified by the Engineer that they meet the requirements of these specifications.

4.4.5 Waterstops

Waterstops shall be furnished and installed in accordance with the details indicated on the Contract plans, the provisions of Section 21.9.1.6 and Section 21.9.2.4 of Chapter 21, Concrete Structures, of theses standard specifications, and as directed by the Engineer.

4.4.6 Concrete Protection Coating

All exposed items or surfaces not in contact with soil throughout concrete structures, except as otherwise indicated on the Contract plans, shall be painted in accordance with Section 24.7 of Chapter 24, Painting, of these standard specifications.

All exposed surfaces for concrete structures indicated on the Contract plans not to be painted or waterproofed shall be sealed as per the requirements of Section 29.6 of Chapter 29, Miscellaneous Items for Structures, of these standard specifications.

4.4.7 Reinforcing

Fabrication and installation of concrete reinforcement shall meet the applicable requirements of Chapter 5, Reinforcing steel.

4.4.8 Concrete for Precast Elements

Precast concrete work shall be as indicated on the Contract plans, as specified herein, and as directed by the Engineer. Tilt-up wall construction is allowed if so shown in the Contract plans and shop drawings and approved by the Engineer.

All precast units shall be manufactured of diverse sizes with materials as specified in these specifications and the Contractor shall be responsible for transporting the same to the site of the works.

Manufacturing plant for precast concrete units shall be inspected and approved by the Engineer for the type of precast member to be produced prior to the start of production. This inspection and approval shall be renewed annually during production, and the Engineer reserves the right to inspect the plant at any time.

Quality control (QC) inspections shall be done by the Contractor while the Engineer shall perform quality assurance (QA) inspections to facilitate the work and verify its quality. QA inspection shall not relieve the Contractor of any responsibility for identifying and replacing defective material and workmanship.

Contractor shall notify the Engineer prior to precasting concrete units. Contractor shall provide the Engineer with the opportunity to inspect the precast forms and units before, during, and after casting. Prior to the start of production of the precast concrete units, the Contractor shall advise the Engineer of the production schedule and shall give the Engineer safe and free access to the work. If the inspector observes any non-specification work or unacceptable QC practices, the Engineer shall advise the plant manager. If the corrective action is not acceptable to the Engineer, the units will be rejected.

Self-compacting concrete (SCC) may be used for precast concrete barriers and drainage items. If the Engineer has approved the use of SCC, the consistency requirements in Section 4.3.11 shall not apply. SCC is concrete that can flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without any vibration, while maintaining homogeneity. For SCC, the following modified testing procedures for air content and compressive strength shall apply:

1. Moulds shall be filled completely in 1 continuous lift without any rodding, vibration, tamping, or other consolidation methods other than lightly taping around the exterior of the mould with a rubber mallet to allow entrapped air bubbles to escape
2. Fabricators' QC testing shall include slump flow test results that demonstrate no segregation
3. Plant approval for use of SCC shall require the plant fabricator to cast 1 barrier or drainage item and then sawed it in half for examination by the Engineer to determine that segregation has not occurred.

4.4.8.1 Shop Drawings

Before precasting, the Contractor shall submit shop drawings for approval by the Engineer. These shop drawings shall show complete details of the methods, materials, and equipment the Contractor proposes to use in precasting work. Shop drawings shall follow the design conditions shown in the Contract plans unless otherwise approved by the Engineer.

Shop drawings shall contain as a minimum:

1. Unit shapes, including elevations and sections, and dimensions
2. Finishes and method of constructing the finish, such as forming or rolling
3. Reinforcing, joint, and connection details
4. Lifting, bracing, and erection inserts
5. Locations and details of hardware attached to the structure
6. Relationship to adjacent material

Approval of these shop drawings shall not relieve the Contractor of responsibility for accuracy of the drawings or conformity with the Contract. Approval shall not indicate a check on dimensions.

4.4.8.2 Casting

Plant, quality checking and approving procedures, casting process, curing, finishing, shop drawings, and concrete mix shall be approved by the Engineer before the Contractor begins casting precast concrete units. Manufacturer shall keep and make available to the Engineer the complete records of all the concrete mixes and strength tests pertaining to each member cast. Contractor shall notify the Engineer which members are to be cast in advance of the casting dates so that arrangements for inspecting and testing the precast members can be made.

Concrete shall meet the requirements of Section 4.3.11 for annual preapproval of the concrete mix design and slump.

Precast units shall not be removed from forms until the concrete has attained sufficient strength so as not to sustain damage from the removal, typically a minimum compressive strength of 70 % of the specified design strength, as verified by rebound numbers determined in accordance with ASTM C 805M.

Precast units shall not be moved until the concrete has reached the specified design strength as determined by testing cubes made from the same concrete as the precast units. Test cubes shall be made, prepared and tested in accordance with Article 4.3.12.3.

Forms may be steel or plywood-faced, providing they impart the required finish to the concrete.

4.4.8.3 Curing

Concrete in the precast units shall be cured by either moist or accelerated curing methods. Methods to be used shall be preapproved by the Engineer.

1. For moist curing, the surface of the concrete shall be kept covered or moist until such time as the compressive strength of the concrete reaches the strength specified for stripping. Exposed surfaces shall be kept continually moist by fogging, spraying, or covering with moist burlap or cotton mats. Moist curing shall commence as soon as possible following the completion of surface finishing.
2. For accelerated curing, heat shall be applied at a controlled rate following the initial set of concrete in combination with an effective method of supplying or retaining moisture. Moisture may be applied by a cover of moist burlap, cotton matting, or other effective means. Moisture may be retained by covering the unit with an impermeable sheet.

Radiant, convection, conducted steam, or hot air may be used to heat the concrete to no more than 37° C during the first 2 hours after pouring the concrete, and then increase by no more than 13° C per hour to a maximum of 79 °C. After curing is complete, the Contractor shall cool the concrete by no more than 13° C per hour to 37° C. Contractor shall maintain the concrete temperature above 16° C until the unit reaches stripping strength.

Concrete temperature shall be monitored by means of a thermocouple embedded in the concrete that is linked with a thermometer accurate to ±3° C. A recording sensor, accurate to ±3° C, shall be arranged and calibrated to continuously record, date, and identify concrete temperature throughout the heating cycle. This temperature record shall be made available to the Engineer for inspection and become part of the required documentation.

Dry heat shall never be allowed to directly touch exposed unit surfaces at any point.

For tilt-up wall panels, Contractor shall moist-cure the panels for a minimum of 6 calendar days after stripping the forms.

4.4.8.4 Contractor’s Control Strength

All sections referring to cast-in-situ concrete shall apply to precast concrete. In addition, the Contractor shall satisfy the Engineer that the precast concrete units are not moved or loaded until they have attained the required strength.

Concrete strength at stripping and the verification of design strength shall be determined by testing cubes made from the same concrete as the precast units.

Concrete acceptance and testing shall meet the applicable requirements of Section 4.3.12.

For accelerated cured units, concrete strength shall be measured on test cubes cast from the same concrete as that in the unit. These cubes shall be cured under time-temperature relationships and conditions that simulate those of the unit. If the forms are heated by steam or hot air, test cubes shall remain in the coolest zone throughout curing. If forms are heated another way, the Contractor shall provide a record of the curing time-temperature relationship for the cubes for each unit to the Engineer. When 2 or more units are cast in a continuous line and in a continuous pour, a single set of test cubes may represent all units provided the Contractor demonstrates uniformity of casting and curing to the satisfaction of the Engineer.

Enough cubes shall be moulded, cured, and tested by the Contractor to satisfy specification requirements for measuring concrete strength. Contractor shall let cubes cool for at least 30 minutes before testing for release strength.

Test cubes may be cured in a moist room or water tank in accordance with AASHTO T 23, after the unit concrete has obtained the required release strength. If the Contractor intends to ship the unit prior to the standard 28-day strength test, the design strength for shipping shall be determined from cubes placed with the unit and cured under the same conditions as the unit. These cubes may be placed in a non-insulated, moisture-proof envelope.

To measure concrete strength in the precast unit, the Contractor shall randomly select 2 test cubes and average their compressive strengths. Compressive strength in either cube shall not fall more than 5 % below the specified strength. If these 2 cubes do not pass the test, 2 other cubes shall be selected and tested.

All test results and certifications shall be kept at the fabricator’s facility for the duration of the works for review by the Engineer or the Owner.

4.4.8.5 Finishing and Marking

On removal from the forms, the precast concrete units shall be examined and all surfaces that will be permanently visible shall have a smooth and dense finish or uniform texture free from holes, fins, and shutter staining. Any precast concrete unit that is found to be defective in any respect shall be rejected.

For the purposes of identification, all members shall be marked with paint in neat lettering with the member number shown on the drawings or as agreed on and an identification number relating to the manufacturing records.

4.4.8.6 Tolerances

Units shall be fabricated to the dimensions and tolerances shown in the drawings, and shall meet the dimensional tolerances listed in the latest edition of PCI-MNL-166, unless otherwise required by the Contract plans or Particular Specifications.

4.4.8.7 Handling and Storage

Units shall be so stored, transported, and fixed to avoid overstressing or damage at any time.

All units shall be lifted only by adequate devices at locations designated on the shop drawings.

Precast units shall be stored off the ground on foundations suitable to prevent differential settlement or twisting. Stacked units shall be separated and supported by dunnage of uniform thickness capable of supporting the units. Dunnage shall be arranged in vertical planes. Upper units of a stacked tier shall not be used as storage areas for shorter units unless substantiated by Engineering analysis and approved by the Engineer.

Tilt-up wall construction is allowed if so shown in the Contract plans and approved shop drawings.

For tilt-up wall construction, the Contractor will erect the wall panels in place by tilting them up to their permanent location, temporarily bracing the panels in place, completing the permanent connections required to secure the precast tilt-up panel, and finally removing the temporary supports.

4.4.8.8 Shipping

Precast units shall not be shipped until the concrete has reached the specified design strength and the Engineer has reviewed the fabrication documentation for Contract compliance and stamped the precast concrete units “approved for shipment”. Units shall be supported in such a manner that they shall not be overstressed or damaged during transport or by anticipated impact of their dead load. Sufficient padding material shall be provided between tie chains and cables to prevent chipping or spalling.

4.4.8.9 Erection

When the precast units arrive on the project, the Engineer shall confirm that they are stamped “Approved for shipment.” Precast units shall be evaluated by the Engineer for damage before they are accepted.

All units shall be lifted by suitable devices at locations designated on the shop drawings. Temporary shoring or bracing shall be provided, if necessary. Units shall be properly aligned and levelled, as required by the drawings. Variations between adjacent units shall be levelled out by a method approved by the Engineer.

Markings shall be so positioned as not to be visible when the structural member is placed in its final position in the completed structure.

All precast members that have been chipped, cracked, warped, or otherwise damaged to the extent that such damage will, in the opinion of the Engineer, prejudice the appearance, function, or structural integrity of the members shall be rejected or, where so allowed, repaired to the satisfaction of the Engineer.

4.4.9 Waterproofing

This work shall consist of applying waterproofing materials to cementitious concrete surfaces, as required by the Contract plans and these Standard Specifications.

All surfaces of concrete structures in contact with soil or backfill shall be protected in accordance with Section 28.2 of Chapter 28, Waterproofing, of these standard specifications.

All concrete structures that require water-tightness shall be waterproofed in accordance with Section 28.3 of Chapter 28, Waterproofing, of these standard specifications.

4.5 Self-Consolidating Concrete (SCC)

4.5.1 Definitions

a. Self-Consolidating Concrete (SCC): A highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation.

b. Passing Ability: The ability of SCC to flow under its own weight (without vibration) and fill completely all spaces within intricate formwork, containing obstacles, such as reinforcement.

c. J-Ring Test: Test used to determine the passing ability of SCC, or the degree to which the passage of concrete through the bars of the J-Ring apparatus is restricted.

d. J-Ring Flow: The distance of lateral flow of concrete using the J-Ring in combination with a slump cone.

e. Slump Flow: Test method used to measure the unconfined flow and stability of SCC using a slump cone (upright or inverted).

f. Slump Flow Spread: The numerical value in mm of flow determined as the average diameter of the circular deposit of SCC at the conclusion of the slump test.

g. T_{50} Value: Time (in seconds) the edge of the concrete mass takes to reach 500 mm diameter from the time the mold is first raised in the slump flow test.

h. Stability: The ability of a concrete mixture to resist segregation of the paste from the aggregates.

i. Static Segregation (Segregation Factor): Segregation of the mortar from the coarse aggregate that occurs after placement while the concrete is still in a plastic state.

j. Visual Stability Index (VSI) Rating: An assessment of the homogeneity of concrete based on the visual inspection of the concrete sample at the end of the slump flow test.

4.5.2 Quality Assurance

1. In accordance with ACI 301M-10 for mixing, transportation and placing of concrete.
2. In accordance with ACI 305.1-06 for hot weather concrete placement and protection.
3. In accordance with ACI 308.1-11 for curing.
4. In accordance with ACI 301M-10 for concrete consolidation.

5. Testing and Inspection Agency Qualifications: Independent agency conforming to the requirements of ASTM E329 - 13b.

4.5.3 Materials

The materials shall be suitable for the intended use in concrete and not contain harmful ingredients in such quantities that may be detrimental to the quality or the durability of the concrete, or cause corrosion of the reinforcement.

a. Portland cement shall conform to ASTM C150 / C150M - 12, Type I, II, I/II, III, and V.

b. Fine and coarse aggregates shall conform to ASTM C33 / C33M - 13.

c. Water shall conform to ASTM C1602 / C1602M – 12.

d. Admixtures shall be furnished from one manufacturer:

1. Characteristics: Compatible with each other and free of intentionally-added chlorides.
2. Air-Entraining Admixture: Shall conform to ASTM C260 / C260M - 2010a.
3. Water-Reducing Admixture: Shall conform to ASTM C494 / C494M – 2011, Type A.
4. Mid-Range Water-Reducing Admixture: Shall conform to ASTM C494 / C494M – 2011, Type A.
5. High-Range Water-Reducing Admixture: Shall conform to ASTM C494 / C494M – 2011, Type F (or ASTM C1017 / C1017M – 07, Type I).
6. Accelerating Admixture: Shall conform to ASTM C494 / C494M – 2011, Type C or E.
7. Retarding Admixture: Shall conform to ASTM C494 / C494M – 2011, Type B or D.
8. Hydration Control Admixture: Shall conform to ASTM C494/C494M–2011, Type B or D.
9. Workability-Retaining Admixture:
   i. Shall retain concrete workability without affecting time of setting or early age strength development.
   ii. Shall conform to ASTM C494 / C494M – 2011, Type S.
10. Permeability-Reducing Admixture:
    i. Shall be an integral crystalline capillary waterproofing admixture for concrete.
    ii. Shall satisfy the following requirements, when used at the manufacturer's recommended dosage:
        - Reduction in capillary absorption: Not less than 40 percent relative to a companion untreated concrete mixture, when tested in accordance with ASTM C 1585 - 13.
        - Reduction in water penetration: Not less than 40 percent relative to a companion untreated concrete mixture, when tested in accordance with DIN 1048-5.
        - The admixture shall not affect the setting time, strength or durability properties of concrete.
11. Viscosity-Modifying Admixture: Shall conform to ASTM C494 / C494M – 2011, Type S.
12. Corrosion-Inhibiting Admixture: Shall be a nominal 30% solution of calcium nitrite or an amine/ester – based organic corrosion – inhibiting admixture.
13. Shrinkage-Reducing Admixture: Shall conform to ASTM C494 / C494M – 2011, Type S.
14. Alkali-Silica Reaction Inhibiting Admixture:

i. Shall contain a nominal lithium nitrate content of 30 percent.

ii. Shall conform to ASTM C494 / C494M – 2011, Type S.

15. Other admixtures shall be approved by the Engineer.

e. Supplementary Cementitious Materials (SCM):

1. The substitution of supplementary cementitious materials for cement shall be made on the basis of mass.
2. Fly Ash: Shall conform to ASTM C618 - 2008.
3. Slag Cement: Shall conform to ASTM C989 / C989M - 12a.
4. Silica Fume: Shall conform to ASTM C1240 - 12.
5. Metakaolin: Shall conform to ASTM C618 - 2008, Class N.

f. Fibers:

1. Microsynthetic Fibers:
   i. Shall conform to ASTM C1116 / C1116M - 10a.
   ii. Shall provide a minimum crack reduction ratio (CRR) of 40% when tested in accordance with ASTM C1579 - 13.
2. Macrosynthetic Fibers:
   i. Shall conform to ASTM C1116 / C1116M - 10a.
   ii. Shall have an equivalent flexural strength ratio as recommended by the manufacturer and approved by the Engineer, and tested in accordance with ASTM C1609 / C1609M - 12. Or
   iii. Shall have toughness as recommended by the manufacturer and approved by the Engineer, and tested in accordance with ASTM C1550 - 12a.
3. Steel Fibers:
   i. Shall conform to ASTM A820 / A820M - 11.
   ii. Shall have an equivalent flexural strength ratio as recommended by the manufacturer and approved by the Engineer, and tested in accordance with ASTM C1609 / C1609M - 12. Or
   iii. Shall have toughness as recommended by the manufacturer and approved by the Engineer, and tested in accordance with ASTM C1550 - 12a.

   Dosage of fibers for composite steel decks shall not be less than 2.4 kg/m3 for macrosynthetic fibers and 14.8 kg/m3 for steel fibers, as recommended in ANSI/SDI C – 2011.

g. Evaporation Reducer:

16. Shall be a monomolecular film-forming liquid for application to fresh concrete to prevent rapid drying of the surface.
17. Evaporation reducer shall not be used as a finishing aid.

4.5.4 Concrete Mixtures

The Contractor shall furnish to the Engineer a mixture proportion for the SCC to be used.

- Proportion mixture shall be in accordance with the particular specifications (Compressive Strength, Air Content, Slump Flow, T50, VSI, J-Ring Value and Segregation Factor).
- The Contractor shall use the same components in the trial batches as that to be used in the Project including coarse and fine aggregates, inert non-cementitious fillers, water, source and type of cement, supplementary cementitious materials and admixtures including any site-added admixtures intended to be used.

4.5.4.1 Mixture Specifications

- Water-to-cementitious materials ratio shall not exceed 0.45 by mass.
- Supplementary Cementitious Materials: Fly ash or other pozzolans and silica fume shall not constitute more than 25 and 10 percent, respectively, of the total mass of cementitious material.

4.5.4.2 Slump Flow

- Slump flow shall be measured in accordance with ASTM C1611 / C1611M - 09be1.
- Typical ranges of slump flow are outlined in Table 4-31.
- The design slump flow of the SCC mixture shall be established after consideration of the Project requirements.
- The slump flow of SCC used on the Project shall be the design slump flow plus or minus 50 mm.

Table 4-31: Typical ranges of slump flow

Type of Construction	Range of Slump Flow Values mm
Slabs	500-750
Architectural members	600-750
Wall, lightly reinforced	500-750
Column or wall, densely reinforced	600-750
Drilled Shafts	500-600

4.5.4.3 Visual Stability Index (VSI)

VSI Rating (in accordance with ASTM C1611 / C1611M - 09be1) shall not exceed 1.

4.5.4.4 J-Ring Flow

Difference between slump flow and J-Ring flow (as measured by ASTM C1621 / C1621M - 09b) shall not be more than 50 mm.

4.5.4.5 Stability

The stability of the concrete shall be determined in the laboratory prior to approval of the SCC mixture using test method ASTM C1610 / C1610M - 10. Concrete mixtures shall have a maximum static segregation (segregation factor) of 15 percent.

4.5.4.6 Air content

Air content shall be less than 3%, as recommended by the manufacturer, and as approved by the Engineer.

4.5.4.7 Maximum nominal size of coarse aggregate

1. Not larger than 1/5 the narrowest dimension between sides of forms.
2. Not larger than 1/3 the depth of slabs.
3. Not larger than ¾ of the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, individual tendons, bundled tendons, or ducts.
4. Maximum size of aggregate shall be 20 mm.

4.5.5 Execution

4.5.5.1 Formwork

Concrete formwork shall be in accordance with Section 4.6. Additional measures shall be taken to seal the formwork to prevent leakage of cement paste or mortar.

4.5.5.2 Batching

Materials shall be batched in accordance with ASTM C94 / C94M - 13a and ASTM C1116 / C1116M - 10a.

In addition to the use of a moisture probe, the moisture content of the aggregates shall be determined once a day prior to batching in accordance with ASTM C70 – 13 or ASTM C566 - 13. Aggregate samples shall be taken as close as possible to the area where moisture probe is located. Use of microwave oven or hot plate to dry the aggregates is permitted in addition to using an oven.

Volume of concrete batched shall be such that no spillage occurs during transport.

4.5.5.3 Transporting

Concrete shall be transported in accordance with ASTM C94 / C94M - 13a and ASTM C1116 / C1116M - 10a.

4.5.5.4 Hot Weather Concreting

Concrete shall be placed and protected in accordance with ACI 305.1-06.

4.5.5.5 Field Quality Control

The Contractor shall provide the following:

1. Provide adequate facilities for safe storage and proper curing of concrete test cylinders onsite for the first 24 hours or for additional time as may be required before transporting samples to the test lab.
2. Provide concrete for testing of slump flow, air content, density (unit weight) and temperature and, for making cylinders.
3. Water shall not be added to the concrete at the job site.
4. Field addition of admixtures, if needed for logistics reasons, shall be approved by the Engineer.

The Contractor shall consult with the admixture manufacturer in developing quality control operations appropriate to the Project.

Field testing and inspection shall be performed in accordance with ACI 301M-10.

Concrete tests shall be conducted by an ACI Concrete Field Testing Technician Grade I, or equivalent, knowledgeable in testing self-consolidating concrete.

Tests shall be conducted on the first batch of the day and for each 110 m^3 or fraction thereof, for each concrete mixture placed in any one day.

The testing agency provided by the Contractor and approved by the Owner and the Engineer shall provide the following services:

a. Inspect concrete placement.

b. Sample the concrete in accordance with ASTM C172 / C172M - 10.

c. Test concrete slump flow in accordance with ASTM C1611 / C1611M - 09be1. Cone can either be used upright or inverted. Same procedure shall be followed throughout the Project.

d. Record the Visual Stability Index (VSI).

e. Test passing ability in accordance with ASTM C1621 / C1621M - 09b. Cone shall be used in the same way as in slump flow test.

f. Determine the air content of concrete sample for each strength test in accordance with ASTM C231 / C231M – 10 or ASTM C173 / C173M - 12, except that the concrete shall be filled in one lift and not consolidated. Light tamping of the sides of the air-meter is permitted.

g. Determine the density (unit weight) of concrete sample for each strength test in accordance with ASTM C138 / C138M - 13a, except that the concrete shall be filled in one lift and not consolidated.

h. Record the temperature of concrete for each strength test in accordance with ASTM C1064 / C1064M - 12.

i. Cast concrete specimens for compressive strength test as follows:

   Cast and cure at least three 150 mm by 300 mm cylinders or four 100 mm by 200 mm cylinders in accordance with ASTM C31 / C31M - 12, except that the concrete shall be placed in one lift and not consolidated. However, light tapping of the sides of the cylinders with an open hand is permitted. Number of cylinders to be cast may be adjusted if strength tests at other than standard ages are required.

j. Record the fresh concrete data for each set. The datasheet shall include the following:

   1. Mixture number
   2. Specified 28-day strength
   3. Date and time of batching
   4. Time of testing
   5. Location of placement
   6. Truck number
   7. Ticket number
   8. Slump flow, VSI, passing ability, air content, density (unit weight) and temperature of concrete
   9. Ambient temperature
   10. Names and quantities of admixtures added on site, and, name and title of the person who authorized the addition
   11. Set number, if more than one set of cylinders are cast on a single day
   12. Name of the testing agency
   13. Name and signature of the inspector who conducted the test, and

14. Any additional observations or comments.

k. Mark the cylinders and write the date of casting on each cylinder.

l. Store and protect the cylinders at the job site immediately after casting in accordance with ASTM C31 / C31M - 12.

m. Transport the cylinders from job site to the laboratory in accordance with ASTM C31 / C31M – 12 after the cylinders have attained acceptable strength.

n. Cure the cylinders in the laboratory in accordance with ASTM C31 / C31M - 12.

o. Test cylinders for compressive strength in accordance with ASTM C39 -C39M 2011.

   1. Test one cylinder at 7 days for information and at least two cylinders at 28 days for acceptance when testing 150 mm by 300 mm cylinders unless otherwise specified.

   2. Test one cylinder at 7 days for information and at least three cylinders at 28 days for acceptance when testing 100 mm by 200 mm cylinders unless otherwise specified.

   Tests at other ages may be specified as necessary.

p. Base strength value on the average of at least two 150 mm by 300 mm cylinders or three 100 mm by 200 mm cylinders tested at 28 days.

q. Test report shall include all the information in Item 10 above and compressive strength data, and shall be signed by the laboratory manager.

r. Strength of concrete shall be deemed satisfactory if both of the following requirements are met (ACI 318M -11):

   1. Every arithmetic average of any three consecutive compressive strength tests equals or exceeds the specified compressive strength, and

   2. No compressive strength test falls below the specified compressive strength by more than 3.5 MPa when the specified strength is 35 MPa or less; or by more than 10 percent of specified strength, when the specified strength is above 35 MPa.

   If any strength test of laboratory-cured cylinders falls below the specified compressive strength by more than the values specified above, remedial measures shall be taken as recommended by the Engineer.

4.5.5.6 Consolidation

Consolidation is typically not necessary for SCC. However, the Contractor shall have internal vibrators as recommended in ACI 301M-10 on site in case internal vibration is needed due to delays in placement or the concrete has a lower than expected slump flow and has to be placed to prevent the formation of a cold joint.

Prior approval by the Engineer shall be obtained if minimal vibration (external or internal) is required for proper consolidation due to congested reinforcement or space restrictions.

4.5.5.7 Finishing

Concrete finishing shall be in accordance with Section 4.4.3 and Article 4.4.8.5.

4.5.5.8 Curing and Protection

Curing and protection of concrete shall be in accordance with ACI 308.1-11.

4.6 Formwork

Forms are temporary works that shall comply with the requirements of Section 1.20, Chapter 1, General Requirements, of these standard specifications. Materials and design requirements for forms shall be in accordance with Article 1.20.8.2 and Article 1.20.8.4 of Chapter 1, General

Requirements. Construction requirements for formworks shall be in accordance with Section 4.6.2, and removal of formwork shall be in accordance with the requirements of Section 4.6.3.

Slip-form formwork shall comply with the requirements of Section 4.6.1 and Article 4.6.2.5. The Contractor shall receive Engineer's approval of slip-form formwork prior to fabrication or bringing the slip-form equipment to the site of the works.

4.6.1 Slip-form Formwork

4.6.1.1 Timber Connections

Timber connections shall be designed in accordance with the methods, stresses, and loads allowed in the Timber Construction Manual, Fifth Edition by the American Institute of Timber Construction (AITC), or equivalent as approved by the Engineer. Frictional resistance shall not be considered as contributing to the stability of any timber connection.

4.6.1.2 Bolted Connections

Tabulated values in the *AITC Timber Construction Manual-Fifth Edition* are based on square posts. For a round post or pile, the main member thickness shall be the side of a square post having the same cross-sectional area as the round post used.

Design values for bolts are typically given for load is applied either parallel or perpendicular to the direction of the wood grain. For load is applied at an angle to the grain, the design value for the main member shall be obtained from the Hankinson formula shown in the AITC manual. Design values in the AITC Table 6.20 apply only to 3-member joints (bolt in double shear) in which the side members are each ½ the thickness of the main member.

Threaded rods and coil rods may be used in place of bolts of the same diameter with no reduction in the tabulated values. At openings for roadways and railroads, all connections shall be bolted using 15mm diameter or larger through bolts.

Bolt holes shall exceed the bolt diameter by 0.8 mm to 3 mm. A washer not less than a standard cut washer shall be installed between the wood and the bolt head and between the wood and the nut to distribute the bearing stress under the bolt head and nut and to avoid crushing the fibres. In lieu of standard cut washers, metal plates or straps with dimensions at least equal to that of a standard cut washer may be substituted.

When steel bars or shapes are used as diagonal bracing, the tabulated design values shown in AITC Table 6.20 for the main members loaded parallel to grain (P value) are increased 75 % for joints made with bolts 12 mm or less in diameter, 25 % for joints made with bolts 38 mm in diameter, and proportionally for intermediate diameters. No increase in the tabulated values is allowed for perpendicular-to-grain loading (Q value).

Clearance requirements for end, edge, and bolt spacing distance shall be as shown below. All distances are measured from the end or side of the wood member to the center of the bolt hole. For members which are subject to load reversals the larger controlling distances shall be used for design. For parallel-to-grain loading, the minimum distances for full design load:

- In tension, minimum end distance shall be 7 times the bolt diameter
- In compression, minimum end distance shall be 4 times the bolt diameter
- In tension or compression, the minimum edge distance shall be 1.5 times the bolt diameter.

For perpendicular-to-grain loading, the minimum distance for full design load:

1. Minimum end distance shall be 4 times the bolt diameter
2. Edge distance toward which the load is acting shall be at least 4 times the bolt diameter
3. Distance on the opposite edge shall be at least 1.5 bolt diameters

Minimum spacing between adjacent bolts in a row shall be 4 times the bolt diameter, measured centre-to-centre of the bolt holes.

When more than 2 bolts are used in a line parallel to the axis of the side member, additional requirements shall be followed as shown in the AITC manual.

a. Lag Screw Connections

Design values for lag screws subject to withdrawal loading can be found in AITC Table 6.27. An equivalent standard may be used with the approval of the Engineer. Maximum load on a given screw shall not exceed the allowable tensile strength of the screw at the root section.

If subjection of lag screws to end-grain withdrawal loading cannot be avoided, the design value shall be 75 % of the corresponding value for withdrawal from the side grain.

When the load is applied at an angle to the grain, the design value shall be obtained from the Hankinson formula shown in the AITC manual. When lag screws are subjected to a combined lateral and withdrawal loading, as would be the case with longitudinal bracing when the falsework bents are skewed, the effect of the lateral and withdrawal forces shall be determined separately. Withdrawal component of the applied load shall not exceed the allowable value in withdrawal. Lateral component of the applied load shall not exceed the allowable lateral load value. Lag screws shall be inserted in lead holes as follows:

1. Clearance hole for the shank shall have the same diameter as the shank, and the same depth of penetration as the length of unthreaded shank
2. Lead hole for the threaded portion shall have a diameter equal to 60 % to 75 % of the shank diameter and a length equal to at least the length of the threaded portion. Larger percentile figure in each range shall apply to screws of the greater diameters used in Group II wood species
3. Threaded portion of the screw shall be inserted in its lead hole by turning with a wrench, not by driving with a hammer
4. To facilitate insertion, soap or other lubricant shall be used on the screws or in the lead hole.

b. Drift Pin and Drift Bolt Connections

When drift pins or drift bolts are used, the required length and penetration shall be determined using the following criteria. Lateral load-carrying capacity of drift pins and drift bolts driven into the side grain of a wood member shall be limited to 75% of the design values for a common bolt of the same diameter and length in the main member. For drift pin connections, the pin penetration into the connected members shall be increased to compensate for the absence of a bolt head and nut. For drift bolts or pins driven into the end grain of a member, the lateral load-carrying capacity shall be limited to 60 % of the allowable side grain load (perpendicular to grain value) for an equal diameter bolt with nut. To develop this allowable load, the drift bolt or pin shall penetrate at least 12 diameters into the end grain. To fully develop the allowable load of the drift bolts or pins, they shall be driven into predrilled holes, 1.5mm less in diameter than the drift pin or bolt diameter.

Criteria shown in the AITC Timber Construction Manual-Fifth Edition shall apply to drift bolt or pin connection allowable loads for the following conditions:

1. Withdrawal resistance; and
2. When there are more than 2 drift bolts or pins in a joint, allowable loads shall be further reduced by applying applicable modification factors shown in the AITC Table 6.3.

4.6.1.3 Nailed and Spiked Joints

Joints using nails or spikes shall conform to the provisions of AITC. End grain withdrawal shall not be used. Diameters listed in the tables apply to fasteners before application of any protective coating.

When more than 1 nail or spike is used in a joint, the total design value for the joint in withdrawal or lateral resistance shall be the sum of the design values for the individual nails or spikes.

Tabulated design values for lateral loads are maximum values for the type and size of fastener shown. Tabulated values shall not be increased even if the actual penetration is exceeded. When main member penetration is less than required, the design value shall be determined by straight-line interpolation between zero and the tabulated load, except that penetration shall not be less than 1/3 of that specified.

Double-headed or duplex nails used in formwork construction are shorter than common wire nails or box nails of the same size designation. They have less penetration into the main member and therefore their load-carrying capacity shall be adjusted accordingly.

Nail and spike minimum spacing in timber connections shall be as follows:

a. Average center-to-center distance between adjacent nails, measured in any direction, shall not be less than the required penetration into the main member for the size of nail being used
b. Minimum end distance in the side member, and the minimum edge distance in both the side member and the main member, shall not be less than ½ of the required penetration

Allowable values for withdrawal and lateral load resistance are reduced when toe nails are used in accordance with the following:

1. For withdrawal loading, the design load shall not exceed 2/3 of the value shown in the applicable design table
2. For lateral loading, the design load shall not exceed 5/6 of the value shown in the applicable design table

Toe nails are recommended to be driven at an approximate angle of 30-degrees with the piece and started approximately 1/3 of the length of the nail from the end or side of the piece.

4.6.1.4 Timber Connection Adjustment for Duration of Load

Tabulated values for timber fasteners are for normal duration of load and may be increased for short duration loading, except for connections used in formwork for staged construction sequences.

Duration of load adjustment for timber connections shall not be allowed for staged construction sequences where delayed and/or staged loading occurs for any type of concrete structure. Adjustment for duration of load as described in this section applies only to design values for timber connectors, such as nails, bolts, and lag screws, not for timber and structural steel components. Tabulated values for nails, bolts, and lag screws may be adjusted by the following duration-of-load factors:

- 1.25 for falsework design governed by the minimum design horizontal load or greater (3 % or greater of the dead load)
- 1.33 for falsework design governed by wind load
- 2.00 for falsework design governed by impact loading

4.6.1.5 Face Lumber, Studs, Wales, and Metal Forms

Elements of this section shall be designed for the required loads, deflections, and conditions. Forms battered or inclined above the concrete shall have positive anchorage or counterweights designed to resist uplift as concrete is placed. Anchorages shall be shown in the formwork drawings.

Where the concrete pouring sequence causes fresh concrete to be significantly higher along one side of tied forms than the opposite side, a positive form anchorage system capable of resisting the imbalance of horizontal thrust, and preventing the dislocation and sliding of the entire form unit, shall be designed and installed.

All timber or lumber forms shall be free from defects affecting the accuracy of shape, strength, rigidity, water tightness and smoothness of the surface. Wooden forms shall be faced with smooth sanded, exterior plywood, or equivalent as approved by the Engineer.

Timber and lumber shall be grade stamped and certified by a lumber grader or grading company certified by an accredited certification agency meeting the approval and requirements of the United Kingdom Timber Grading Committee or equivalent international timber grading certification organization as approved by the Engineer.

Mill providing the lumber and timber shall provide a certificate providing the following grading certification for the lumber/timber supplied. Certification shall include the following:

a. Name, address, name of manager and contact information of the mill
b. Name of the certified grader or grading organization and certifying standard organization.
c. Grading procedure and to what international standards the grading procedure complies with (i.e. softwood visual strength grading to BS 4978: machine grading to BS EN 338; tropical hardwood visual grading to BS 5756; and temperate hardwood visual grading to BS 5756)
d. Name and signature of the person doing the grading and their current certification or qualification
e. Name and signature of the responsible mill official
f. Date the timber or lumber was graded at the mill
g. Grade (both visual and strength class), species, timber/lumber condition (wet, kiln dried, dry) dimensions, and quantity of the timber or lumber
h. Source location of the timber or lumber

Each piece of timber used for structural work shall be grade stamped with the following information:

1. Grading certification organization logo
2. Standard reference, (i.e. BS EN 14081 for machine grading)
3. Grader and/or grader company reference (usually a number issued by the grading certification organization to the grader when certified)
4. Timber condition (dry, kiln-dry or wet)
5. Species or species group
6. Grade (visual grading)
7. Strength class (machine grading)

Grading certification or approved for shipment stamp or tag shall not constitute final acceptance of the material. Engineer may reject any or all of the timber or lumber that does not comply with these specifications or has been damaged during storage, shipping, or upon delivery.

Contractor shall list in the form drawings the grade and class of wood required for the forms. Engineer shall approve the manufacturer’s certification of structural properties. Wood panels stamped “shop” or “shop cutting,” shall not be used.

Plyform, a plywood specifically designed and manufactured for concrete forming, is acceptable for formwork. Plyform differs from conventional exterior plywood grades in strength and the exterior face panels are sanded smooth and factory oiled. Contractor shall specify on the formwork drawings whether Class 1, Class 2, or Structural I Plyform is required when used. Grades of plywood for various form applications shall be as follows:

Table 4-32: Plywood grades and formwork applications

Formwork application	Requirements to meet or exceed
Traffic and pedestrian barriers that will not receive an architectural surface treatment	APA* grade High Density Overlaid (HDO) Plyform Class I
	APA* grades B-B Plyform Class I or B-C (Group I species) The Contractor shall coat the form to prevent it from leaving joint and grain marks on the surface The Contractor shall submit for the Engineer’s approval a 1.2 m^2 test panel of concrete formed with the same plywood and coating as proposed in the form drawings Panel shall include 1 form joint along its centerline Contractor shall apply coating material per the manufacturer’s instructions before applying chemical release agents
Other exposed surfaces (not traffic and pedestrian barriers)	APA* grades B-B Plyform Class I or B-C (Group I series) If one face is less than B quality, the B (or better) face shall contact the concrete
Unexposed surfaces, including barrier than will receive an architectural finish	APA* grade CDX, provided the Contractor complies with required stress and deflection limitations
*American Plywood Association (APA) grades provided for reference. Equivalent materials acceptable with the Engineer’s approval.	

Form joints on an exposed surface shall be in a horizontal or vertical plane. But in wingwalls, side form joints shall be placed at right angles and parallel to the roadway grade.

Joints parallel to studs or joists shall be backed by a stud or joist. Joints at right angles to studs and joists shall be backed by a stud or other backing the Engineer approves. Perpendicular backing is not required if studs or joists are spaced:

- 230 mm or less on center and covered with 12 mm plywood
- 300 mm or less on center and covered with 20 mm plywood

Face grain of plywood shall run perpendicular to studs or joists unless shown otherwise on the Contractor’s formwork plans and approved by the Engineer. Proposals to deviate from the perpendicular orientation shall be accompanied by supporting calculations of the stresses and deflections.

Forming for all exposed curved surfaces shall follow the shape of the curve shown in the drawings and shall not be chorded except as follows. On any retaining wall that follows a horizontal circular curve, the wall stems may be a series of short chords if:

a. Chords within the panel are the same length, or otherwise as approved by the Engineer
b. Chords do not vary from a true curve by more than 12 mm at any point
c. All panel points are on the true curve

Where architectural treatment is required, the angle point for chords in wall stems shall fall at vertical rustication joints. For exposed surfaces of walls, the Contractor shall build forms of plywood at least 20mm thick with studs no more than 300 mm on center. Engineer may approve exceptions, but deflection of the plywood, studs, or wales shall never exceed 1⁄360 of the span (or 1⁄270 of the span for unexposed surfaces).

All form plywood shall be at least 12mm thick except on sharply curved surfaces. On sharp curves, the Contractor may use 6mm plywood if it is backed firmly with heavier material.

Round columns or rounded pier shafts shall be formed with a self-supporting metal shell form or form tube that leaves a smooth, nonspiralling surface. Wood forms are not permitted.

Metal forms shall not be used elsewhere unless the Engineer is satisfied with the surface and approves in writing. Engineer may withdraw approval for metal forms at any time. If permitted to use a combination of wood and metal in forms, the Contractor shall coat the forms so that the texture produced by the wood matches that of the metal. Aluminum shall not be used for metal forms.

For design purposes, the Contractor shall assume that on vertical surfaces concrete exerts 732 kg-force/m^2 of depth. However, when the depth is reached where the rate of placement controls the pressure, the following table applies:

Table 4-33: Placement rates

Rate of Placing (metres per hour)	Pressure (kg/cm^2) for Temperature Of Concrete	
	15° C	21° C and above
0.6	0.23	0.18
0.9	0.31	0.27
1.2	0.35	0.30
1.5	0.40	0.34
1.8	0.44	0.37
2.1	0.48	0.40
2.4	0.52	0.43
2.7	0.57	0.46
3.0	0.61	0.49
4.6	0.81	0.63

Pressures in the above table have been increased to provide an allowance for the vibration and impact.

4.6.2 Construction of Formwork

Formwork shall be constructed accurately to represent the shape of the concrete as detailed on the Contract plans. It shall be of suitable design and substantial construction and be approved by the Engineer. Contractor shall make any necessary adjustments to allow for shrinkage, settlement or deflection which may occur during construction so that the finished concrete sections conform accurately to the specified dimensions true to line, level and camber.

Contractor shall give the Engineer at least 24 hours' notice of the Contractor's intention to place the concrete to enable the Engineer to inspect all aspects of the completed work. However, before notifying the Engineer, the Contractor shall ensure that the work complies in all respects with these standard specifications.

When prefabricated formwork, shoring or scaffolding units are used, the manufacturer's recommendations for allowable loads may be followed if supported by test reports or successful experience records. For materials which will experience substantial reuse, reduced allowable load values may be required.

No accessory for supporting the formwork or staging shall be built into the permanent structure except with the Engineer's approval.

Formwork shall be constructed to provide completed concrete surfaces complying with the tolerances specified therein and within these standard specifications.

Materials used in the construction of falsework and formwork shall be suitable for the purpose for which they are required and be of such quality as to produce the specified standard of work. Type, grade and condition of the material shall be subject to the Engineer's approval.

Timber boards shall be fixed with such openings between the individual boards that they will close completely after the wetting which will precede the concreting.

As directed by the Engineer, Class C15 blinding concrete will be placed to a minimum depth of 100 mm in the foundation of footings of structures to provide a working platform and to protect the stability of the foundation soils. Area shall be sufficient to provide support for formwork.

Forms for all surfaces which will not be completely enclosed or hidden below the permanent surfaces of the ground, or for surfaces where plywood forms are not specified, shall be made of surfaced lumber or material which will provide a surface at least equally satisfactory. Any lumber or material which becomes warped or checked prior to placing of the concrete will be rejected.

Forms for all exposed surfaces shall be constructed with new plywood or metal on the face of the form that will be in contact with the concrete. This form surface shall be maintained equal to the new surfaces at all times as needed to produce the desired concrete surface. Engineer shall be the sole judge as to when the form faces shall be replaced.

All exposed sharp edges shall be chamfered with triangular fillets not less than 20 mm by 20 mm to prevent mortar runs and to preserve smooth, straight lines, unless otherwise directed by the Engineer. Triangular fillets or chamfer strips shall be milled from clear, straight grain lumber and shall be surfaced on all sides. Curved surfaces shall be formed of plywood, metal, or other suitable material.

Form clamps or bolts shall be used to fasten forms.

Bolts or form clamps shall be positive in action and shall be of sufficient strength and number to prevent spreading of the forms. Lifting anchors may be installed in precast members. Bolts, form clamps and lifting anchors shall be of such type that they can be entirely removed or cut back 20 mm or more below the finished surface of the concrete, leaving no metal within 30 mm of the concrete surface. All forms for the outside surfaces shall be constructed with stiff wales at right angles to the studs and all form clamps shall extend through and fasten such wales.

No concrete shall be deposited in the forms until all work connected with constructing the forms and placing all reinforcing steel, ducts, and anchorages has been completed for the unit to be poured and the Engineer has inspected said forms, reinforcing steel, ducts, or anchorages.

Openings shall be provided in forms to accommodate other work, including mechanical and electrical work. Accurately place and securely support items required to be built into the forms.

Drainage holes and weep holes shall be constructed as detailed on the drawings. Forms for weep holes shall be as approved by the Engineer.

Contractor shall install in the formwork required inserts, anchors, expansion joint elements, sleeves, and other items specified under other sections of these specifications and shall coordinate installation with other trades in the proper location of such items. Ends of conduits, piping and sleeves embedded in concrete shall be closed with caps or plugs.

Tests on piping and other items which are required to be tested shall have been completed before starting concrete placement.

If the Contractor uses metal forms, they shall be of a type which does not require the use of wire or other ties that remain embedded in the concrete after the forms have been removed. Where ties are necessary, bolts and rods shall be used, but they must be arranged so that when the forms are removed no metal shall be within 30mm of any surface.

Where holes are boxed out in the concrete for the subsequent building-in of pipes, brackets, lagbolts or other ironwork or details, the boxes shall become part of the formwork and shall be accurately set out and securely fixed. If the Contractor uses other methods for building in the above mentioned ironwork or details, such methods shall be used only with the Engineer's prior approval, and such approval shall in no way relieve the Contractor of his responsibility for the accuracy of the final finished positions of such ironwork and details to be built in.

Openings for the inspection of the inside of the formwork and for the escape of water used for washing out shall be formed so that they can be conveniently closed before placing of the concrete.

Shutters shall be provided for all slopes exceeding 15 degrees to the horizontal to enable the concrete to be properly placed. Formwork shall be constructed so that the side shutters of members can be removed without disturbing the soffit shutters and, if the Contractor wishes to leave some of the props in place when the soffit shutters are removed, these props shall not be disturbed during the striking. Detailed arrangement of the props shall be submitted to the Engineer in advance for his approval.

Before any concrete is placed in it, the formwork shall be cleaned of all sawdust shavings and dirt and other debris washed out and all openings closed. Interior face of all formwork shall be carefully coated with an approved non-staining preparation to prevent the adhesion of the concrete thereto. This preparation must not be allowed to come into contact with the reinforcement and no organic oil will be permitted to be used to coat the forms.

All formwork shall be inspected and approved by the Engineer before any concrete is placed in it, and such approval shall not relieve the Contractor of his responsibility for the safety, accuracy or efficiency of the work.

Use of permanent forms, of any material, that are proposed to remain in place at the completion of construction will not be permitted unless otherwise specified in these specifications or in the project particular specifications.

No load shall be applied to any part of a structure until the specified curing period has expired, after which applied loading shall be allowed only when approved by the Engineer. Engineer's decision will be based on the type of load to be applied, the age of the concrete, the magnitude of stress induced and the propping of the structure.

Formwork shall be sufficiently rigid to maintain the forms in their correct position, shape and profile and shall be of such tight construction that the concrete can be placed and compacted without undue loss or leakage of the mortar component of the concrete.

Joints between contiguous formwork elements shall be of a tight fit and, where necessary, the joints shall be caulked, taped or packed with a sealing gasket, all at no extra payment if undue leakage occurs or can be expected. Paper, cloth or similar material shall not be used for this purpose.

Formwork construction shall permit accurate erection and easy stripping without shock, disturbance or damage to the cast concrete. Where necessary, the formwork assembly shall permit the removal or release of side forms independently of the soffit forms.

Metal supports, ties, hangers and accessories embedded in the concrete shall be removed to a depth of not less than the cover specified for the reinforcement. No wire ties shall be used.

All external corners shall be chamfered by fillet strips being fixed into the corners of the formwork to form 25mm x 25mm chamfers. Re-entrant angles need not be chamfered unless specified. Where polystyrene or similar material, susceptible to damage is used, it shall be lined with a hard surface on the side to be concreted. Hard material shall be sufficiently resilient to ensure that the required quality of work can be achieved.

Where it is specified, all formwork ties shall be provided with recoverable truncated cones between sleeve ends and formwork faces to ensure that sleeve ends are not exposed on concrete surfaces. Cones shall have a minimum depth of 15 mm.

4.6.2.1 Drainage of Substructure

Contractor shall use weep holes and gravel backfill that complies with Table 2-4, Article 2.5.2.5 of Chapter 2, Earthworks, for drain fill material behind retaining walls or minor structures. To maintain thorough drainage, weep holes shall be placed as low as possible. Weep holes shall be covered with geotextile meeting the requirements of Table 2-7, Article 2.5.2.8 of Chapter 2, Class 1, before backfilling. Geotextile shall have an apparent opening size (AOS) not greater than 0.180 mm and a minimum water permittivity of 0.3 sec^{-1}. Geotextile screening shall be bonded to the concrete with an approved adhesive. Gravel backfill shall be placed and compacted as required in Section 2.7.3. Additional tiling, French or rock drains, or other drainage devices shall be installed per the drawings. If underdrains are not installed behind the wall, all backfill within 450 mm of weep holes shall comply with Article 2.5.2.5 of Chapter 2. Unless the drawings require otherwise, all other backfill behind the wall shall be structural backfill as specified in Article 2.5.2.4 of Chapter 2, Earthworks.

4.6.2.2 Formwork to Enclosed Surfaces

Formwork and boards shall be so arranged as to form a uniform and regular pattern in line with and perpendicular to the main axis of the member, unless otherwise approved or directed by the Engineer. Joints between contiguous members shall, after caulking, taping or sealing, be treated to prevent blemishes, stains and undue marks from being imparted to the concrete surface. Bolt and tie positions shall be so arranged that they conform to the symmetry of the formwork panels or boards. Bolt and rivet heads which will be in contact with the formed surface shall be of the countersunk type and shall be treated to prevent marks from forming on the concrete surface.

Formwork at construction joints shall be braced to prevent steps from forming in the concrete surfaces at the joints between successive stages of construction. Where moulding or recess strips are specified, they shall be neatly butted or mitred.

4.6.2.3 Formwork for Open Joints

Requirements for formwork for open joints shall, unless otherwise specified, apply only to cases where the distance between opposite concrete surfaces is equal to or less than 150 mm. Formwork for open joints shall be constructed to produce a Class 1 surface finish to concealed surfaces or a Class 2 surface finish corresponding to the in-plane surface finish of the bordering concrete surfaces. Material used and construction of the formwork shall permit its complete removal to form the open joint.

No solvent shall be used to remove formwork unless approved by the Engineer.

4.6.2.4 Openings and Wall Chases

Openings and wall chases shall be provided only where indicated on the drawings or as authorized by the Engineer. Frames for openings shall be rigid and firmly secured in position to prevent their moving. Temporary holes shall be so formed that they will not create an irregular pattern in relation to the rest of the exposed formed concrete surface.

4.6.2.5 Slip-form Formwork

Equipment shall meet the requirements of Article 7.5.3.4 of Chapter 7, Incidental Construction. All equipment shall be thoroughly tested and inspected before installation and shall be maintained in a good working order throughout the entire slip-form operation. Contractor shall keep adequate back-up equipment and quantities of materials on the site of the works to ensure that the slide casting can proceed without interruption.

4.6.2.6 Fixed Formwork

Void formers shall be secured in position at regular intervals to prevent displacement and distortion during concreting. Void formers shall be supported. Ties securing the void formers shall be attached to the formwork. Void formers shall not be tied to or supported on the reinforcement.

Fibre-cement plates shall be supported so that the plate spans in the direction parallel to the orientation of the asbestos fibres.

Void formers used in permanent work shall be subject to the approval of the Engineer. Where void formers of a special design are required, details thereof will be specified. Void formers shall be manufactured from material which will not leak, tear or be damaged during the course of construction and shall be of such tight construction as to prevent undue loss of the mortar component of the concrete through leakage. Units shall be sufficiently rigid so as not to deform during handling or under the pressure of the wet concrete.

For mild-steel spiral-lock-formed void formers, the metal thickness shall be as follows, unless otherwise specified:

a. Unbraced void formers
   1. 0.6 mm for diameters of up to 600 mm
   2. 0.8 mm for diameters exceeding 600 mm and up to 800 mm
   3. 1.0 mm for diameters exceeding 800mm and up to 1000 mm.
b. Braced void formers
   1. 0.6 mm for diameters of up to 800 mm
   2. 0.8 mm for diameters exceeding 800 mm and up to 1000 mm
   3. 1.0 mm for diameters exceeding 1000 mm and up to 1200 mm
   4. 1.2 mm for diameters exceeding 1200 mm.

Thickness specified for braced void formers shall apply to formers internally braced with timber or equivalent braces. Braces shall be at spacing not exceeding 2 m and not further than 1.0 m from the end of each unit. Timber cross braces shall consist of members with cross-sectional dimensions of at least 50 mm x 50 mm. All hollow void-former units shall be provided with a 12 mm diameter drainage hole at each end.

4.6.2.7 Preparing the Formwork

Surfaces of forms which are to be in contact with plastic concrete shall be treated to ensure non-adhesion of the concrete to the forms and easy release from the concrete during the stripping of the formwork.

Release agents shall be applied strictly in accordance with the manufacturer's instructions, and every precaution shall be taken to avoid the contamination of the reinforcement. In the selection of release agents, due regard shall be given to the necessity for maintaining a uniform colour and appearance throughout on the exposed concrete surfaces. Release agent shall not contain materials that could affect bond of subsequent finishes or natural appearance of exposed concrete surfaces. Contractor is responsible for using a release agent that is compatible with the proposed finish.

If an exposed concrete surface will be sealed, the release agent shall not contain silicone resin. Before applying the agent, the Contractor shall provide the Engineer a written statement from the manufacturer stating whether the resin in the base material is silicone or nonsilicone. Contractor shall submit to the Engineer a sample of the release agent at least 14 working days before its use. Approval or disapproval shall be based on laboratory test results. Engineer may reject any forms that will not produce a satisfactory surface.

Forms to be treated with a release agent shall be treated before placing reinforcing and embedded items. Contractor shall take care not to scuff the release agent when placing reinforcing and embedded items. Scuffed areas shall be re-treated with the release agent, using care not to coat reinforcing and embedded items. Holes and spalling within the slab surface from previous cast shall be repaired and allowed to cure before the Contractor applies a new coat of releasing agent. Before the concrete is placed, all dirt and foreign matter shall be removed from the forms and the forms shall be thoroughly wetted with water.

4.6.2.8 Embedded Articles

Sleeves, pipes or conduits of any material shall be located so as not to impair unduly the strength of the concrete. Articles embedded in concrete shall be as indicated on the drawings and as directed by the Engineer.

Special care shall be taken to ensure that the articles are securely fixed in the correct position and the Contractor shall at his own expense provide all necessary templates, temporary supports and other equipment and labour required.

Articles to be embedded in concrete shall be clean and free from oil or foreign matter that would weaken the bond of the concrete to these items.

Clear space between such embedded articles and any reinforcing steel shall be at least 40 mm or the maximum size of the aggregate plus 5mm, whichever is the greater. Thickness of the concrete cover over pipes and fittings shall be at least 25 mm. Ends of all ferrules used for bracing formwork shall be neatly finished off to the details shown on the drawings. Where no details are given on the drawings, ferrules shall be cut back to a depth of at least the specified cover, and the holes shall be filled in with mortar and finished off flush with the concrete surface.

4.6.2.9 Formwork Accessories

Formwork accessories such as form ties, form anchors, form hangers, anchoring inserts, and similar hardware shall be specifically identified in the formwork plans including the name and size of the hardware, manufacturer, safe working load, and factor of safety. Grade of steel shall also be indicated for threaded rods, coil rods, and similar hardware. Wire form ties and taper ties shall not be used. Welding or clamping formwork accessories to reinforcing steel will not be allowed.

Table 4-34, from ACI 347R-88, provides minimum safety factors for formwork accessories. Hardware proposed shall meet these minimum ultimate strength requirements or the manufacturer's minimum requirements, whichever provides the greater factor of safety. Contractor shall attach copies of the manufacturer's catalog cuts and/or test data of hardware proposed, to the formwork plans and submit the formwork plans and calculations for review and approval by the Engineer.

Table 4-34: Minimum safety factors of formwork accessories

Accessory	Safety factor*	Type of construction
Form tie	2.0	All applications
Form anchor	2.0	Formwork supporting form mass and concrete pressures only
Form anchor	3.0	Formwork supporting masses of forms, concrete, construction live loads, and impact
Form hangers	2.0	All applications
Anchoring inserts	2.0	Placed in previous opposing concrete placement to act as an anchor for form tie
*Safety factors are based on ultimate strength of the formwork accessory.		

Bearing area of external holding devices shall be adequate to prevent excessive bearing stress on form lumber. Form ties and form hangers shall be arranged symmetrically on the supporting members to minimize twisting or rotation of the members. Form tie elongation shall not exceed the allowable deflection of the wale or member that it supports. Inserts, bolts, coil rods, and other fasteners shall be analyzed and designed for appropriately combined bending, shear, torsion, and tension stresses.

Formwork shall not be attached to rebar or rebar cages installed per the drawings. However, the Contractor may install additional reinforcing steel for formwork anchorage. Frictional resistance shall not be considered as contributing to the stability of any connection or connecting device, except those designed as friction connectors such as U-bolt friction-type connectors.

Form anchors and anchoring inserts shall be designed considering concrete strength at time of loading, available embedment, location in the member, and any other factors affecting their working strength, and shall be installed in concrete per the manufacturer's published requirements. Form anchors and anchoring inserts embedded in previous concrete placements shall not be loaded until the concrete has reached the required design strength. Required design strength of concrete for loading of an anchor shall be shown in the formwork drawing if it is assumed that the anchor will be loaded before the concrete has reached its 28-day strength.

Installation of permanent concrete inserts, such as form ties hangers, or embedded anchor assemblies, shall permit removal of all metal to at least 12 mm below the concrete surface. Holes shall be patched in accordance with Section 4.4.3. During removal of the outer unit, the bond between the concrete and the inner unit or rod shall not be broken.

All corners except for footings, footing pedestals, and seals shall be bevelled 20 mm unless otherwise shown on the drawings. All forms shall be as mortar-tight as possible with no water standing in them as the concrete is placed.

4.6.3 Removal of Formwork

The Contractor shall be responsible for the safe removal of formwork. Contractor shall inform Engineer in advance when the Contractor intends to strike any formwork.

Formwork shall not be removed before the concrete has attained sufficient strength to support its own mass and any loads which may be imposed on it. The Engineer will decide, on the basis of post-placement curing conditions, the exact number of hours that shall elapse before form removal. If the Engineer does not specify otherwise, the Contractor may request to remove forms based on any one of the criteria listed in the table below. Both compressive strength and time criteria must be met if both are listed. Time shall be from the time of the last pour the forms support. In no case shall the Contractor remove forms without the Engineer's approval.

Table 4-35: Removal of forms

Option	Form Use	Percent of Specified Minimum Compressive Strength	Time After Last Concrete Placed
A	Walls, footings, traffic and pedestrian barriers, and any side form not supporting the concrete weight.	---	72 hours
B	Side forms not supporting the concrete weight	68 kg/cm^2 *	24 hours
C	Side forms, traffic barrier forms, and pedestrian barrier forms made of steel or dense plywood, provided an approved water reducing additive was used.	68 kg/cm^2 *	24 hours
D	Side forms of footings, provided a curing compound was applied immediately after concrete placement. Compound shall not be applied to joint areas.	80 %	5 days
G	Other forms	70 %	24 hour**
*Strength shall be proved by test cubes per section 4.6.3.1.			

Option	Form Use	Percent of Specified Minimum Compressive Strength	Time After Last Concrete Placed
** Time shall be 48 hours if the concrete mix included more than 15 % by weight GGBS or fly ash			

Removal of formwork shall in all cases be supervised by an experienced foreman. All formwork shall be removed without such check or vibration as may damage the concrete, and any work showing signs of damage through premature loading shall be removed and entirely reconstructed.

All formwork shall be constructed in a manner to facilitate removal of formwork. Forms inside of hollow structures shall be removed through openings shown in the drawings or approved by the Engineer. All materials removed shall become the property of the Contractor and shall be disposed of by the Contractor at disposal areas as approved by the Owner.

Concrete surface shall not become dry during the entire curing period due to form removal or any other cause.

4.6.3.1 Early Concrete Test Cube Breaks

Fabrication, curing, and testing of early cubes shall be the responsibility of the Contractor. Early cubes are defined as all cubes tested in advance of the design age of 28 days whose purpose is to determine the in-place strength of concrete in a structure prior to applying loads or stresses. Contractor performed testing shall be performed by a testing laboratory whose equipment has been calibrated within 1 year prior to testing, and testers shall be either ACI certified or qualified in accordance with AASHTO R 18.

Concrete cubes shall be moulded, cured, and tested in accordance with Section 4.3.12 from concrete last placed in the forms and representative of the quality of concrete placed in that pour.

Engineer may approve the use of cure boxes meeting the requirements of this test method. Special cure boxes to enhance cylinder strength will not be allowed.

Number of early cube breaks shall be in accordance with the Contractor's need and as approved by the Engineer. Contractor shall furnish the Engineer with all test results, proof of equipment calibration, and tester's certification. Test results will be reviewed and approved before any forms are removed. Contractor shall not remove forms without the approval of the Engineer.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 5 - REINFORCING STEEL

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 5: Reinforcing Steel

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5 REINFORCING STEEL

This work shall consist of furnishing and placing concrete reinforcing steel in accordance with these Specifications and in conformity with the Contract Documents.

5.1 General

Unless otherwise specified in the Contract documents, all reinforcement steel bars shall be grade 60 (grade 420) uncoated deformed billet steel that meets the requirements of the American Association of State Highway and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM), as outlined in Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement (AASHTO M 31M/M 31-10 (2011)) and (ASTM A615 / A615M - 12). Type 2 deformed bars to BS 4449:2005+A2:2009 grade B500B may be proposed as an alternative.

When coated reinforcement is specified in the Contract documents, coated steel bars shall comply with requirements of AASHTO and ASTM, as outlined in *Standard Specification for Epoxy-Coated Reinforcing Bars: Materials and Coating* Requirements (AASHTO M 284M/M 284-09) and (ASTM A 775/A 775M-07b), or Stand*ard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars* (AASHTO M 317M/M 317-03 (2007)) and (ASTM D3963 / D3963M - 01(2007)). Coated steel wire and welded fabric, as appropriate and as specified in this chapter, shall comply with requirements outlined in *Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement* (ASTM A884 / A884M - 12).

In post-tensioned members, spirals, or wire mesh behind anchorages, spiral reinforcement steel shall comply with the requirements of ASTM's *Standard Specification for Steel Wire, Plain, for Concrete Reinforcement* (ASTM A82 / A82M - 07).

In reinforced concrete compression members, spiral reinforcement shall be grade 60 (grade 420) as defined in ASTM A615 / A615M – 12 (AASHTO M 31M/M 31-10 (2011)).

The Contractor shall furnish, place and test reinforcing steel in accordance with these specifications and in compliance with AASHTO/ ASTM or BS standards. Where reinforcing steel are manufactured, fabricated, placed and tested by other standards not included in this chapter, products conforming to equivalent or higher standards may be acceptable if proven to be suitable.

5.2 Reference Standards and Codes

Standards and codes for reinforcing steel shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition.

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Construction Specifications;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
ACI	American Concrete Institute;
ACI 315-99	Details and Detailing of Concrete Reinforcement;
ACI SP-66(04)	ACI Detailing Manual-2004;
ADQCC (TR-516)	Road Structures Design Manual;
AISI	American Iron and Steel Institute;
ASTM	American Society for Testing and Materials;

AWS	American Welding Society;
AWS - D1.4/	American Welding Society - Structural Welding Code – Reinforcing Steel; D1.4M:2011
BS	British Standards;
BS EN	European Standards;
CRSI	Concrete Reinforcing Steel Institute;
CRSI's	Manual of Standard Practice, 2009;
ICC-ES	International Code Council Evaluation Service;
IBC	International Building Code;
ISO	International Organization for Standardization;
ISO 9001:2015	Quality management systems – Requirements.

Table 5-1 and Table 5-2 identify a set of American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that support the manufacture and use of reinforcement steel.

Table 5-1: Designations and titles for AASHTO and ASTM standards that apply to reinforcing steel works

AASHTO Designation	ASTM Designation	Title
AASHTO M 284M/M 284-09	ASTM A 775/A 775M-07b	Standard Specification for Epoxy-Coated Reinforcing Bars: Materials and Coating Requirements
AASHTO M 317M/M 317-03 (2007)	ASTM D3963 / D3963M - 01(2007)	Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars
	ASTM A82 / A82M - 07	Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
	ASTM A934 / A934M - 07	Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
	ASTM A884 / A884M - 12	Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement
AASHTO M 31M/M 31-10 (2011)	ASTM A615 / A615M - 12	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
	ASTM A706 / A706M - 09b	Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
AASHTO M 225M/M 225-09	ASTM A496 / A496M - 07	Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement
AASHTO M 55M/M 55-09	ASTM A185 / A185M - 07	Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

AASHTO Designation	ASTM Designation	Title
AASHTO M 221M/M 221-09	ASTM A497 / A497M - 07	Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
	ASTM A955 / A955M - 12e1	Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement
	ASTM A1035 / A1035M - 11	Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement
AASHTO MP 18M/MP 18-09 (2010)		Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels
	ASTM A493 - 09	Standard Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
	ASTM A580 / A580M - 12a	Standard Specification for Stainless Steel Wire
AASHTO T 68M/T68-09	ASTM E8 / E8M - 11	Standard Method of Test for Tension Testing of Metallic Materials
	ASTM G12 - 07	Standard Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel
	ASTM A370 - 12a	Standard Test Methods and Definitions for Mechanical Testing of Steel Products

Table 5-2: Designations and titles for BS, and BS EN standards that apply to reinforcing steel works

BS Designation	BS EN Designation	Title
BS 4449:2005+A2:2009		Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification
BS 6744:2001+A2:2009		Stainless steel bars for the reinforcement of and use in concrete. Requirements and test methods
	BS EN 10088-3:2005	Stainless steels. Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes
BS 8666:2005		Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete . Specification

BS Designation	BS EN Designation	Title
	BS EN 1011-1:2009	Welding. Recommendations for welding of metallic materials. General guidance for arc welding
	BS EN 1011-2:2001	Welding. Recommendations for welding of metallic materials. Arc welding of ferritic steels

5.3 Materials

All reinforcing steel and related materials for which the Contract documents do not define specific requirements shall comply with the requirements for applicable materials that are outlined in this section.

5.3.1 Uncoated Reinforcement

Uncoated reinforcing steel shall conform to one of the following specifications, as applicable:

- *Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement* (AASHTO M 31M/M 31-10 (2011)) *or* (ASTM A615 / A615M - 12). Deformed and plain steel bars for concrete reinforcement shall be grade 60 (grade 420) unless otherwise specified in the Contract documents.
- Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement (ASTM A706 / A706M - 09b).
- Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement (AASHTO M 225M/M 225-09) or (ASTM A496 / A496M - 07).
- Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete (ASTM A185 / A185M - 07) or (AASHTO M 55M/M 55-09).
- Standard Specification for Steel Wire, Plain, for Concrete Reinforcement (ASTM A82 / A82M - 07).
- Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete (AASHTO M 221M/M 221-09) or (ASTM A497 / A497M - 07).
- Steel for the Reinforcement of Concrete - Weldable Reinforcing Steel - Bar, Coil and Decoiled Product - Specification (BS 4449:2005+A2:2009).

5.3.2 Coated Reinforcement

Any reinforcing steel that is to be epoxy-coated shall conform to Section 5.3.1, *Uncoated Reinforcement*. When reinforcing bars require epoxy coating, the coating materials, coating process, fabrication, handling, identification of the bars, and repair of damaged coating that occurs during fabrication and handling through completion of the shipment to the job site shall conform with the requirements of AASHTO M 284M/M 284-09 (ASTM A 775/A 775M-07b) or AASHTO M 317M/M 317-03 (2007) (ASTM D3963 / D3963M - 01(2007)) or to ASTM A934 / A934M - 07, as specified in the Contract documents.

Epoxy-coated wire and welded wire fabric shall conform to the Class A requirements outlined in ASTM A884 / A884M - 12.

When epoxy coating is specified, only fusion bonded epoxy-coated reinforcement steel shall be accepted. No other means of epoxy-coating shall be approved

Epoxy coated reinforcing bars shall be coated in a certified epoxy coating Applicator plant in accordance with *Concrete Reinforcing Steel Institute* (CRSI) requirements, as outlined in *Voluntary Certification Program for Fusion-Bonded Epoxy Coating Applicator Plants*, or an equivalent standard.

Coating material shall be epoxy resin powders as specified in ASTM A 775/A 775M-07b. Before using epoxy resin powders that do not meet the above requirements, the Contractor shall have them tested by an approved independent testing laboratory for acceptance by the Engineer.

The Contractor shall supply a representative 1.0 kg sample of the coating material from each batch of material. Such samples shall be packaged in an airtight container and identified by the batch number.

Patching material, which shall be furnished by the epoxy coating manufacturer, shall be as approved by the Engineer, compatible with the coating, and inert in concrete. Such material shall be suitable for repairs that the Contractor or the coating Applicator might make to coated reinforcing bars at the Project site.

Reinforcement steel bars that are to be coated shall be clean and free from rust, scale, oil, grease, and similar contaminants. The surface of the steel bars shall be cleaned by abrasive blast cleaning. The Contractor shall apply the coating to the cleaned surface as soon as possible after cleaning, before any visible oxidation to the surface occurs, and not more than eight hours after cleaning. If reinforcement steel bars to be coated have surface defects that prohibit proper coating, the Engineer shall reject them.

To apply coating to cleaned steel reinforcing bars, the Contractor shall apply the electrostatic spray method and fully cure the bars in accordance with the recommendations of the coating material's manufacturer.

Epoxy coating film shall be cured and/or post cured to a fully cured condition. The epoxy coating Applicator shall check a representative portion of each production lot, using the method most effective for measuring cure, to ensure that the entire production lot of epoxy coating is fully cured.

Binding wire used for tying epoxy-coated steel reinforcement shall be PVC coated wires.

5.3.2.1 Requirements for Coated Bars at Coating Applicator's Plant

Coated bars shall meet the requirements outlined in this section before leaving the coating Applicator's plant.

a. Thickness of Coating

After curing, the coating's film thickness shall be 0.13 to 0.30 mm inclusive. The Applicator shall take at least 15 evenly-spaced measurements along each side of the test bar. No less than 90% of these measurements shall be within the specified limits. Thickness measurements below 0.13mm or more 0.30mm shall be considered cause for rejection of the coated bar. The limits on coating thickness do not apply to repaired areas of damaged coating.

The thickness of the coating film shall be measured in accordance with ASTM G12 - 07, SSPC-PA 2 (Procedure for Determining Conformance to Dry Coating Thickness Requirements) or another equivalent thickness measuring method.

The thickness of the coating film shall be measured on the body of the reinforcing bar between the deformations or ribs on a straight length of bar.

b. Continuity of Coating

After curing, the coating shall be free from holes, voids, cracks, and damaged areas that are discernible to the unaided eye. There shall not be more than two holidays (pinholes that are not discernible to the unaided eye) in any 300 mm of the coated bar, except at the point of manufacturer's bar markings, where holidays may be more frequent. For example, a coated bar that is 12 meters long shall not have more than 80 holidays, excluding the exceptions at point where the bar has a manufacturer's markings.

Patching of holidays is not required unless a bar has more than two holidays per 300 mm. As directed by the Engineer, the Contractor shall either clean and recoat or replace bars with three or more holidays per 300 mm.

To check holidays, the Contractor shall use a 67.5 volt D.C. holiday detector.

c. Adhesion of Coating

For epoxy-coated bars, the Contractor shall evaluate the adhesion and flexibility of the epoxy coating on test bars that have been coated with each production lot. The Contractor shall furnish such test bars in addition to the bars to meet the Contract and the Project requirements. The Contractor shall supply either six meters of test bars or one percent of the total length of all epoxy coated bars for the Project, whichever is less. Test bars may be in one length or multiple lengths, as long as there is one test bar of each size for each production lot.

To evaluate the epoxy-coated test bars, the Contractor shall bend them 120 degrees (after rebound) around a mandrel of a diameter corresponding to size of bar indicated in Table 5-3. Each bend shall be made at a uniform rate and may take as long as 1.5 minutes to complete. The bend test shall be conducted at room temperature (20-30° C.) after the specimen has been exposed to room temperature for a sufficient time to ensure that it has reached thermal equilibrium. No cracking or disbonding of the epoxy coating shall be visible to the unaided eye on the outside radius of the bent bar.

Table 5-3: Mandrel diameters for evaluation of epoxy-coated test bars

Bar Diameter (mm)	Diameter of Mandrel (mm)
10	79
12	95
14	111
16	127
18	143
20	159
22	175
24	191
25	198
26	206
28	222
30	238
32	254
34	270
36	286

Bar Diameter (mm)	Diameter of Mandrel (mm)
38	302
40	318
45	357

Fractures or partial failures of the steel reinforcing bar do not indicate that the coating failed to adhere. Neither do visible cracking or disbonding that is caused by imperfections in the bar surface. In all such cases, however, the Contractor shall test two additional samples. These two samples shall then meet all adhesion test requirements.

Evidence of cracking or disbonding of the coating shall be considered cause of rejection of the coated bars represented by the sample subject to conducting 2 re-tests.

Before shipment from the manufacturer's plant, coated bars shall meet all of the requirements outlined in this section.

5.3.2.2 Inspection

The Owner, the Engineer, or the Engineer's representative reserve the right to access to the epoxy coating Applicator's plant to witness epoxy coating processes for the Project work and to obtain example test bars for any tests.

Unless the Project specifies that they do otherwise, the coating Applicator shall conduct all tests at their plant, before shipment, in such a way as to avoid unnecessary interference with the coating operation.

5.3.2.3 Rejection

The Owner or the Engineer shall reject coated bars that do not meet the requirements of this specification. The coating Applicator has an option to either replace bars with defective coating or strip the coating from such bars of coating, clean them, and coat them again in accordance with the requirements of this specification.

5.3.2.4 Certification

Each shipment of epoxy coated reinforcing steel shall have a Certificate of Compliance that has been signed by the Applicator of the coating. Such documentation shall certify that the epoxy coated reinforcing bars were cleaned, coated, and tested in accordance with the requirements of these specifications and that they conform as appropriate to the requirements of the following standards:

- Standard Specification for Epoxy-Coated Reinforcing Bars: Handling Requirements for Fabrication and Job Site (AASHTO M 317M/M 317-03 (2007))
- Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars (ASTM D3963 / D3963M - 01(2007))
- Standard Specification for Epoxy-Coated Reinforcing Bars: Materials and Coating Requirements (AASHTO M 284M/M 284-09)
- Standard Specification for Epoxy-Coated Steel Reinforcing Bars (ASTM A 775/A 775M-07b)
- Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars (ASTM A934 / A934M - 07)
- *Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement* (ASTM A884 / A884M - 12), Class A (for epoxy-coated wire or welded wire fabric)

The Contractor shall retain such test results for seven years and shall make them available to the Engineer upon request.

Furthermore, the Contractor shall have the coating Applicator regularly and frequently visit the Contractor's steel storage, bending facilities, handling facilities, and construction site to ensure procedural compliance.

5.3.3 Stainless Steel Reinforcing Bars

When specified in the Contract document, deformed or plain stainless steel reinforcing bars shall conform to the requirements outlined in ASTM's Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement (ASTM A955 / A955M - 12e1), AISI 316 or 316LN (depending on bar diameter) or BS 6744:2001+A2:2009 type 316 (S31 or S33). The geometrical classification for the bars shall be Type 2.

Because of the very long term performance expected from the stainless steel reinforcement, the Contractor shall ensure at the time of arrival of the steel on the Project site that it meets all Project specification requirements and that all the factors important for long-term performance are checked carefully. Damaged or contaminated stainless steel shall not be accepted.

All stainless steel reinforcement shall be supplied by a mill approved by the Owner. In addition, fabrication (cutting, bending, shaping, making spirals) of the steel shall be by a firm approved by the Engineer. If the steel has been supplied, or fabricated by a company that is not approved, the steel shall not be acceptable for use.

5.3.3.1 Binding Wire

Binding wire used for tying stainless steel reinforcement shall be 16 or 18 gauge (1.6mm or 1.2mm diameter) stainless steel wire to ASTM A580 / A580M - 12a or BS EN 10088-3:2005.

5.3.3.2 Certificates and Tags

Stainless steel that arrives on the Project site shall be tagged, indicating the mill and Fabricator, stainless steel type and grade, and bar mark number including stainless designation. The steel shall be accompanied by a "mill certificate" verifying that the bars conform to these standard specifications, and the Contract documents where applicable, including the stainless steel type and name; chemical composition; finish; tensile properties and bend test results. The mill certificate shall be checked by the Contractor to make sure it includes all the information required by the Contract documents.

5.3.3.3 Bar Markings and Appearance

The bars shall be marked with a symbol that indicates which mill they are from. The marking shall match the paper work (e.g. tag, mill certificate). Marks shall be made on the steel when it is rolled into bars, so these markings are permanent and are a part of the bar. Bars shall be marked approximately every 1 to 1.5 m, and the marks shall appear as a raised area of steel with a recognizable “picture” such as a letter of the alphabet or a shape like an empty box. Each mill shall have a special mark that only that mill uses; the Contractor shall supply the Owner or the Engineer with this information when they are approved for use.

If the marking on the bar does not match one of the common markings or markings used by currently-approved mills, the steel should not go in the Project work unless it can be confirmed in writing that the steel is from an approved source. This confirmation shall be from the supplier of the steel, not just the Contractor or Fabricator.

The surface “colour” of stainless steel does not always look exactly the same. The surface shall be uniformly silver-grey in colour, but it may be quite bright or it can be dull in appearance, and still be of acceptable quality. However, if the steel does not look grey and looks discoloured or has a “brown” appearance, or has irregularities on the surface, it shall not be acceptable and shall not be included in the Project work.

5.3.3.4 Surface Contamination and Mechanical Defects

Reinforcing stainless steel bars at the time the concrete is placed shall be free of mud, oil and other contaminants that adversely affecting bonding strength, and deposits of iron and non-stainless steel. Fabrication of reinforcing stainless steel bars shall be such that the bar surfaces are not contaminated with deposits of iron and non-stainless steels, or damage due to straightening from coil.

The Contractor shall use the proper bending equipment not to press the steel from the bending equipment or the environment into the stainless steel surface to avoid rust contamination on the bar. If the amount of rust contamination is excessive, or occurs frequently along the length of the bar, the reinforcing bar shall be rejected.

During the pickling process, stainless steel bars could be contaminated due to excessive iron in rinse water. Rinse water shall require periodic changing. If surface has dull appearance, the stainless steel bar was not left in acid bath for the required minimum length of time, and shall be cause of rejection.

Stainless steel with excessive contamination by iron particles due to spray of metal particles from adjacent black bar cutting operation shall not be acceptable.

The selection of the wrong equipment for straightening can damage the bar (flattening the deformations, gouging the surface) and reduce the corrosion resistance of the stainless steel; it shall be cause of rejection.

The reinforcing bar shall be rejected if:

a. any area of contamination of the stainless steel by iron exceeds 100 mm in length;
b. two or more areas of iron contamination greater than 25 mm in length occur along the length of the reinforcing bar;
c. there are frequent small occurrences of rust contamination along the full length of the bar.

If reinforcing bars have been rejected due to excessive iron contamination, it may be possible for the Contractor to have the bar treated to remove the contamination. This can be accomplished by mechanical cleaning with a (stainless steel) wire brush, by use of a polishing machine or even by chemical treatment (pickling) if the contamination is excessive or other approved methods are not successful.

5.3.4 Low-carbon, Chromium, Steel Reinforcing Bars

When specified in the Contract documents, deformed, low carbon, chromium, steel reinforcing bars shall conform to the requirements outlined in ASTM's Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement (ASTM A1035 / A1035M - 11) and AASHTO's Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels (AASHTO MP 18M/MP 18-09 (2010)), with a minimum chromium composition by weight of 9.2%. The steel reinforcing bars shall have the minimum yield strength, as required by the Contract documents, and as measured by using the 0.2% offset test method of ASTM A370 - 12a.

5.3.4.1 Acceptance Requirements

The Manufacturer of deformed low-carbon chromium steel reinforcing bars shall submit to the Owner and the Engineer the following documents for review, evaluation, and acceptance or rejection.

a. Trade license
b. Complete product description and specifications
c. Brief description of manufacturing process
d. Copy of the quality manual (Controlled copy)
e. Description of quality assurance laboratory
f. Evaluation report

g. Test reports by independent testing laboratories
h. Vicinity map and factory layout
i. Valid certification to ISO 9001:2015 (If available)
j. List of personnel and their designation

a. Evaluation Report

The Manufacturer shall submit evaluation report issued by the International Code Council Evaluation Service (ICC-ES), under the 2012 and 2009 International Building Code (IBC), recognizing the deformed low-carbon chromium steel reinforcing bars. The basis of recognition shall be IBC Section 104.11.

b. Quality Management System

The Manufacturer of reinforcing steel bars shall have a Quality Management System that is aligned to the requirements of ISO 9001:2015 standard.

c. Quality Assurance Laboratory

The Manufacturer of reinforcing steel bars shall have a quality assurance laboratory to carry out factory production control testing to ensure that the reinforcing steel bars comply with the requirements of these Standard Specifications.

As a minimum requirement, the laboratory shall have the following testing equipment:

- Calipers and other linear measuring test equipments
- Weighing Scale (with an accuracy of 100 grams)
- Chemical Analyzer
- Tensile Test Equipment
- Bend Test Equipment

5.3.4.2 Identification

Bundled reinforcing bars shall have an attached tag identifying the Manufacturer's name, heat number and roll number. The tag shall also bear the ICC-ES evaluation report number. Individual reinforcing bars shall be identified by a distinguishing set of marks, rolled into the surface of one side of the bar, denoting point of origin, size designation and minimum yield strength designation in accordance with ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010). Illustrations of the bars highlighting the identifying marks shall be submitted for reproduction in the evaluation report.

5.3.4.3 Independent Testing Laboratories

Independent testing laboratories shall comply with the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports, and shall be approved by the Owner. The cost of the independent testing shall be borne by the Manufacturer.

5.3.4.4 Test Reports

Test reports shall comply with AC85. In addition, the test reports shall include sampling procedures, test specimen preparation, test procedures, and results of all tests. Where indicated, photographs shall be included in the report.

5.3.4.5 Product Sampling

Sampling of the reinforcing bars for tests shall comply with Sections 3.1, 3.3 and 3.4 of AC85.

Three sets of samples per size per grade shall be taken randomly. The first set shall be tested in the plant supervised by the Engineer, the second set shall be sent to independent testing laboratory. The third set will be kept by the Manufacturer as reference for future use.

The test sample(s) for independent test shall be identified and signed in the presence of the Engineer and shall be submitted to the approved independent testing laboratory.

Number of samples for testing shall be at least 10 pieces by one meter length per size per grade.

5.3.4.6 Product Evaluation

Independent test shall only be conducted if the result of the in-plant test shows satisfactory result. If the result of the test conducted by the independent testing laboratory shows non- conformance, the retest shall be carried out on the reference sample kept by the Manufacturer or on new samples collected by the Owner/Engineer, on which full testing shall be carried out, if necessary. If the retest passed, the initial product assessment is considered conforming to product specification, otherwise the product shall be rejected.

5.3.4.7 Mechanical Properties

Testing for tensile and bending properties of reinforcing bars shall be in accordance with ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010). Each reinforcing bar size shall be tested.

Conditions of acceptance are as set forth in ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).

5.3.4.8 Dimensions

The following dimensions shall be determined and reported by the testing laboratory for each reinforcing bar size: weight, kg/m; diameter, mm; cross-sectional area, mm^2; perimeter, mm; deformation pattern, spacing and height, mm; and finish.

Deformations shall be determined based on procedures in Section 8 of ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).

Conditions of acceptance are as noted in ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).

5.3.4.9 Chemical Composition

The chemical analysis of a heat shall be determined in accordance with Section 7 of ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).

Conditions of Acceptance are as noted in Section 7 of ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).

5.3.4.10 Quality Control

a. The reinforcing bars shall be produced under a quality control program demonstrating compliance with ASTM A1035 / A1035M – 11 or AASHTO MP 18M/MP 18-09 (2010).
b. Mechanical splices shall be produced under a quality control program in accordance with ICC-ES Acceptance Criteria (AC133).
c. Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted for each facility manufacturing or labelling products that are recognized in the ICC-ES evaluation report.
d. A qualifying inspection shall be conducted at each manufacturing facility in accordance with the requirements of the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).
e. An annual inspection shall be conducted at each manufacturing facility in accordance with AC304.
f. Special inspections for reinforcing bars and mechanical connectors shall comply with IBC Section 1704.4. The evaluation report shall describe the special inspector's duties.

5.3.5 Bar Lists and Bending Diagrams

When the Contract documents do not include detailed bar lists and bending diagrams, the Contractor shall provide such lists and diagrams to the Engineer for review and approval. Fabrication of material shall not begin until the Engineer has approved such lists. The Engineer's approval of bar lists and bending diagrams, however, shall in no way relieve the Contractor of responsibility for the correctness of such lists and diagrams. The Contractor shall bear any expenses incurred for the revision of material furnished in accordance with such lists and diagrams to make them comply with design drawings.

5.4 Fabrication

Fabrication methods for steel to be used on the Project shall conform to the standards and specifications outlined in this section.

5.4.1 Cutting and Bending

Bar reinforcement shall be cut and bent to the shapes shown in the Contract documents. Tolerances shall be in accordance with the standards of the American Concrete Institute (ACI) Detailing Manual, as documented in the details and detailing of concrete reinforcement (ACI 315-99). All bars shall be bent cold in accordance with BS 8666:2005 unless otherwise permitted.

All cutting and bending of reinforcement bars shall be done by competent workmen using equipment that has been approved by the Engineer. Cutting and bending by the application of heat is not allowed (flame cutting). Unless shown otherwise on the Contract plans or unless written approval is obtained from the Engineer, fabricators shall cut and bend all reinforcement bars in an on-site fabrication shop. Bars that will be partially embedded in concrete shall not be bent by fabricators in the field, except as specified in the Contract documents.

Unless otherwise provided on the plans or with written authorization from the Engineer, the minimum pin diameter (D) around which a bar (with a diameter d) may be bent shall be as follows:

- D = 6d for 5 to 22 mm bar sizes
- D = 8d for 24 to 28 mm bar sizes

If coated reinforcement is specified, bent reinforcement steel bars shall be coated after bending. On-site cut and bent of epoxy-coated reinforcing bars shall not be permitted, it shall be in the fabricator's shop. The Engineer shall reject any steel with visible cracks in the coating on the outside of a bend or damage to coating that causes debonding of the coating. Fabricators may shear or saw bars that are shorter than 7.6 meters after coating, as long as resulting damage to the coating does not extend more than 12 mm back and fabricators patch the cut ends before any visible oxidation appears. The Owner and the Engineer do not permit flame cutting.

Deformed low-carbon chromium steel reinforcing bars shall be accurately fabricated to the dimensions shown in the Contract documents, within the tolerances shown in the ACI 315-99 or CRSI Manual of Standard Practice. Bends shall conform to the dimensions and details in accordance with ACI 315-99, ACI SP-66(04) and/or CRSI Manual of Standard Practice, unless otherwise shown in the Contract documents. Bars shall be bent cold, and shall not be bent or straightened in a manner that will injure the material. Heating of the bars shall not be permitted. Bar cutting shall be accomplished by shearing or with a fluid-cooled saw, and flame cutting shall not be permitted. Reinforcing bars partially embedded in concrete shall not be field bent. Fabricated bent bars shall not be straightened or rebent in the field.

5.4.2 Hooks and Bend Dimensions

Hook dimensions and bend diameters on the inside of each bar shall be as shown in the Contract documents. When the Contract documents do not show the dimensions of hooks or the diameter of bends, such measurements shall meet the specifications of Section 5.4.1 of these standard specifications, Section 5.10.2 of the latest AASHTO LRFD Bridge Design Specifications or ACI's Building Code Requirements for Structural Concrete and Commentary (ACI 318-08).

5.4.3 Mill Test Reports

When uncoated steel reinforcing bars are to be spliced by welding or when otherwise requested, the Contractor shall provide a certified copy of the mill test report showing physical and chemical analysis for each heat or lot of reinforcing bars to the Engineer. Bars that conform to ASTM's Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement (ASTM A706 / A706M - 09b) are exempt from this requirement. However, welding of steel reinforcement shall be upon a specific approval of the Engineer.

For deformed low-carbon chromium steel reinforcing bars, a certified copy of a mill certification report showing physical and chemical analysis for each heat of reinforcing bars shall be provided to the Engineer upon request.

5.4.4 Identification

The Contractor shall ship reinforcement bars in standard bundles, after tagging and marking the bars in accordance with Concrete Reinforcing Steel Institute (CRSI) requirements, as outlined in their Manual of Standard Practice.

If the coating Applicator is also the Supplier of the reinforced bars, each lot of bars delivered to the Project site shall have both a tag for the coating Applicator and the original tag of the reinforcing bars' manufacturer or fabricator.

5.5 Application Methods

5.5.1 Handling and Storing Reinforcement Steel

5.5.1.1 Handling Uncoated Bars

Uncoated reinforcement steel shall be stored above the ground on platforms, skids, or other supports and shall be protected from conditions that can cause mechanical damage, surface deterioration, and rust. When placed into a construction work, reinforcement steel shall be free from dirt, loose rust, loose scale, mortar, paint, grease, oil, and any non-metallic coatings that can reduce bond. Reinforcement steel shall be free from defects such as cracks and laminations. The Engineer will not reject reinforcement steel with discoloration as long as the minimum dimensions, cross-sectional area, and tensile properties of a hand wire-brushed specimen meet the physical requirements for the specified size and grade of steel.

5.5.1.2 Handling Epoxy-coated Bars

Epoxy-coated reinforcing steel shall be handled and stored by methods that shall not damage the epoxy coating. All systems for handling epoxy-coated reinforcement shall have adequately padded contact areas. All bundling bands shall be padded and all bundles shall be lifted with a strong back, multiple supports, or Platform Bridge so as to prevent bar-to-bar or wire-to-wire abrasion from sags in the bundles. Bars or bundles shall not be dropped or dragged. Epoxy-coated reinforcing steel shall be transported and stored on wooden or padded supports.

The Contractor shall immediately cover bundled epoxy-coated reinforcing steel with dense black plastic or other suitable lightproof material to protect the steel from sunlight, salt spray, and weather exposure. The Contractor shall ensure that air can circulate sufficiently around the protected reinforcement to minimize condensation under the protective covering.

Bars shall not be dragged out from the bundles. Rather, the Contractor shall lift bars vertically to avoid damaging the coating on deformations. The Contractor shall ensure that each bar is properly supported as it is fed into the cutting or bending machine. An ideal method to provide this support involves threading a PVC pipe onto a rebar frame to function as a soft roller. The Contractor shall handle bars carefully at all times to avoid dropping or otherwise damaging them with tools, heavy footwear, or wheelbarrows.

5.5.2 Placing and Fastening Reinforcement Steel

The Contractor shall accurately place reinforcement steel shall as shown in the Contract documents, firmly holding bars in position during the placement and consolidation of concrete. Bars shall be tied at all intersections around the perimeter of each mat and elsewhere at centres of no less than 600 mm or at every intersection, whichever is greater. Bundled bars shall be tied together at centres of no more than 1.8 meters. Tie wire and metals clips used to fasten epoxy-coated reinforcement bars shall be PVC coated wires. If uncoated welded wire fabric is shipped in rolls, the Contractor shall straighten it into flat sheets before placing it. Unless the Engineer provides written approval for such activity, the Contractor shall not weld crossing bars (a technique called tack welding) to assemble reinforcement.

All chairs and other devices used in supporting, securing, or fastening epoxy coated reinforcement steel shall be made of or coated with a dielectric material. The specific hardware that the Contractor proposes shall be approved by the Engineer.

5.5.2.1 Support Systems for Reinforcing Steel

The Contractor shall use precast concrete blocks, wire bar supports, supplementary bars, or other approved devices to support reinforcing steel bars in their proper positions. Such reinforcing supports or devices shall be of such height and placed at sufficiently frequent intervals to maintain the distance between the reinforcing steel and the formed surface or the top surface of deck slabs within 6 mm of that indicated in the Contract documents.

Platforms that support workers and equipment during concrete placement shall be supported directly on the forms and not on the reinforcing steel.

5.5.2.2 Precast Concrete Blocks

Precast concrete blocks shall have a compressive strength not less than that of the concrete in which they are to be embedded. Block faces that contact forms for exposed surfaces shall not exceed 50 mm × 50 mm and shall have a colour and texture that matches the concrete surface. When used on vertical or sloping surfaces, each such block shall have an embedded wire to secure the block to the reinforcing steel. Such concrete blocks, when used in slabs, shall have a tie wire, unless the weight of the reinforcement is sufficient to firmly hold the blocks in place, in which a groove in the top of the block is sufficient. For epoxy-coated bars, such tie wires shall be PVC coated wires.

5.5.2.3 Wire Bar Supports

Wire bar supports, such as ferrous metal chairs and bolsters, shall conform to industry practice as described in the CRSI’s Manual of Standard Practice. Such chairs or bolsters which bear against the forms for exposed surfaces shall be either Class 1-Maximum Protection (Plastic Protected) or Class 2, Type B-Moderate Protection (Stainless Steel Tipped) for which the stainless steel is type 430 as defined in ASTM’s Standard Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging (ASTM A493 - 09). All wire bar supports and bar clips for epoxy-coated reinforcement shall be PVC coated wires.

5.5.2.4 Adjustments

The Contractor shall adjust or relocate all non-prestressed reinforcement bars that support post-tensioned concrete during the installation of prestressing ducts or tendons, as required to provide planned clearances for the prestressing tendons, anchorages, and stressing equipment and as approved by the Engineer.

5.5.2.5 Repairing Damaged Epoxy Coating

All reinforcing bars that require epoxy coating shall comply with the specifications in Section 5.3.2, Coated Reinforcement. In addition, the Contractor shall repair all damaged coating on epoxy-coated reinforcing steel that occurs during shipment, handling, and placement. If damage to any 300 mm segment of rebar exceeds one percent of that total area, the Contractor shall remove and replace that bar with an appropriate and acceptably undamaged epoxy-coated replacement bar. Therefore, the Contractor shall only repair bars with damaged areas that do not exceed more than one percent of any 300 mm segment. This restriction to bar repair does not include sheared or cut ends that are coated with patching material. Repairs to any single rebar throughout all of the Project's work stages shall not exceed five percent of the total surface area of any bar; no single bar shall have patching material on a greater area than five percent of its total surface. Patching material shall be pre-qualified as required for the coating material and shall be either identified on the container as meeting the following requirements:

- Annex A1 of the Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars (AASHTO M 317M/M 317-03 (2007))
- Annex A1 of the Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars (ASTM D3963 / D3963M - 01(2007))
- Standard Specification for Epoxy-Coated Reinforcing Bars: Materials and Coating Requirements (AASHTO M 284M/M 284-09)
- Standard Specification for Epoxy-Coated Steel Reinforcing Bars (ASTM A 775/A 775M-07b)
- Annex A1 of the Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars (ASTM A934 / A934M - 07)

When submitting patching material to the Engineer for pre-qualification, the Contractor shall also provide a Certificate of Compliance that certifies that the material meets the requirements of the appropriate standards. The Contractor shall patch damaged areas of rebar in accordance with the patching material manufacturer's recommendations. The Contractor shall also allow all patches to cure fully before placing concrete over the coated bars.

Before the Contractor lowers reinforcement steel bars into place and places concrete, the Engineer shall inspect coated bars for damage to their epoxy coating. Using the specified patching and repair materials, the Contractor shall repair any bars with sheared ends, scars, or minor defects.

If the bent portion of a fabricated bar has only hairline cracking and its coating has no discernible loss of bond (loss of adhesion), repairs are not mandatory. When the bent portion of a bar has disbondment, however, the Contractor shall remove the disbonded coating, clean the affected areas, and repair the bar with patching material.

In addition to meeting the requirements outlined above, the Contractor shall, as approved by the Engineer, suitably wrap and protect any partially embedded bars that will be left temporarily exposed to prevent mechanical or environmental damage to the bars' coating before they are fully embedded in concrete. Dowels shall project a minimum of 40 bar diameter unless otherwise indicated in the Contract plans.

5.5.3 Minimum Test Procurement

The Contractor shall take one sample of every 100 tons or a fracture of 100 tons of reinforcing bars of each size and test them for the following properties:

- Tensile strength
- Yield point
- Elongation after fracture
- Behaviour in the bend test
- Behaviour in the re-bend test
- Deviation from cross section
- Bond test

- Chemical composition
- Thickness of coating
- Continuity of coating
- Adhesion of coating

Testing shall comply with the requirements outlined in AASHTO's *Standard Method of Test for Tension Testing of Metallic Material*s (AASHTO T 68M/T68-09) or ASTM's *Standard Test Methods for Tension Testing of Metallic Materials* (ASTM E8 / E8M - 11). For bars with areas that vary from the nominal bar area by six percent or more, testers shall use the measured bar area to calculate unit stress.

All the testing shall be performed at no cost to the Owner and is solely borne by the Contractor.

If a reinforcing steel sample under test fails to meet the specification requirements at any time, if the Engineer considers that the samples presented for test are not truly representative, or if reinforcing steel that was not approved have been used on the Project works, the Engineer may instruct the Contractor to break out and completely remove all such constructed sections that may include such suspect reinforcement steel.

5.5.4 Splicing of Bars

The Contractor shall furnish all reinforcement bars in their full lengths, as specified in the Contract documents, unless otherwise permitted. Except for splices that are specified in the Contract documents and splices for bars with diameters of 16 mm diameter or smaller, the Contractor shall not splice bars without written approval from the Engineer. When the Engineer permits splices, the Contractor shall stagger them as far as possible.

5.5.4.1 Lap Splices

Lap splices shall be of the lengths specified in the Contract documents. If the Contract documents do not specify lap splice lengths, the Contractor shall adhere to Sections 5.11.5.3.1 and 5.11.5.5.1 of the AASHTO LRFD Bridge Design Specifications or approved directions from the Engineer.

In lap splices, the Contractor shall place and tie bars in a manner that maintains the minimum distance from the surface of the concrete, as specified in the Contract documents. The Contractor shall not use lap splices for bars with diameters from 40 mm to 50 mm, except as provided in either Section 5.11.5.2.1 or Section 5.11.5.5.1 of the *AASHTO LRFD Bridge Design Specifications*.

Lap splices for coated bars shall match those for uncoated bars except that tension lap lengths for coated bars shall be 50% longer than those for uncoated bars or as required by the *AASHTO LRFD Bridge Design Specifications*.

5.5.4.2 Welded Splices

The Contractor shall only use welded splices for reinforcing bars if the Contract details such work or if the Engineer provides written authorization. Welding shall conform to the Contract documents and American Welding Society (AWS) specifications as outlined in Section 1.4 of the Structural Welding Code - Reinforcing Steel (AWS - D1.4/D1.4M:2011) or BS EN 1011-1:2009 and BS EN 1011-2:2001. Only approved welders shall be employed. Tensile testing is required for all welded splices and must be performed in accordance with ASTM's Standard Test Methods and Definitions for Mechanical Testing of Steel Products (ASTM A370 - 12a) and California Test 670 (Method of Tests for Mechanical and Welded Reinforcing Steel Splices).

The Contractor shall not use welded splices on epoxy-coated reinforcing bars. To avoid heating their coating, the Contractor shall not perform welding in close proximity to epoxy-coated bars.

The Contractor shall not use welded splices on all stainless steel reinforcing bars because welding may detrimentally affect the physical characteristics of the material.

The Contractor shall not use welded splices for deformed low-carbon chromium steel reinforcing bars that conform to ASTM's *Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement (*ASTM A1035 / A1035M - 11) or AASHTO's *Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels* (AASHTO MP 18M/MP 18-09 (2010)).

5.5.4.3 Mechanical Splices

The Contractor shall use mechanical splices only if the Contract documents specify such work or if the Engineer provides written authorization. Such mechanical splices shall develop in tension or compression, as required, at least one hundred and twenty-five percent (125%) of the specified yield strength of the bar being spliced.

When requested by the Engineer, the Contractor shall remove as many as two field splices out of each 100 placed in the work, chosen at random by the Engineer, for testing by the Engineer to verify that they have 125% of the yield strength specified for the bars being spliced. Slip test is also required for all mechanical splices and must be performed in accordance with California Test 670 (*Method of Tests for Mechanical and Welded Reinforcing Steel Splices*).

Mechanical connectors for deformed low-carbon chromium steel reinforcing bars shall comply with Section 12.14.3 of ACI 318 and shall be either Type 1 or Type 2 in compliance with the ICC-ES *Acceptance Criteria for Mechanical Connector Systems for Steel Reinforcing Bars* (AC133), except the testing shall demonstrate 125% of the full tensile strength and full elongation of the actual tested reinforcing bars at failure. Verification of compliance, in the form of test results, shall be provided.

5.5.4.4 Splicing of Welded Wire Fabric

Sheets of welded wire fabric shall be spliced by overlapping each other sufficiently to maintain a uniform strength and shall be securely fastened at the ends and edges. The edge lap shall not be less than 50 mm more than the width of a single mesh.

5.5.5 Substitutions

The Contractor may substitute different size reinforcing bars only when so authorized by the Engineer. Substituted bars shall have an area equivalent to the design area or larger, and shall comply with the specifications outlined in Section 5.7.3.4 of the AASHTO LRFD Bridge Design Specifications.

When substituting bars of different sizes, the total number of substitute bars may also be different. In such cases, although the number of bars may differ, the substitute bars must provide the same total area per unit spacing. Substitution of millimetre bars for bar sizes not readily available from the Contractor's source may be made on the same basis. All bar substitutions shall be approved in writing by the Engineer. Table 5-4 shows the minimum size, weight, and area required for reinforcing bars, as indicated on the Contract plans.

5.5.6 Calculated Weights

To compute the weight (mass) of reinforcing bars and wire reinforcement, the Contractor shall refer to Table 5-4 and Table 5-5.

Table 5-4: Reinforcing bars - nominal weights and areas

Bar Designation	Nominal Diameter Mm	Nominal Area mm^2	Nominal Weight kg/m
Dia. 6	6	28	0.222
Dia. 8	8	50	0.395

Bar Designation	Nominal Diameter Mm	Nominal Area mm^2	Nominal Weight kg/m
Dia. 10	10	79	0.617
Dia. 12	12	113	0.888
Dia. 14	14	154	1.21
Dia. 16	16	201	1.58
Dia. 18	18	254	2.00
Dia. 20	20	314	2.47
Dia. 22	22	380	2.98
Dia. 25	25	491	3.85
Dia. 28	28	616	4.83
Dia. 32	32	804	6.31
Dia. 36	36	1018	7.99
Dia. 40	40	1257	9.87
Dia. 45	45	1590	12.49
Dia. 50	50	1963	15.4

Table 5-5: Standard wire reinforcement - nominal weights and areas

Wire designation	Nominal diameter mm	Nominal area mm^2	Nominal weight kg/m	Area (mm^2/m) Center-to-center spacing, mm								
				50	75	100	150	200	250	300	350	400
MW13	4.0	12.6	0.099	252	168	126	84	63	50	42	36	32
MW16	4.5	15.9	0.125	318	212	159	106	80	64	53	45	40
MW20	5.0	19.6	0.154	392	261	196	131	98	78	65	56	49
MW24	5.5	23.8	0.187	476	317	238	159	119	95	79	68	60
MW28	6.0	28.3	0.222	566	377	283	189	142	113	94	81	71
MW33	6.5	33.2	0.260	664	443	332	221	166	133	111	95	83
MW38	7.0	38.5	0.302	770	513	385	257	193	154	128	110	96

Wire designation	Nominal diameter mm	Nominal area mm²	Nominal weight kg/m	Area (mm²/m) Center-to-center spacing, mm								
				50	75	100	150	200	250	300	350	400
MW44	7.5	44.2	0.347	884	589	442	295	221	177	147	126	111
MW50	8.0	50.3	0.396	1006	671	503	335	252	201	168	144	126
MW57	8.5	56.7	0.445	1134	756	567	378	284	227	189	162	142
MW64	9.0	63.6	0.499	1272	848	636	424	318	254	212	182	159
MW71	9.5	70.9	0.556	1418	945	709	473	355	284	236	203	177
MW78	10.0	78.5	0.617	1570	1047	785	523	393	314	262	224	196
MW87	10.5	86.6	0.680	1732	1155	866	577	433	346	289	247	217
MW95	11.0	95.0	0.746	1900	1267	950	633	475	380	317	271	238
MW104	11.5	103.9	0.815	2078	1385	1039	693	520	416	346	297	260
MW113	12.0	113.1	0.888	2262	1508	1131	754	566	452	377	323	283

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STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 6 - MASONRY

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 6: Masonry

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6 MASONRY

This work shall consist of furnishing, placing, and constructing concrete blocks, brick masonry, and rock masonry in accordance with these specifications and conforming to the dimensions shown in the Contract documents.

6.1 Reference Standards and Codes

Standards and codes for masonry works shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO American Association of State Highway and Transportation Officials - Roadside Design Guide;

AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing;

ASTM American Society for Testing and Materials;

FHWA Federal Highway Administration, Eastern Federal Lands Highway Divison, 1996;

BSI British Standards Institution;

BS EN European Standards.

Table 6-1 and Table 6-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for masonry works. It also includes designations and titles.

Table 6-1: Designations and titles for AASHTO and ASTM standards that apply to masonry works

AASHTO DESIGNATION	ASTM DESIGNATION	TITLE
AASHTO M 114-07	ASTM C62 - 12	*Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale).*
	ASTM C55 - 11	*Standard Specification for Concrete Building Brick.*
	ASTM C90 - 11b	*Standard Specification for Loadbearing Concrete Masonry Units.*
	ASTM C139 - 10	*Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes.*
	ASTM C780 - 11	*Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.*
AASHTO T 22-10		*Compressive Strength of Cylindrical Concrete Specimens.*
	ASTM C39 / C39M - 11	*Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.*
	ASTM C270 - 12	*Standard Specification for Mortar for Unit Masonry.*
	ASTM A884 / A884M - 06	*Standard Specification for Epoxy Coated Steel Wire and Welded Wire Reinforcement.*

Table 6-2: Designations and titles for BS and BS EN standards that apply to masonry works

BS Designation	BS EN Designation	Title
	BS EN 1015-10:1999	*Methods of test for mortar for masonry. Determination of dry bulk density of hardened mortar.*

6.2 Concrete Block and Brick Masonry

6.2.1 Description

Concrete block and brick masonry shall consist of concrete blocks or brick laid in cement mortar, and may be unreinforced or reinforced with steel. Block and brick pavements are not included under this designation.

6.2.2 Materials

6.2.2.1 Concrete Block

Concrete blocks shall be hard, durable, and clean with sharp, well-defined edges, and free from any cracks, flaws, or other defects. Unless otherwise specified in the Contract Documents, their dimensions shall be 400 mm long by 200 mm wide by 200 mm tall, or such other dimensions shall be approved by the Engineer.

Unless otherwise specified in the Contract Documents or approved in writing by the Engineer, all concrete block for masonry construction shall be Type I moisture controlled units (Grade N-I) that meet the requirements of ASTM C90 – 11b. The value of f'_m (specified compressive strength of masonry) shall be as shown in the Contract Documents and shall be verified by means of prism testing. Prism shall be a sample assembly of masonry units, mortar joints and grout.

Concrete block units should be protected from rain or other moisture during storage on or off the job site to ensure that they will meet the Type I moisture requirements at the time they are placed during construction.

6.2.2.2 Brick

Brick for masonry construction shall conform to the Specification for Building Brick (solid masonry units made from clay or shale) AASHTO M 114 -07 (ASTM C62 - 12), Concrete Building Brick (ASTM C55 - 11), or Solid Load-Bearing Concrete Masonry Units (ASTM C90 – 11b). Type and grade of the brick to be furnished shall be as specified in the Contract Documents.

Bricks shall have a fine-grained, uniform, and dense structure, free from lumps of lime, laminations, cracks, checks, soluble salts, or other defects that may in any way impair their strength, durability, appearance, or usefulness for the purpose intended. Bricks shall emit a clear, metallic ring when struck with a hammer.

6.2.2.3 Concrete Masonry Units

Concrete masonry units for use in manholes, inlets, and similar structures shall meet the requirements of ASTM C139 - 10.

6.2.2.4 Reinforcing Steel

Reinforcing steel shall be of the strength, spacing, dimensions and type as shown in the Contract plans. Reinforcing steel used in the construction of concrete block or brick masonry structures shall conform to the applicable requirements for reinforcing in Chapter 5, Reinforcing Steel, of these standard specifications.

6.2.2.5 Mortar and Grout

Mortar and grout ingredients and mix design shall meet the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works, of these standard specifications, for the class and application types as otherwise specified in these Standard Specifications, as shown on the Contract plans or as included in the Particular Specifications.

a. Sampling and Testing

Grout and mortar testing shall meet the sampling and testing requirements specified in Article 4.3.10.4 of Chapter 4, Concrete Works, of these standard specifications, and as may be modified by the requirements below, if so directed by the Engineer.

1. Mortar

Unless otherwise specified in the Particular Specifications or shown on the Contract plans, mortar shall have a minimum 28-day compressive strength of 12.5 mPa, based on the average of three specimens tested in accordance with the requirements of ASTM C780 - 11. Field samples shall be obtained using the following procedure:

i. Spread 12.5 mm or the thickness of the mortar joint of mortar on masonry units.

ii. After one minute, remove the mortar and compress it into a 50 mm by 100 mm cylinder (or equivalent cube as per test procedure per BS EN 1015-10:1999) in two layers using the flat end of a rod or fingers, being sure to see that the mold is solidly filled.

iii. Lightly tap the cylinder immediately, and maintain it in a damp condition.

iv. After 48 hours, remove the mold and store it in clean water until testing.

2. Grout

When required by the Contract documents or requested by the Engineer, the Contractor shall manufacture grout prisms for testing. Prisms shall be manufactured at the site during construction using the following procedure:

i. Place masonry units that have the same moisture condition as those already placed on a non-absorptive base to form a void for a square prism, with a height twice the side of the masonry unit and a minimum side of 75 mm.

ii. Line the side faces of the prism with a permeable paper or porous separator to allow water passage through the liner into the masonry units.

iii. Fill the prism with a fully-representative grout sample in two layers. Puddle each layer to eliminate air voids.

iv. Level off the specimen and maintain it in a damp condition.

v. Remove the prisms from the masonry units after 48 hours and deliver them to the Engineer.

Grout prisms shall be tested in accordance with the provisions of AASHTO T 22 - 10 (ASTM C39/C39M - 11). Grout shall have attained a compressive strength of 13.8 MPa at 28 days, unless otherwise specified in the Contract Documents.

6.2.3 Construction

6.2.3.1 General

a. Brick Masonry

Foundations shall be constructed firm and dry. All brick shall be damp at the time of laying. Bricks shall be laid in courses in full, close, uniform joints of mortar. Adjoining courses shall break joints by one-half length, as near as practicable. Courses shall be level in all places, except where otherwise directed. All exposed surfaces shall be smooth and clean, and the tie joint shall not exceed 12.5 mm in width. Broken or chipped bricks shall not be used in the faces of the masonry. Joints shall be cleaned and pointed before the mortar sets. Exposed surfaces of the bricks shall not be smeared with mortar forced out of the joints or that used in pointing, but shall be kept clean and free from mortar stains. For straight masonry walls, at least one course in seven shall be a header course.

b. Concrete Block Masonry

When shown on the Contract plans and/or in the Particular Specifications, masonry walls may be constructed of hollow concrete blocks instead of bricks. Applicable construction details shall be the same as for brick masonry.

c. Manholes, Inlets, and Catch Basins

Brick masonry for manholes, inlets, and catch basins shall conform to details shown on the Contract plans. Construction requirements shall be as specified in Section 12.4 of Chapter 12, Storm Water Drainage, of these standard specifications. Where shown on the Contract plans, a plaster coat shall be applied to the faces of these and similar structures. Mortar for this coat shall be of the same mix as used in laying the brick, and the coat shall be no less than 6 mm thick. Before applying the plaster coat, the brick shall be thoroughly wetted and the surface allowed to dry sufficiently to ensure a proper bond of the plaster coat.

Full mortar beds shall be provided for setting castings required by the Contract plans. Castings shall be set carefully to the required elevations.

6.2.3.2 Mixing Mortar

Proportions of materials, water retention, workability, and related requirements shall be in such a manner as to produce the specified strength. Before commencing work, the Contractor shall have the mortar mix approved by the Engineer. Mortar mix and mixing requirements shall meet the requirements included in Article 4.3.10.4 of Chapter 4, Concrete Works, of these standard specifications, and as specified herein.

Mortar shall be hand- or machine-mixed, as may be required by the Engineer. In the preparation of hand-mixed mortar, the sand and cement shall be thoroughly mixed together in a clean, tight mortar box until the mixture is of uniform color, after which clean water shall be added in such quantity as to form a stiff plastic mass. Machine-mixed mortar shall be prepared in an approved mixer and shall not be mixed less than three minutes or more than 10 minutes. Mortar shall be used within 1.5 hours after mixing and before final setting begins. Re-tempering of mortar shall be performed as necessary to maintain proper consistency during placement.

6.2.3.3 Laying Block and Brick

Blocks or bricks shall be laid in such a manner as will thoroughly bond them into the mortar by means of the “shove-joint” method; “buttered” or plastered joints shall not be permitted. All clay or shale brick shall be thoroughly saturated with water before being laid. Dampening of concrete masonry units before or during construction shall not be permitted unless approved by the Engineer. Headers and stretchers shall be arranged to thoroughly bond the mass, and unless otherwise specified, alternate headers and stretchers shall be used with consecutive courses breaking joints. Other types of bonding, as for ornamental work, shall be as may be specified in the Particular Specifications or as shown on the Contract plans.

All joints shall be completely filled with mortar. They shall not be less than 6 mm wide and not more than 19 mm thick, with the thickness uniform throughout. All joints shall be finished properly as the work progresses, using the “weather” joint. Exposed faces shall be neatly struck.

No spalls or bats shall be used except for shaping around irregular openings or when unavoidable to finish out a course, in which case full bricks shall be placed at the corners, with the bats placed in the interior of the course.

Each masonry unit shall be adjusted to its final position while the mortar is still soft and plastic. Units that are disturbed after the mortar has stiffened shall be removed and laid again in fresh mortar.

Vertical cells to be filled with grout shall be aligned to provide a continuous unobstructed opening.

Piers and walls may be built of solid brick work, or may consist of a brick or block shell backed with concrete or other suitable material as shown on the Contract plans. All details of the construction shall be in accordance with approved practices and to the satisfaction of the Engineer.

6.2.3.4 Placement of Reinforcement

Prior to and during grouting, the reinforcing steel shall be securely held in position at the top and bottom and at intermediate points not exceeding 200 bar diameters or 3 meters apart. Bars shall be maintained clear of the cell walls and within ±12.5 mm of their planned position transverse to the wall and within ±50 mm of their planned position longitudinal to the wall.

6.2.3.5 Grouting of Voids

Grouted masonry shall be constructed in such a manner that all elements of the masonry acts together as one structural element.

Prior to grouting, the grout space shall be clean so that all spaces to be filled with grout do not contain mortar projections greater than 12.5 mm, mortar droppings, or other foreign material. Grout shall be placed so that all spaces to be grouted do not contain voids.

Grout materials and water content shall be controlled to provide adequate fluidity for placement without segregation.

Size and height limitations of the grout space or cell on the average shall not be less than as shown in Table 6-3. Higher grout pours or smaller cavity widths or cell sizes than shown in Table 6-3 may be used when approved by the Engineer, if it is demonstrated that grout spaces are properly filled.

When required by Table 6-3, cleanouts shall be provided in the bottom course at every vertical bar, but shall not be spaced more than 813 mm on center for solidly grouted masonry. Cleanouts shall be of sufficient size to allow removal of debris.

Units may be laid to the full height of the grout pour, and grout shall be placed in a continuous pour in grout lifts not exceeding 1.8 meters. If construction joints are used in columns of grout, they shall be located at least 38 mm below the level of a mortar bed joint.

Segregation of the grout materials and damage to the masonry shall be avoided during the grouting process.

Grout shall be consolidated before the loss of plasticity in a manner to fill the grout space. Grout pours greater than 300 mm in height shall be mechanically reconsolidated to minimize voids due to water loss. Grout not mechanically vibrated shall be puddled.

In non-structural elements, mortar of pouring consistency may be substituted for grout when the masonry is constructed and grouted in pours of 300 mm or less.

Vertical barriers of masonry may be built across the grout space. Grouting of any section of wall between barriers shall be completed in one day with no interruption longer than one hour.

Table 6-3: Grouting limitations

		Least Clear Dimensions		
Grout Type	**Grout Pour Maximum Height metre**	**Width of Grout Space, mm**	**Cell Dimensions, mm × mm**	**Cleanouts Required**
Fine	0.3	19	38 × 50	No

		Least Clear Dimensions		
Grout Type	**Grout Pour Maximum Height metre**	**Width of Grout Space, mm**	**Cell Dimensions, mm × mm**	**Cleanouts Required**
Fine	1.5	38	38 × 50	No
Fine	2.4	38	38 × 76	Yes
Fine	3.6	38	44 × 76	Yes
Fine	7.3	50	76 × 76	Yes
Coarse	0.3	38	38 × 76	No
Coarse	1.5	50	63 × 76	No
Coarse	2.4	50	76 × 76	Yes
Coarse	3.6	63	76 × 76	Yes
Coarse	7.3	76	76 × 101	Yes

6.2.3.6 Copings, Bridge Seats, and Backwalls

In general, tops of retaining walls, abutment wingwalls, and similarly exposed brick or block work shall be provided, with either a stone or concrete coping as specified in the Contract documents. Underside of coping shall have a batter or drip bead at least 25 mm beyond the face of the block or brick work wall. Coping on an abutment backwall shall commonly have no projection beyond its bridge seat face. Unless otherwise specified, when concrete is used, it shall conform to the requirements for Class C35/20 concrete specified in Section 4.3.9 and other applicable requirements of Chapter 4, Concrete works. For thin copings, mortar of the same proportions as used for laying the block or brick may be used to produce precast sections no less than 0.9 m or more than 1.5 m in length. No coping shall be less than 100 mm thick.

Copings of piers and abutment bridge seats may be of ashlar stone work or of concrete conforming to the requirements of Articles 6.2.3.7 and 6.2.3.8 respectively. Unless otherwise shown in the Contract documents, concrete shall be used.

6.2.3.7 Ashlar Stone Copings

Ashlar masonry is composed of rectangular stones laid with mortar in horizontal courses. Ashlar masonry shall consist of first-class cut stone masonry laid in regular courses, and shall include all work in which the individual stones (as distinguished from rubble masonry) are dressed or tooled to exact dimensions.

Stone for ashlar masonry shall be reasonably fine grained and uniform in color. Preferably, stone shall be from a quarry, the product of which is known to be of satisfactory quality. Stone shall be of such character that it can be brought to such lines and surfaces, whether curved or plane, as may be required. Any stone having defects that have been repaired with cement or other materials shall be rejected.

Each stone shall be free from depressions and projections that might weaken or prevent it from being properly bedded, and shall be of a shape to meet the requirements for the class of masonry specified.

Stones for copings of wall, pier, and abutment bridge seats shall be carefully selected and be fully-dimensioned stones. On piers, not more than two stones shall be used to make up the entire width of coping. Copings of abutment bridge seats shall be of sufficient width to extend at least 100 mm under the backwall. Each step forming the coping of a wingwall shall be formed by a single stone that shall overlap the stone forming the step immediately below it by at least 300 mm.

Tops of copings shall be given a bevel cut at least 50 mm wide, and beds, bevel cuts, and tops shall be fine-finished. Vertical joints shall be smooth-finished, and the copings shall be laid with joints no more than 6.5 mm thick. Preferably, undersides of projecting copings shall have a drip bead.

Joints in copings shall be located so as to provide no less than a 300 mm bond with the stones of the under course, and so that no joint will come directly under the superstructure masonry plates.

a. Shipment and Storage of Stone

Quarry operations and delivery of stone to the point of use shall be organized to ensure deliveries well ahead of masonry operations. Sufficiently large stocks of the specified stone shall be kept on the site at all times to permit adequate selection of stone by the masons.

All stone shall be kept free from dirt, oil, or any other injurious material that may prevent the proper adhesion of the mortar or detract from the appearance of the exposed surfaces.

b. Surface Finishes of Stone

Stone surface finishes are defined as follows:

1. Smooth-finished: Having a surface in which the variations from the pitch line do not exceed 1.5 mm.
2. Fine-finished: Having a surface in which the variations from the pitch line do not exceed 6.5 mm.
3. Rough-finished: Having a surface in which the variations from the pitch line do not exceed 12.5 mm.
4. Scabbled: Having a surface in which the variations from the pitch line do not exceed 19 mm.
5. Rock-faced: Having an irregular projecting face without indications of tool marks. Projections beyond the pitch line shall not exceed 76 mm and no part of the face shall recede back of the pitch line.

c. Selection and Placing of Stone

Each stone shall be cleaned and thoroughly saturated with water before being set, and the bed that is to receive it shall be clean and well moistened. All stones shall be well-bedded in freshly made mortar. Mortar joints shall be full and the stones carefully settled in place before the mortar has set. No spalls shall be permitted in the beds. No pinning up of stones with spalls shall be permitted in beds.

Stone shall not be dropped upon or slid over the wall, nor will hammering, rolling, or turning of stones on the wall be permitted. Stone shall be carefully set without jarring the stone already laid, and shall be handled with a Lewis tool or other appliance that will not cause disfigurement.

In case any stone is moved or the joint broken, the stone shall be taken up, the mortar thoroughly cleaned from the bed and joints, and the stone reset in fresh mortar.

d. Dowels and Cramps

Where required, coping stone, stone in the wings of abutments, and stone in piers shall be secured with wrought-iron cramps or dowels as indicated in the Contract plans.

Dowel holes shall be drilled through each stone before the stone is placed and, after it is in place, such dowel holes shall be extended by drilling into the underlying course not less than 150 mm.

Cramps shall be of the shapes and dimensions shown in the Contract plans or approved by the Engineer. They shall be inset in the stone so as to be flush with the surfaces.

Cramps and dowels shall be set in lead, care being taken to completely fill the surrounding spaces with the molten metal, or shall be rigidly anchored by other means approved by the Engineer.

6.2.3.8 Concrete Copings

Copings, bridge seats, and backwalls shall be of the material specified in the Contract documents, and when not otherwise specified, shall be of C35/20 concrete, which shall conform to the requirements of Section 4.3.9 and other applicable requirements of Chapter 4, Concrete Works, of these standard specifications.

Concrete copings shall be made in sections extending the full width of the wall, no less than 300 mm thick, and from 1.5 to 3.0 m long, or as shown on the Contract plans. Sections may be cast-in-place or precast and set in place in full mortar beds.

6.2.3.9 Weep Holes

All walls and abutments shall be provided with weep holes. Unless otherwise specified in the Contract documents or directed by the Engineer, the weep holes shall be placed at the lowest points where free outlets can be obtained, and shall be spaced no more than 3.0 m center-to-center. At each weep hole, a minimum of 0.057 m^3 of permeable material encapsulated with filter fabric shall be placed.

6.3 Rock Masonry

6.3.1 Description

Rock masonry shall consist of rock laid in a bed of mortar, dressed, pointed, cured, and constructed in conformance to the Contract plans, the Particular Specifications, the direction of the Engineer, and these Standard Specifications.

6.3.2 Materials

Rock masonry materials shall conform to the requirements established in Table 6-4.

Table 6-4: Material requirements for rock masonry

Material	Requirements
Cement, fly ash, admixtures	Section 4.3 of Chapter 4, Concrete Works.
Mortar	Article 4.3.10.4 of Chapter 4, Concrete Works ASTM C270 - 12, Type M or S only
Class G6 grout	Article 4.3.10.4 of Chapter 4, Concrete Works Maximum water-to-cement ratio of 0.44.

6.3.2.1 Rock for Masonry Structures

Contractor shall furnish sound, durable rock that meets the requirements of the Contract plans or as required in the Particular Specifications. Rock native to the vicinity of the work similar in texture and colour to native rock is preferred. Dimensioned masonry rock shall be free of reeds, rifts, seams, laminations, and minerals that may cause discolouration or deterioration. Rock with depressions or projections that might weaken it or prevent it from being properly bedded shall not be used. Contractor shall submit samples to the Engineer for approval and construction shall not begin until written approval is received.

Rocks shall be furnished in the sizes and face areas necessary to produce the general characteristics and appearance indicated on the Contract plans. Unless otherwise specified, rock fragments shall meet the dimensional requirements in Table 6-5.

Table 6-5: Physical requirements for rock for masonry

Dimension	Requirements
Minimum thickness	125 mm
Minimum width	300 mm or 1.5 times the thickness, whichever is greater
Minimum length	1.5 times the width

At least half of the rocks shall have a volume greater than, or equal to, 0.03 m^3. When headers are required, furnish headers with lengths no less than the width of bed of the widest adjacent stretcher plus 300 mm.

6.3.3 Construction Requirements

Excavation and backfill shall be performed per Sections 2.4 and 2.5 of Chapter 2, Earthworks, of these standard specifications. Foundation bed shall be prepared normal to, or in steps normal to, the face of the masonry. Where foundation masonry is used, the bearing surface shall be thoroughly cleaned and shall be wetted immediately before spreading the mortar bed.

Prior to placing rocks, the Contractor shall clean and moisten the bed.

Unless otherwise shown on the Contract plans, mortar shall be proportioned and supplied per ASTM C270 - 12, Type M or S only, and may be preblended or mixed on site. Mortar bed shall not lay longer than 45 minutes or until mortar begins to set before placing rock.

Rocks shall be placed to provide a uniform pattern and color. To provide sufficient variety of rocks for the masons, the Contractor shall maintain an adequate inventory of the rock on site. When rock is added, the new rock shall be mixed with the existing rock in a uniform pattern and color. All rocks shall be cleaned thoroughly and moistened immediately before placing. When removing and resetting rock masonry, the Contractor shall use hand tools to clean the exposed faces of the rocks of all mortar before resetting.

Mortar shall be spread to the thicknesses of beds and joints for face stones shown in Table 6-6. Bed of each course shall be uniform in thickness.

Joints in dimensioned masonry shall be vertical. In all other masonry, joints may be at angles with the vertical from 0^o to 45^o.

Cross beds for vertical walls shall be level. Beds for battered walls may vary from level to normal to the batter line of the face of the wall.

Rocks shall be laid with the longest face horizontal and the exposed face parallel to the masonry face, and then the joints shall be flushed with mortar.

Contractor shall take care to not jar or displace rocks that are already set. If a rock is loosened after the mortar has taken initial set, it shall be removed, cleaned of mortar, and relaid with fresh mortar.

Dressing shall remove all thin or weak portions. Face rock bed and joint lines shall be dressed to the maximum variation from true line shown in Table 6-6. The Contractor shall dress face rock as follows:

a. Dress bed surfaces to a depth of 75 mm, normal to the face, after which the departure from normal may not exceed 25 mm in 300 mm for dimensioned masonry or 50 mm in 300 mm for all other classes.

b. Dress joint surfaces normal to the face to a depth of 50 mm, after which the departure from normal may not exceed 25 mm in 300 mm.

Table 6-6: Rock masonry classes and construction requirements

Class	Stones and Laying	Bed Thickness (mm)	Joint Thickness (mm)	Dressing (mm from true line, angle to bed)	Rounding corners where bed and joint lines meet
Dimensioned masonry	Stones are cut in ≥ 2 dimensions, laid in broken-course pattern	10 to 25	19 to 25	Reasonably true, normal to bed	No rounding
Class A masonry	Stones are shaped, dressed to 5 mm	13 to 50	13 to 38	5 mm, ≥ 45° to bed surface	No rounding
Class B masonry	Stones are shaped, dressed to 20 mm	13 to 50	13 to 50	20 mm, ≥ 45° to bed surface	Radii ≤ 25 mm
Rubble masonry	Stones vary in size and shape, laid in random courses	13 to 64	13 to 64	40 mm, ≥ 45° to bed surface	Radii ≤ 40 mm

To finish exposed surfaces, the Contractor shall remove all drill or quarry marks from exposed faces and pitch face stones to the line along all beds and joints. Classes for finishing exposed faces are as defined in Table 6-7, and shall be executed as shown in the Contract plans or the Particular Specifications, or as directed by the Engineer.

Table 6-7: Rock masonry finishing classes

Class (abbreviation)	Approximate spacing for point depressions	Maximum surface variation from the pitch line	Appearance
Fine pointed (FP)	10 mm	±3 mm	
Medium pointed (MP)	15 mm	±5 mm	
Coarse pointed (CP)	30 mm	±10 mm	
Split or seam face (S)	-	+20 mm -0mm	Smooth, no tool marks
Rock faced (RF)	-	+Defined* -0 mm	Irregular, no tool marks, projections with no concave surfaces below the pitch line[1]

*Projections beyond the pitch line shall be specified, i.e. “Class 40RF” means no projections exceeding 40mm beyond the pitch line. Where a "variable rock face" is specified, the Contractor shall uniformly distribute stones of the same height of projection.

To point new joints, the Contractor shall crown the mortar in the joints on top surfaces slightly at the centre of the masonry for drainage. For raked joints, the Contractor shall squarely rake all mortar in exposed face joints and beds to the required depth. For weather joints, the joints shall be slightly raked. Mortar shall not remain flush with the rock faces. All face rock shall be cleaned of mortar stains while the mortar is fresh. After the mortar sets, the Contractor shall clean again using wire brushes and acid. Masonry shall be protected during hot or dry weather kept wet for at least 3 days after the work is completed.

To repoint joints, the Contractor shall remove loose mortar from joints using a small mason’s chisel, small pneumatically-power chisel, or other raking tool approved by the Engineer. Power saws or grinders shall not be used. If power equipment is used before removing mortar from the structure, the operator shall demonstrate proficiency to the Engineer. After removing mortar the Contractor shall complete the following sequence to repoint:

1. Remove mortar to a depth of 2.5 times the width of the joint.
2. Remove any dirt or vegetation with a wire brush or other tools approved by the Engineer.
3. Clean joint of all loose fragments and dust with pressurized air or water.
4. Before filling the joint, dampen adjacent stone.
5. Do not place mortar to a depth greater than 2.5 times the joint width.
6. Place mortar in layers of approximately 6mm for joints deeper than 2.5 mm.
7. Add successive layers, once mortar has reached thumb-print hardness.
8. Tool the final layer to match the approved joint appearance.

A 1 m test section of joint shall be constructed along the structure for the Engineer's approval before continuing with work. Approved test section maybe incorporated into the work.

After the mortar has dried, but before the initial set, the Contractor shall clean excess mortar and stain from rock masonry using a bristle brush. Chemicals shall not be used for cleaning unless approved by the Engineer. Joints shall be protected by keeping damp for 3 days after work has been completed.

6.3.3.1 Rock Walls

Rock walls shall be constructed per Article 7.3.4.2 of Chapter 7, Incidental Construction, of these standard specifications.

6.3.3.2 Facing for Concrete

Rock masonry may be used as a facing for concrete in two scenarios: where the rock is placed before the concrete, and where the concrete is placed before the rock

a. Rock Placed before Concrete

To improve the bond to the concrete backing, the back of the masonry shall be made uneven. Contractor shall use 32 mm reinforcing steel bent into an elongated letter S to anchor the rock. Each anchor shall be embedded in a mortar bed to within 50 mm of the face of the stones while the opposite end shall project ±250 mm into the concrete backing. Anchor spacing shall be 0.5m both horizontally and vertically.

After the mortar has attained sufficient strength, Contractor shall clean the back masonry surface of all dirt, loose material, and mortar drippings, and then wash surfaces using a high-pressure water jet just before placing the concrete.

When placing the concrete, a neat cement grout of the consistency of cream shall be carried on top of the concrete and against the masonry at all times. All interstices in the back of the masonry shall be coated with grout.

b. Concrete Placed before Rock

Facing thickness shall be allowed as shown on the Contract plans. Galvanized metal slots with anchors shall be set in the concrete face. Anchors spacing shall be at most 600 mm in the vertical and horizontal directions. Contractor shall place a temporary filling of felt or other material in the slots to prevent filling with concrete.

Where setting the rock facing, the metal anchors shall be fit tightly in the slots at an average vertical spacing of 600 mm. At least 25 % of the anchors shall be bent at a short right angle to engage a recess cut in the stone. Anchors shall extend to within 75 mm of the exposed face of the stone work.

Where the shape of the concrete face is unsuitable for the use of metal slots, the Contractor shall use 3.8 mm coated steel wire ties conforming to ASTM A884/A884M - 06, Class A.   at a rate of 7 ties for each m^2 of exposed surface. Contractor shall use a gut to install ties after the concrete has cured.

Concrete face shall be kept continuously wet for 2 hours preceding the placing of the rock and spaces between the stones and concrete shall be filled with mortar.

6.3.3.3 Masonry Guardwall

When shown on the Contract plans or required in the Particular Specifications, decorative rock masonry may be used for guardwalls (refer to Figure 6-1, below for typical sections of typical guardwall used for traffic barriers, refer to AASHTO, *Roadside Design Guide, Section 5.4.1.10*). Concrete corewalls for guardwall may be cast-in-situ or precast units as shown on the Contract plans, otherwise defined in the Particular Specifications, or as approved by the Engineer. Concrete shall have a minimum 28-day compressive strength of 25 mPa. Contractor shall construct an 8 m sample section of guardwall and shall not construct additional guardwall before the sample is approved.

Guardwall shall be constructed true and uniform along its length with no stone projecting more than 38 mm. Mortar beds and joints shall be made according to Table 6-6. Joints and beds shall be raked to a depth of 50 mm on the front and top, and to 38 mm on the back.

A 1-piece capstone shall be used for the full width of the guardwall for at least 25 % of the total length. A 2-piece capstone with the joint within 100 mm of the guardwall centre shall be used for the remaining length.

All stones, including the capstones, shall be placed randomly to avoid a pattern. Stones shall be laid to reflect the width of the expansion joints without leaving a gap or a mortar edge at the expansion joint. Stones of various sizes shall be used to coin or key the corners of the guardwall. Typical examples of masonry guardwalls are shown below.

Figure 6-1: Typical examples of masonry guardwalls.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 7 - INCIDENTAL CONSTRUCTION

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 7: Incidental Construction

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LIST OF TABLES

7 INCIDENTAL CONSTRUCTION

This work shall consist of furnishing, placing, and constructing incidental construction works including guardrails and attenuators, walls, slope protection, concrete kerbs, gutters, and barriers, sidewalks, fencing, and decorative finishes for concrete and masonry in accordance with these specifications and conforming to the Contract documents.

7.1 Reference Standards and Codes

Standards and codes shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Construction Specifications;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
AASHTO-AGC-	Joint committee on New Highway Materials Task Force 13 - A Guide to Standardized Highway
ACI	ACI 506.2-95 American Concrete Institute;
ACI 301-10:	American Concrete Institute - Specifications for Structural Concrete;
ACI Committee	American Concrete Institute - Metric Building Code Requirements for Structural
318 318M-11	Concrete and Commentary;
ARTBA	Barrier Hardware;
AASHTO	Guide Specifications for Structural Design of Sound Barriers;
ADQCC (WA-726)	Stormwater and subsoil drainage system (Vol. 1,2,3, and 4);
ANSI A137.1: 2008	American National Standards Specifications for Ceramic Tile;
ANSI A108/A118/	American National Standards Specifications for the Installation of Ceramic Tile;
A136.1:2011	
ANSI/AWS	American Welding society - ANSI/AWS D1.1/D1.1M:2010 - Structural Welding Code – Steel;
ASTM	American Society for Testing and Materials;
BSI	British Standards Institution;
BS EN	European Standards;
CI	ACI 551.1R-05: American Concrete Institute, 2005. ISBN: 551105;
CRSI	Manual of Standard Practice, Concrete Reinforcing Steel Institute;
Federal Test	U.S. Government Printing Office Paint, Varnish, Lacquer and related materials:
Method Standard	Methods of inspection, sampling and testing, 2001, FED-STD-141D;
FED-STD-141D	
GSA	General Services Administration, 2008. FED-STD-595C;
NCHRP	Transportation Research Board, National Research Council, National Academy;

QQ-W-461H Federal Specification - Wire, Steel, Carbon (Round, Bare, and Coated). U.S. Government Printing Office, 1978;

SAE Steel, Bars, Forgings, and Tubing, 0.31 - 0.38C (AISI C 1035/SAE 1035);

TCNA Tile Council of North America - Handbook for Ceramic, Glass, and Stone Tile Installation, 2011;

USGSA RR-W-410G, Federal Specification - Wire Rope and Strand;

U.S. DOT FHWA Department of Transportation Federal Highway Administration - Manual of Uniform Traffic Control Devices.

Table 7-1 and

Table 7-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for incidental construction works. It also includes designations and titles.

Table 7-1: Designations and titles for AASHTO and ASTM standards that apply to incidental construction works

AASHTO Designation	ASTM Designation	Title
AASHTO M 180-00		*Corrugated Sheet Steel Beams for Highway Guardrail.*
	ASTM A36 / A36M - 08	*Standard Specification for Carbon Structural Steel.*
	ASTM A992 / A992M - 11	*Standard Specification for Structural Steel Shapes. West Conshohockan, PA*
AASHTO M 111M/M 111-09		*Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.*
	ASTM A123 / A123M - 09	*Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products.*
AASHTO. AASHTO M 30		*Standard Specification for Zinc-Coated Steel Wire Rope and Fittings for Highway Guardrail.*
AASHTO M 232M:		*Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.*
AASHTO. M 232M/M 232-10		*Zinc Coating (Hot-Dip) on Iron and Steel Hardware.*
	ASTM A153 / A153M - 09	*Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware.*
	ASTM A143 / A143M - 07	*Standard Practice for Safeguarding Against Embrittlement of Hot Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement.*
	ASTM A384 / A384M - 07	*Standard Practice for Safeguarding Against Warpage and Distortion During Hot Dip Galvanizing of Steel Assemblies.*
	ASTM A307 - 10	*Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.*
	ASTM A325 - 10	*Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

AASHTO Designation	ASTM Designation	Title
	ASTM A563 - 07a	*Standard Specification for Carbon and Alloy Steel Nuts. West Conshohockan, PA*
	ASTM F844 - 07a	*Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use.*
	ASTM A500 / A500M - 10a	*Standard Specification for Cold Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.*
	ASTM A501 - 07	*Standard Specification for Hot Formed Welded and Seamless Carbon Steel Structural Tubing.*
	ASTM F738M - 02(2008)	*Standard Specification for Stainless Steel Metric Bolts, Screws, and Studs.*
AASHTO T 24M/T 24-07		*Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.*
AASHTO T 85		*Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate*
AASHTO T 96-02 (2010)	ASTM C131 - 06	*Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
	ASTM A641 / A641M - 09a	*Standard Specification for Zinc Coated (Galvanized) Carbon Steel Wire.*
	ASTM A809 - 08	*Standard Specification for Aluminum Coated (Aluminized) Carbon Steel Wire.*
	ASTM A370 - 11a	*Standard Test Methods and Definitions for Mechanical Testing of Steel Products.*
	ASTM A975 - 11	*Standard Specification for Double–Twisted Hexagonal Mesh Gabions and Revet Mattresses (Metallic Coated Steel Wire or Metallic Coated Steel Wire With Poly(Vinyl Chloride) (PVC) Coating).*
	ASTM A974 - 97(2011)	*Standard Specification for Welded Wire Fabric Gabions and Gabion Mattresses (Metallic Coated or Polyvinyl Chloride (PVC) Coated).*
	ASTM A185 / A185M - 07	*Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.*
	ASTM D792 - 08	*Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.*
	ASTM D638 - 10	*Standard Test Method for Tensile Properties of Plastics.*
	ASTM D2240 - 05(2010)	*Standard Test Method for Rubber Property 8212; Durometer Hardness.*
	ASTM D746 - 07	*Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.*
	ASTM B117 - 11	*Standard Practice for Operating Salt Spray (Fog) Apparatus.*
	ASTM D1499 - 05	*: Standard Practice for Filtered Open Flame Carbon Arc Exposures of Plastics.*

AASHTO Designation	ASTM Designation	Title
AASHTO T 27-06		*Sieve Analysis of Fine and Coarse Aggregates.*
AASHTO T 11-05		*Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing.*
AASHTO T 89-10		*Determining the Liquid Limit of Soils.*
AASHTO M 181-10		*Chain-Link Fence.*
	ASTM A392 - 11a	*Standard Specification for Zinc Coated Steel Chain Link Fence Fabric.*
	ASTM A603 - 98(2009)e1	*Standard Specification for Zinc Coated Steel Structural Wire Rope.*
	ASTM A475 - 03(2009)e1	*Standard Specification for Zinc Coated Steel Wire Strand.*
AASHTO. M 232M/M 232-10		*Zinc Coating (Hot-Dip) on Iron and Steel Hardware.*
	ASTM A36 / A36M - 08	*Standard Specification for Carbon Structural Steel.*
AASHTO T 96-02		*Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.*
AASHTO T 85-10		*Specific Gravity and Absorption of Coarse Aggregate.*
AASHTO T 210-10		*Aggregate Durability Index.*
AASHTO M 182-05		*Burlap Cloth Made from Jute or Kenaf and Cotton Mats.*
	ASTM F1554 - 07ae1	*Standard Specification for Anchor Bolts, Steel, 36, 55, and 105 ksi Yield Strength.*
AASHTO M 291M-07		*Carbon and Alloy Steel Nuts [Metric].*
	ASTM F436 - 11	*Standard Specification for Hardened Steel Washers.*
	ASTM C33 / C33M - 11a	*Standard Specification for Concrete Aggregates.*
	ASTM C881 / C881M - 10	*Standard Specification for Epoxy Resin Base Bonding Systems for Concrete.*
	ASTM C650 - 04(2009)	*Standard Test Method for Resistance of Ceramic Tile to Chemical Substances*
	ASTM C1028 - 07e1	*Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull Meter Method.*
AASHTO M 280-09		*Metallic-Coated (Carbon) Steel Barbed Wire.*

AASHTO Designation	ASTM Designation	Title
	ASTM A116 - 11	*Standard Specification for Metallic-Coated, Steel Woven Wire Fence Fabric.*
AASHTO M 279-09		*Metallic-Coated, Steel Woven Wire Fence Fabric.*
	ASTM F626 - 08(2013)	*Standard Specification for Fence Fittings.*
	ASTM A702 - 89(2006)	*Standard Specification for Steel Fence Posts and Assemblies, Hot Wrought.*
	ASTM F1043 - 11a	*Standard Specification for Strength and Protective Coatings on Steel Industrial Chain Link Fence Framework.*
	ASTM F1083 - 10	*Standard Specification for Pipe, Steel, Hot Dipped Zinc Coated (Galvanized) Welded, for Fence Structures.*
	ASTM A53 / A53M - 10	*Standard Specification for Pipe, Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless.*
	ASTM F626 - 08	*Standard Specification for Fence Fittings.*
	ASTM A121 - 07	*Standard Specification for Metallic Coated Carbon Steel Barbed Wire.*
	ASTM A491 - 11	*Standard Specification for Aluminum Coated Steel Chain Link Fence Fabric.*
	ASTM C309 - 11	*Standard Specification for Liquid Membrane Forming Compounds for Curing Concrete.*
	ASTM C206 - 03(2009)	*Standard Specification for Finishing Hydrated Lime.*
	ASTM C897 - 05(2009)	*Standard Specification for Aggregate for Job Mixed Portland Cement Based Plasters.*
	ASTM C932 - 06	*Standard Specification for Surface Applied Bonding Compounds for Exterior Plastering.*
	ASTM C926 - 11a	*Standard Specification for Application of Portland Cement Based Plaster.*
	ASTM C207 - 06(2011)	*Standard Specification for Hydrated Lime for Masonry Purposes.*
	ASTM C780 - 11	*Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.*
	ASTM E119 - 12	*Standard Test Methods for Fire Tests of Building Construction and Materials.*
	ASTM C1063 - 11b	*Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement Based Plaster.*
	ASTM A653 / A653M - 11	*Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc Iron Alloy Coated (Galvannealed) by the Hot Dip Process.*

AASHTO Designation	ASTM Designation	Title
	ASTM C1002 - 07	*Standard Specification for Steel Self Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs.*
	ASTM C954 - 11	*Standard Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness.*
	ASTM C665 - 11	*Standard Specification for Mineral Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing.*
	ASTM D226 / D226M - 09	*Standard Specification for Asphalt Saturated Organic Felt Used in Roofing and Waterproofing.*
	ASTM C150 / C150M - 11	*Standard Specification for Portland Cement.*
	ASTM C91 - 05	*Standard Specification for Masonry Cement.*
	ASTM C1328 - 05	*Standard Specification for Plastic (Stucco) Cement.*
	ASTM D1751 – 04 (2008)	*Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).*
	ASTM A252 - 10	*Standard Specification for Welded and Seamless Steel Pipe Piles.*
	ASTM A675 / A675M - 03(2009):	*Standard Specification for Steel Bars, Carbon, Hot Wrought, Special Quality, Mechanical Properties.*
	ASTM A474 - 03(2008)	*Standard Specification for Aluminum Coated Steel Wire Strand.*
	ASTM B211 - 03	*Standard Specification for Aluminum and Aluminum Alloy Bar, Rod, and Wire.*
	ASTM A463 / A463M - 10	*Standard Specification for Steel Sheet, Aluminum Coated, by the Hot Dip Process.*
	ASTM A780 / A780M – 09	*Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*
	ASTM B6 - 13	*Standard Specification for Zinc*
	ASTM A90 / A90M - 13	*Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings*
	ASTM C88 - 13	*Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*
	ASTM C293 / C293M - 10	*Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)*

Table 7-2: Designations and titles for BS and BS EN standards that apply to incidental construction works

BS Designation	BS EN Designation	Title
	BS EN 1340:2003	*Concrete kerb units. Requirements and test methods.*
BS 1881-113:2011		*Testing concrete. Method for making and curing no-fines test cubes.*
	BS EN 12004:2007	*Adhesives for tiles. Requirements, evaluation of conformity, classification and designation.*
	BS EN 14411:2006	*Ceramic tiles. Definitions, classification, characteristics and marking.*
	BS EN ISO 1461:2009	*Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods*
	BS EN 1014-1:2010	*Wood preservatives. Creosote and creosoted timber. Methods of sampling and analysis. Procedure for sampling creosote.*
	BS EN 459-1:2010	*Building lime. Definitions, specifications and conformity criteria.*
BS 4551:2005+A1:2010		*Mortar. Methods of test for mortar. Chemical analysis and physical testing.*
	BS EN 1521:1997	*Determination of flexural strength of lightweight aggregate concrete with open structure.*
	BS EN 13914-1:2005	*Design, preparation and application of external rendering and internal plastering. External rendering.*
BS 8481:2006		*Design, preparation and application of internal gypsum, cement, cement and lime plastering systems. Specification.*
BS 4008:2006		*Specification for cattle grids*
	BS EN 10025	*Hot rolled products of structural steels*
BS 3692:2001		*ISO metric precision hexagon bolts, screws and nuts. Specification*
	BS EN 1011-1:2009	*Welding. Recommendations for welding of metallic materials General guidance for arc welding*
	BS EN 1011-2:2001	*Welding. Recommendations for welding of metallic materials Arc welding of ferritic steels*
	BS EN 1011-8:2004	*Welding. Recommendations for welding of metallic materials Welding of cast irons*
	BS EN 12620: 2002+A1:2008	*Aggregates for concrete*
	BS EN 933-1:2012	*Tests for geometrical properties of aggregates Determination of particle size distribution. Sieving method*

BS Designation	BS EN Designation	Title
	BS EN 1744-1:2009+A1:2012	*Tests for chemical properties of aggregates Chemical analysis*
	BS EN 933-7:1998	*Tests for geometrical properties of aggregates Determination of shell content. Percentage of shells in coarse aggregates*
BS 812-110:1990		*Testing aggregates Methods for determination of aggregate crushing value (ACV)*
	BS EN 933-3:2012	*Tests for geometrical properties of aggregates Determination of particle shape. Flakiness index*
BS 812-105.2:1990		*Testing aggregates. Methods for determination of particle shape Elongation index of coarse aggregate*
BS 1377-3:1990		*Methods of test for soils for civil engineering purposes Chemical and electro-chemical tests*
BS 812-2:1995		*Testing aggregates Methods for determination of density*
	BS EN 1338:2003	*Concrete paving blocks. Requirements and test methods*
	BS 7533-3:2005+A1:2009	*Pavements constructed with clay, natural stone or concrete pavers Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements*

7.2 Guardrails and Attenuators

7.2.1 Guardrails

7.2.1.1 Description

This work consists of furnishing, constructing, modifying, removing, and resetting guardrail systems, which shall include, but not by way of limitation, guardrail, posts, transitions, terminals, and anchors. Type of guardrail to be used shall be shown on the Contract plans and as approved by the Engineer. Guardrails specified herein include the w-beam, thrie - beam and wire-rope types.

Completed guardrail shall present a uniform appearance free of scars, stains, or corrosion and shall not show any visible deviations from line and grade. Posts shall be straight and vertical. Guardrails shall not be warped but shall be in a vertical plane, aligned parallel to the road centre line except at end treatment sections.

7.2.1.2 Materials

Certificates of compliance for guardrail materials shall be submitted by the Contractor. When directed by the Engineer, the Contractor shall provide samples of guardrail elements to be tested for compliance with the physical and chemical property requirements detailed in these Standard Specifications.

All materials shall be subjected to inspection and sampling at the fabricating plant, warehouse or after delivery to the site of construction.

a. Rail Element for W-beam and Thrie-beam

Steel rail elements including the terminal sections shall meet the chemical and physical requirements of AASHTO M 180 for Type II, Class B. Base metal for rail elements shall not contain more than 0.04 % phosphorous nor more than 0.05 % sulphur. For 150-mm channel rails and splice plates, the rail elements shall meet the requirements of ASTM A36M or ASTM A992M.

Rail sections and end sections shall be form rolled to the shapes shown on the Contract plans, and shall be hot-dipped galvanised after fabrication, per AASHTO M 111M or ASTM A123M.

Rail elements, back-up plates, reducer sections, and end sections shall conform to AASHTO-AGC-ARTBA, A Guide to Standardized Highway Barrier Hardware, except as modified by these Standard Specifications or the Contract plans.

All fabrication shall be complete before galvanising, including the following:

1. Holes in the plates, which shall be slotted to permit expansion and Contraction and to facilitate erection
2. Edges of the rail, which shall be rolled or rounded so as to present no sharp edges
3. Radius of curvature less than 46 m, which shall be shaped in the fabrication shop

Each rail element shall be permanently marked per AASHTO M 180. Curved sections shall additionally be marked in the same manner with the radius of the curved section in the format “R = xx m”. Markings shall be located on the back of the metal beam rail section away from traffic and visible after erection.

Systems other than AASHTO M180 W-beam and all highway safety hardware accepted shall comply with the Test Level-3 (TL-3) as per National Cooperative Highway Research Program (NCHR) report 350 / AASHTO manual MASH (Manual for Assessing Safety Hard-wares) crash test criteria all as per the Engineer’s recommendations.

b. Wire Rope

Ropes for railing shall be coreless with a diameter of 19 mm. They shall have a breaking load of at least 177 kN. Rope for railing shall exhibit a minimum modulus of elasticity of 83,000 MPa based on an area of 283.5 mm^2, after pre-stressing by an approved method, to ensure that they behave elastically and retains tension when in service.

All wire used for the manufacture of ropes for railing shall be general purpose type II wire that has been zinc-coated by the hot dip method as outlined in AASHTO M 30

All threaded terminals and rigging screws shall be hot dip galvanized according to AASHTO M 232.

c. Posts and Blocks

Posts and blocks shall be fabricated and installed to the dimensions, tolerances, and requirements shown in the Contract plans. Except for terminal or anchor assemblies, all posts for any one continuous length of guardrail shall be of the same material.

Top diameter of posts shall measure 150 mm to 230 mm, provided that posts with widely varying diameters shall not be used together in the same length of guardrail. Posts shall be concrete, steel or composite, as described by the material below. Blocks shall be timber, steel, or composite, as described by the material below.

Impact performance of some features of railing system depends on dynamic soil structure interaction. The soil shall be tested in accordance with the approved backfill and compaction criteria as per Chapter 2, Earthworks, of these standard specifications

1. Concrete Posts

Concrete posts shall be precast in the shape and dimensions shown on the Contract plans in accordance with the requirements of Section 4.4.8 of Chapter 4, Concrete Works.

Class C40/20 concrete shall be used in the construction of all concrete posts. Steel reinforcing bars shall comply with the requirements of Chapter 5, Reinforcing Steel.

2. Steel Posts and Blocks

Steel posts shall be of the type and size shown on the Contract plans or described in the particular specifications.

Steel posts shall be rolled sections conforming to the material requirements of ASTM A36. Steel blocks and base plates shall conform to either ASTM A36 or ASTM A992M. Steel posts, blocks, and base plates shall be galvanised in accordance with Sub-article d of Article 7.2.1.2. All fabrication shall be completed prior to galvanising.

Welding shall conform to Sections 23.4.11 and 23.6.10 of Chapter 23, Steel Structures, of these standard specifications.

3. Composite Posts and Blocks

Contractor shall provide the Engineer with the following documentation for composite posts or blocks to be used for guardrail installations:

- Certification that the material meets the requirements of the National Cooperative Highway Research Program Report 350 Test Level 3 (TL-3) design speed category
- Certification from the producer or supplier stating the material composition. Material shall contain a minimum of 60% recycled material comprised of any combination of recycled polyethylene; polypropylene; polyvinyl chloride; tire cord; and/or rubber, including natural or styrene butadiene rubber
- Certification from the producer or supplier stating that the material is thermal and process stabilised to prevent ultra-violet degradation.

One post and one block shall be submitted by the Contractor to the Engineer for testing. Test samples shall be accompanied by a drawing showing the dimensions of the post and block. If changes occur in the producer, the type, dimensions, or material composition of the posts or blocks, the Contractor shall notify the Engineer and provide additional samples for testing at no cost to the Owner, as requested by the Engineer.

d. Galvanising and Repair

Galvanising shall be by the hot dip process in accordance with the standards identified in Table 7-3. All fabrication shall be completed and ready for assembly before galvanising. No fabrication, including forming, cutting, shearing, punching, drilling, bending, welding, or riveting shall be permitted after galvanising. Galvanised guardrails shall not be nested when stacked for storage.

Table 7-3: Galvanising standards for guardrail applications

Element	Standard
Beam rail elements and terminal sections	AASHTO M 180, Class B, Type 2
Fabricated items, rolled, pressed or forged steel shapes, plates, pipes, tubular items, bars, posts	AASHTO M 111M or ASTM A 123M
Bolts, nuts, washers, plates, rods, casings, fasteners, and other hardware	AASHTO M 232M or ASTM A 153M
Anchor cables	Federal Specification RR-W-410, Table II, galvanized at finished size

Precautions shall be taken against embrittlement, warpage, and distortion in accordance with ASTM A143M, and in accordance with ASTM A384M.

Galvanised parts shall be visually inspected by the Contractor to evaluate their fitness for the works. Galvanising coating shall be uniform and bright. Concerns shall be addressed per Table 7-4.

Table 7-4: Appearance concerns for galvanised parts

Appearance	Remedy
White rust (white powdery residue) Indicates moisture	White rust shall be removed from articles that will be in direct contact with soil and from articles where heavy layers of white dust that have caused the coating to pit. Light coatings of white dust shall remain or be removed at the Engineer's direction.
Red rust Indicates uncoated areas	Articles shall be inspected for gaps in coverage and repaired or rejected at the direction of the Engineer.
Alligator cracking (spider webbing) Dull gray colour	Composition of the base metal may cause dark lines or a dull gray colour. Adhesion shall be tested, as described below, to determine whether the coating is acceptable.

Adhesion of the coating shall be acceptable if, when tapped with a small hammer, the coating does not scale, flake, or break.

1. Repair of Galvanisation

After erection, all parts of galvanised elements on which the galvanising has become scratched, chipped, or otherwise damaged shall be repaired by painting it with 2 coats of high zinc-dust content galvanising repair paint meeting the requirements of ASTM A780 / A780M – 09, Method 2. Bare spots as wide as 3 mm across are acceptable unless they are numerous in the opinion of the Engineer. Runs or drips of zinc coating are acceptable unless they interfere with the intended use of the product. Excessive zinc accumulations shall be carefully hand-filed.

Surfaces to be repaired shall be clean, dry, and free from contaminants such as oil, grease, corrosion products, and welding slag or flux. Surfaces shall be cleaned to near-white metal by wire brushing, light grinding, or mild blasting extending into the surrounding undamaged coating to provide a smooth repair. To attain the required dry-film thickness, the Contractor shall spray or brush-apply the paint to the prepared area in accordance with the paint manufacturer's instructions. Multiple passes shall be required for spray application.

After completing repair and cooling or curing, the measured thickness of the galvanisation in the repaired area shall be 1.5 times the thickness required for the specified galvanising up to 0.1 mm.

Paint shall not be used to repair galvanising damage caused by welding. As an alternative to paint, galvanising repair may be accomplished by zinc-based solders or sprayed zinc. Surfaces shall be prepared as for paint repair, and thickness of the zinc coating in the repaired area shall be the same as the thickness required for the specified galvanising. Procedures for these 2 alternative processes shall be as follows:

i. For zinc-based solders: Preheat cleaned areas to a temperature between 315^{O} C and 400^{O} C. Wire-brush while heating and evenly distribute a layer of zinc solder. When repair is complete, flush the repaired area with water or wipe with a damp cloth to remove flux residue.

ii. For sprayed zinc: Apply coating by metal-spraying pistols fed with either zinc wire or zinc powder. Provide a coating that is uniform and free of lumps, coarse areas, or loose particles.

e. Hardware

All fastenings shall be new wrought iron or medium steel and in conformance with the dimensional requirements of the Contract plans. Structural steel shapes, plates, bars, and strips used in fabrication of hardware and all miscellaneous steel shall conform to the requirements of ASTM A36.

All fastenings, plates, structural shapes, bars, and strips shall be galvanised per Sub-article d of Article 7.2.1.2.

Table 7-5: Hardware requirements and acceptance criteria

Hardware	Criteria	Acceptance
Bolts	ASTM A 307 Grade A	Field verification and documentation that bolt heads are stamped 307A
High-strength bolts	ASTM A 325 Type 3	Manufacturer's certificate of compliance**
Nuts	ASTM A 563 Grade A	Manufacturer's certificate of compliance**
Washers	ASTM F 844*	Manufacturer's certificate of compliance**
Notes: *Unless otherwise specified. **Manufacturer's certificate of compliance must be accepted by the Engineer prior to installing any of the hardware.		

f. Anchors

Guardrail end treatments shall be furnished by the Contractor in accordance with manufacturer requirements and the details shown on the Contract plans. Assembly and installation information for the guardrail end treatments shall by obtained by the Contractor from the manufacturer; and installation and repair manuals specific to the guardrail end treatments shall be prepared by the manufacturer and supplied to the Engineer by the Contractor.

Unless otherwise indicated in the Contract plans or the manufacturer's instructions, anchor assemblies shall meet the requirements of Table 7-6.

Table 7-6: Guardrail anchor requirements

Guardrail anchor component	Requirement
Foundation tubes	Shall be fabricated from steel conforming to the requirements of ASTM A500M, Grade B; or ASTM A501.
Anchor plate assembly	Shall develop a minimum tensile strength of 178 kN.
Anchor plate and metal plates	Shall be fabricated of steel conforming to ASTM A36.
I-beam posts	Shall conform to ASTM A36 or ASTM A992M.
All metal components of the anchor and cable assembly, including fittings, and not less than the top 210 mm of I-beam posts	Shall be hot-dipped galvanized in accordance with Sub-article d of Article 7.2.1.2 of these Specifications.

Guardrail anchor component	Requirement
Anchor cable	Shall be 19 mm preformed, 6 wire strand core or independent wire rope core (IWRC), galvanized, right regular lay manufactured of improved plow-steel with a minimum breaking strength of 190 kN.
Swaged cable fittings	Shall develop 100 % of the cable's specified breaking strength.
Swaged fitting and stud assembly	Shall be of steel conforming to the requirements of AISI C-1035, annealed, and galvanized suitable for cold swaging.
Cement concrete	Shall be Class C15/20 concrete conforming to the requirements of Chapter 4, Concrete Works, of these Standard Specifications.
Cement grout	Shall be Class G2 in accordance with Article 4.3.10.4 of Chapter 4, of these Standard Specifications.

Two certified copies of the mill test reports of the cable used shall be furnished to the Engineer. One swaged fitting attached to 1 m of cable shall be furnished to the Engineer for testing.

g. Reflectors for Guardrail

Reflectors for guardrail shall be prismatic guardrail reflector tabs or prismatic guardrail-mounted barrier markers and shall have the following characteristics:

1. Prismatic guardrail reflector tabs:
    i. Minimum body thickness of 5 mm
    ii. Galvanised steel or ultraviolet-resistant plastic
2. Prismatic reflectors:
    i. 85 mm in diameter
    ii. Secured to the body in accordance with the manufacturer's recommendations
3. Prismatic guardrail mounted barrier markers:
    i. Ultraviolet-resistant
    ii. Trapezoidal-shaped body
4. Post-mounted L-shaped barrier markers and flexible guardrail markers:
    i. Made of a high quality impact and ultraviolet resistant, flexible, white-coloured plastic, or similar material
    ii. Minimum thickness of 5 mm
    iii. Rectangular body that is flat, curvilinear, or tubular with a width between 75 mm and 100 mm
5. Minimum reflective area for L-shaped, post-mounted barrier markers shall be 645 mm^2.
6. Reflectorized surface for flexible guardrail markers shall be 75 mm by 125 mm.

Guardrail delineator material shall be specifically manufactured to provide roadside delineation. All delineators shall consist of complete units that are precut, pre-drilled as applicable, and ready to be installed in the field. Delineators shall be packaged in such a manner as to prevent damage and deterioration during shipping, handling, and storage.

A certificate of compliance stating that the reflectors comply with the following requirements shall be supplied by the Contractor:

1. Retro-reflectors shall consist of a plastic face, referred to as the lens, and an opaque back fused to the lens under heat and pressure around the entire perimeter to form a homogeneous unit permanently sealed against dust, water, and water vapour
2. Retro-reflectors shall be of the colour shown in the Contract plans
3. Lens shall consist of a smooth front surface free from projections or indentations other than for identification and a rear surface bearing a prismatic configuration such that it will effect total internal reflection of light
4. Manufacturer's trademark shall be moulded legibly into the face of the lens

Specific intensity of each acrylic retro-reflector shall be at least the minimum values in Table 7-7 with measurements made with retro-reflectors spinning.

Lenses shall have a retro-reflective area of not less than 4,195 mm^2. Retro-reflection shall be provided by the lens prismatic optical elements. To test if a retro-reflector is adequately sealed against dust, water, or air, the Contractor shall perform the following:

1. Submerge 50 samples in water bath at room temperature
2. Subject the submerged samples to a vacuum of 127 mm gauge for 5 minutes.
3. Restore atmospheric pressure and leave samples submerged for 5 minutes.
4. Remove and examine the samples for water intake, which shall constitute a failure.

Failure of 3 or more units shall be cause for rejection of the entire lot.

Delineators shall consist of an acrylic plastic retro-reflector unit mounted in a housing fabricated of 1.60 mm 3003-H-14 or similar aluminium, or of cold-rolled, hot-dipped galvanised steel, having a thickness of 1.62 mm. Housing dimensions, including assembly and post-mounting hardware, will be as shown on the Contract plans or as specified in the Contract. Attachment hardware shall permit easy removal with the proper tools, but removal shall not be possible without the use of such tools. Housing shall be protected against corrosion, as recommended by the manufacturer.

Table 7-7: Minimum specific intensity per unit area (SIA) for clear reflectors

Observation Angle (degrees)	Entrance Angle (degrees)	Minimum SIA (candelas per Lux per m^2)
0.1	0	2,550
0.1	20	995

h. Inspection and acceptance of materials

Before the rail elements are fabricated, the Contractor shall notify the Engineer so that inspections may be provided. Arrangements for facilities necessary for the inspection of material and workmanship at the point of fabrication of the rail element shall be made by the Contractor and the Engineer shall be allowed free access to necessary parts of the premises.

Materials or workmanship that does not fulfil the requirements of these Standard Specifications shall be rejected by the Engineer. Mill test reports certifying that the steel used in fabricating the rail elements meet the requirements of these Standard Specifications shall be accepted by the Engineer, who reserves the right to require the Contractor to furnish samples of the steel proposed for use and to determine that the steel meets the requirements of these specifications. Steel rail elements, fittings, end section hardware, and bolts, as well as reflectors, may be accepted by the Engineer based on the manufacturer’s certification of compliance.

7.2.1.3 Construction Requirements

Guardrail shall be installed in accordance with approved shop drawings and in compliance with the lines, dimensions, details, and locations indicated on the Contract plans or directed by the Engineer. Guardrail installation shall be consistent with the manufacturer's recommendations.

Minimum height of the guardrail shall be 725 mm, ±25 mm measured from the top of the rail to the finished shoulder surface.

Guardrail shall be braced to prevent movement, and all bolts shall be tightened prior to any post holes being backfilled.

Guardrail shall be erected such that the final configuration has no projecting ends that might interfere with or endanger traffic. Anchors and terminals shall be provided and reflectors shall be fixed in accordance with the details shown on the Contract plans.

Any pavement damaged during guardrail construction shall be repaired as approved by the Engineer.

a. Erection of Posts

Unless otherwise indicated on the Contract plans, all posts shall be set vertically in holes with the diameters, spacing, and positions indicated on the Contract plans. Post holes shall be backfilled with C30/20 concrete tamped into place or as indicated on Contract plans. After backfilling is complete and the bracing has been removed, the posts shall be rigid and vertical; and the guardrail shall be firmly fixed to the posts and true to line and level.

In any continuous length of guardrail, the same type of post shall be used.

When the Contract plans require that the ends of a section of guardrail be curved outward or downward, posts shall be set to accommodate the curve. End treatment of the guardrail and length of post shall be as shown in the Contract plans.

Posts may be placed in dug or drilled holes. Ramming or driving will be permitted only if approved by the Engineer and if it can be accomplished without damaging the posts, pavement, shoulders, and adjacent slopes. In broken rock embankments, pre-punching holes will be permitted only prior to final shoulder or median compaction, surfacing, and paving. Posts shall be protected from traffic at all times by attaching the rail elements or by a method approved by the Engineer.

When driving of posts is approved, it shall be accomplished in a manner that prevents battering, burring, separation of the galvanising from the steel, or distortion of the post. Posts shall be driven plumb with approved power hammers or gravity hammers to the required line and grade. Approved power hammers are steam, compressed air, vibratory, or diesel. A structural steel driving head shall be suitable for the type and size of post being driven. Wood cushion blocks shall be used, as necessary, to prevent damage to the post. Rope mat, belting, or other similar cushioning material may also be used. Any post that is bent or otherwise damaged to the extent it is unfit for use in the finished work, as determined by the Engineer, shall be removed and replaced at no additional cost to the Owner.

Pilot holes may be used when required or permitted. Size and depth of pilot holes shall be as approved by the Engineer based on results of trial operations of the first few posts driven.

Where wood posts with rectangular sections are used, the posts shall be set so that the longest dimension is perpendicular to the rail.

Posts shall be embedded a minimum of 1 m, or as shown on the Contract plans.

Post holes shall be backfilled with Class C25 concrete tamped into place in layers not to exceed 100 mm of compacted thickness, or as indicated on the Contract plans.

Where the elevation of the top surface of a culvert or other similar installation prevents the placement of a post of the specified length, the posts shall be anchored in accordance with the details shown on the Contract plans.

b. Erection of Rail

Rail elements shall be erected to produce a smooth, continuous rail paralleling the line and grade of the roadway surface or as shown on the Contract plans.

Steel rail sections shall be galvanised per Sub-article d of Article 7.2.1.2. After galvanising, special detail holes may be cut in the field, only when necessary and approved by the Engineer. Any holes, nicks, gouges, or scratches in the railing's galvanised surface shall be repaired per Paragraph 1 of Sub-article d of Article 7.2.1.2.

Blocks shall be set so that their tops are level with the top of the post, ±13 mm, unless otherwise shown on the Contract plans.

Bolts at expansion joints shall be located at the centre of the slotted holes. Rail plate splice joints shall lap in the direction of traffic. Splices shall be located at posts, and spaced at intervals of 7.6 m or less. Rail plates shall make contact over the entire area of the splice.

When nested, W-beam or thrie-beam is specified and two sections of guardrail, 1 set inside the other, shall be installed. Inside and outside rail elements shall not be staggered.

Galvanised rail plates shall be fastened to the posts with galvanised hardware of the size and kind shown in the Contract plans. Bolts shall be sufficiently long to extend 13 mm, or 2 threads, beyond the nuts, or longer, where required for adjustments. Bolts extending more than 50 mm beyond the nut shall be cut off so as to be less than 13 mm beyond the nut.

Bolts shall be tightened per the manufacturer's installation instructions and, except where otherwise required at expansion joints, shall be drawn tight. Bolts through expansion joints shall be drawn up as tight as possible without being tight enough to prevent the rail elements from sliding past one another longitudinally.

Reflectorized tabs shall be installed on posts at the locations shown on the Contract plans and spaced at a maximum interval of 11.5 m. Slotted part of the tab shall be installed under the mounting bolt head so that the reflectorized surface of the tab faces oncoming traffic. Exposed ends of the slotted part of the tab shall be bent up against and then over the top of the bolt head.

Guardrail constructed under traffic shall be installed in the direction of traffic flow to constitute the least hazard to the public.

c. Wire Rope Installation

Installation of the cable railing shall comply with the manufacturer's instructions and working drawings for the Project.

Contractor shall install cable in continuous lengths. Before tightening bolts and finishing installation of cables, the Contractor shall check and adjust alignment. Unless the Contract plans, particular specification or manufacturers recommendations specify otherwise, the Contractor shall torque bolted connections from 60 to 70 Nm. Bolts shall extend at least 6 mm but not more than 25 mm beyond the nuts.

Contractor shall use rigging screws to join railing ropes together and to create tension. No rope shall be longer than 154 m. Immediately in front of each anchorage, a 6 m long tail rope shall connect to the anchorage in the ground. Both ends of every rope shall have a threaded terminal of right-hand or left-hand thread as appropriate to ensure that rigging screws effective provide tension. Rope ends shall insert at least 25 mm into rigging screws. A tail rope with right-hand thread on its end shall connect to the anchor.

When all components are in place, the Contractor shall turn the rigging screws to tension ropes uniformly to 25 kN. Contractor shall not place backfill above the tops of concrete anchor footings before tensioning cables.

Each anchor shall have a check rope that is 1.8 m long and 8 mm diameter with a galvanized thimble at one end and a fork terminal at the other. Such check ropes shall have a breaking load of at least

39 kN when tested as an assembly. Each check rope's thimble shall pass over the end of the tail rope and the fork terminal that is connected to the anchor.

Owner shall accept equivalent galvanised wire rope with a minimum breaking strength of at least 194 kN.

d. Terminal and Anchor Installation

Assembly and installation of guardrail anchors and terminals shall include the following:

- Supervised at all times by a manufacturer's representative or an installer who has been trained and certified by the manufacturer. A copy of the installer's certification shall be provided to the Engineer prior to installation
- As shown on the Contract plans and in accordance with the manufacturer's recommendations

Terminal anchor posts shall be backfilled with concrete unless otherwise shown on the Contract plans. Concrete footings shall be poured against moist, undisturbed earth. Concrete footing tops shall be smooth trowelled to slope away from the post. Immediately after placing concrete footings, at least 100 mm of loose moistened earth free of clods or gravel shall be placed over the footing, or the footing shall be sprayed with an approved liquid membrane-curing compound, per Article 4.3.13.2 of Chapter 4, Concrete Works. After the footing has cured, excess excavated material, including earth on top of the footing, shall be removed.

All excavation and backfilling required for installation of anchors shall be performed in accordance with Sections 2.4 and 2.5 of Chapter 2, Earth Works, of these standard specifications. Bolts shall be tightened to the tension specified by the manufacturer or the Contract plans. Anchor cables shall be tightened sufficiently to eliminate all slack. When tightening, the anchor cable shall be restrained to prevent twisting.

Where the elevation of the top surface of a culvert or other similar installation prevents the placement of a post to the specified length, the posts shall be anchored in accordance with the details shown on the Contract plans.

Foundation tubes used with wood breakaway posts shall be driven prior to installing the wood post.

e. Transitions

Guardrail transitions to concrete barriers or other barrier systems shall be constructed in accordance with the details shown on the Contract plans.

f. Kerb

Where the Contract plans call for kerb with guardrail or in the transitions, kerbs shall be installed per Section 7.5.

g. Shop Drawings

Shop drawings shall be submitted by the Contractor to the Engineer for review and approval. Shop drawings shall be complete with all details necessary to fabricate and install the guardrail proposed for use in the works in accordance with the manufacturer's recommendations. Additional drawings required by the Engineer shall be submitted by the Contractor for the Engineer's approval.

h. Guardrail Construction Exposed to Traffic

Any section of beam guardrail that is removed for modification shall be replaced within 5 calendar days of the date the guardrail is removed. These operations shall be conducted in such a manner that fixed objects and beam guardrail posts shall be protected by the Contractor from traffic at all times by attaching the rail elements and all associated hardware or by a method approved by the Engineer. At the end of each day, guardrail sections having an exposed end toward oncoming traffic shall have a terminal end section bolted securely in place.

i. Access Control Gates

Access control gates shall be placed to line and grade as shown in the Contract plans or per the direction of the Engineer. Gate posts shall be installed per Sub-article a of Article 7.2.1.3.

j. Removing Guardrail and Guardrail Anchors

Guardrail end treatments shall be moved or removed in accordance with the Contract plans and as directed by the Engineer. Salvageable materials shall be handled as directed on the Contract plans or in the Particular Specifications. Unsalvageable materials shall be disposed of in accordance with applicable regulations.

Removal of the guardrail shall include removal of all guardrail components, including the rail, cable, hardware, posts, transition sections, expansion sections, and terminal sections.

Removal of guardrail anchors shall include removal of the anchor assembly in its entirety, including concrete bases, rebar, steel tubes and any other appurtenances in the anchor assembly.

All holes resulting from the removal of the guardrail posts and anchors shall be backfilled with granular material in layers no more than 150 mm thick and compacted to the approximate density of the adjacent material. Removed guardrail items shall become the property of the Contractor.

Every effort to reuse suitable existing guardrails rather than dispose of them and purchase new units shall be made by the Contractor. Removal of existing guardrails shall be carried out as follows:

1. All guardrails, reflective plates, and end units shall be loosened
2. Posts shall be carefully dug out and the holes shall be filled and compacted
3. Hardware and reflectors shall be placed into bags, after which all the material shall be transported to a store approved by the Engineer and stored in groups by type

Material intended for reuse shall be unpacked and inspected by the Engineer, who shall determine suitability for reuse. Reusable material shall then be stored separately from material that is deemed unsuitable for reuse.

k. Construct Guardrail from Salvage

Salvaged guardrail, guardrail transitions, anchor assemblies, and other guardrail systems shall be constructed at the locations shown on the Contract plans in accordance with the specifications for new guardrail.

If any salvaged materials are deemed unsuitable for reuse by the Engineer, or if the quantities of salvaged materials are insufficient to complete the work, the Contractor shall furnish new materials in sufficient quantities to complete the work.

Where new bolt holes in rail elements are required, the holes shall be made by drilling or punching. Flame-cut bolt holes shall not be permitted. Galvanisation shall be repaired per Paragraph 1 of Sub-article d of Article 7.2.1.2.

Guardrails, end units, and steel posts suitable for reuse shall be cleaned and regalvanized.

Items designated to be reused that are lost, damaged, or destroyed as a result of the Contractor's operations shall be repaired or replaced by the Contractor at no additional cost to the Owner. Existing posts, blocks, rail elements, or hardware that are not required for guardrail reconstruction or that the Engineer deems unsuitable for reconstruction, shall be removed and disposed of as approved by the Engineer.

l. Raising Guardrail

When raising guardrail anchors and guardrail terminals, the existing guardrail posts shall be raised to attain the height shown in the Contract plans, measured from the top of the rail to the finished shoulder surface. Material around each post shall be tamped to prevent settlement of the raised post.

For raising all other guardrail, the existing guardrail posts shall not be raised to attain the new mounting height. Existing rail elements and blocks shall be removed from the guardrail post. New holes shall be drilled by the Contractor in the existing posts to accommodate the button-head bolts.

Any existing posts and blocks that are unsuitable for reuse shall be removed and replaced by the Contractor, as directed by the Engineer. Voids from post removals shall be backfilled and compacted to the approximate density of the surrounding soil. A new guardrail post shall then be furnished and installed by the Contractor to provide the necessary mounting height.

7.2.2 Impact Attenuator Systems

7.2.2.1 Description

This work shall consist of furnishing, constructing, repairing, and removing permanent and temporary impact attenuator systems, as shown in the Contract plans. Attenuation devices shall be approved by the Engineer in advance of their use in the works.

This work shall include the connection to a concrete barrier, bridge abutment, or a transition section identified in the Contract plans; the construction of a steel reinforced concrete pad or concrete backup; and anchorage to the pavement, if required by the manufacturer's assembly and installation procedures.

All impact attenuator systems accepted shall comply with the Test Level-3 (TL-3) as per National Cooperative Highway Research Program (NCHR) report 350 / AASHTO manual MASH (Manual for Assessing Safety Hard-wares) crash test criteria all as per the Engineer's recommendations.

7.2.2.2 Materials

Materials for impact attenuator systems shall be new, except undamaged sand barrel impact attenuators that have been previously utilised, which may be used in a temporary impact attenuator array only if inspected and approved by the Engineer prior to use.

Sand for inertial barrier systems shall not contain more than 5 % water by weight. Commercial grade urea shall be thoroughly mixed with the sand in an amount equal to 5 %, by weight, of the sand. Materials shall be as required by the manufacturer for proper installation of these proprietary systems.

7.2.2.3 Construction Requirements

Attenuation devices shall be placed at the locations shown on the Contract plans or as directed by the Engineer.

Assembly and installation of all attenuator systems, except those utilising sand barrels, shall be supervised at all times by either a manufacturer's representative or an installer who has been trained and certified by the system manufacturer. If the supervision is provided by a trained installer, a copy of the installer certification shall be provided to the Engineer prior to installation. Assembly and installation shall be in accordance with the manufacturer's recommendations.

A complete set of replacement parts shall be provided by the Contractor on the jobsite for each type of temporary impact attenuator in use on the project and shall repair all damaged impact attenuators immediately.

When installation of the attenuation device is complete, all trash shall be removed from its area, and the soil surface around it shall be graded to the elevation indicated on the Contract plans. When the Engineer determines that a temporary impact attenuator is no longer needed, then the Contractor shall remove that attenuator from the project. Removed equipment shall remain the property of the Contractor.

Any welding required shall be performed in accordance with the requirements of the American Welding Society (AWS) Structural Welding Code AWS D 1.1M.

Attenuators shall be removed from existing locations and stockpiled or discarded as designated on the Contract plans or as directed by the Engineer. Salvageable units shall be cleaned and repaired before inspection by the Engineer and delivered to the Owner storeyards. Unsalvageable or excess materials shall be discarded in accordance with applicable regulations.

7.3 Walls

7.3.1 General

This work shall consist of furnishing all materials and fabricating and installing walls at the locations and in accordance with the details shown on the Contract plans, the Particular Specifications, these Specifications, and as approved by the Engineer.

All walls are presumed permanent unless otherwise specified in the Contract plans. Temporary retaining walls shall be identified as such in the Contract plans, and are defined as those walls and wall components constructed and removed or abandoned before the physical completion date of the work or as shown in the Contract plans.

Areas with continuous retaining walls shall have the same facing design. To use 2 or more wall systems, the Contractor shall provide drawings for approval by the Engineer indicating the proposed design arrangement.

Required pile or drilled shaft foundations shall be constructed in accordance with Chapter 17, Drilled Piles, and Chapter 18, Driven Piles, of these standard specifications, for drilled or driven piles or the pertinent standard. Rustication, colour coating, or other treatments shall be in accordance with the details shown on the Contract plans.

When the Contract plans call for epoxy coating of steel earth reinforcements, all steel used in concrete panels and coping, including connectors, dowels, stirrups, and reinforcing steel, shall be epoxy coated.

7.3.1.1 Submittals

Shop drawings and design calculations that completely describe all the information needed to construct the wall elements and install the walls per Table 7-8 shall be submitted by the Contractor for review and approval.

Table 7-8: Preparation, submittal, and review of submittals for walls

Shop drawings and design calculations shall be:		
Prepared:	**Submitted:**	**Reviewed:**
• Under a lead structural Engineer's direction* • To scale • Per standard drafting procedures • So as to be legible • With all terms defined	• Enough in advance of need to allow for the review process, including rejection, revision, or resubmittal • In accordance with Contract requirements • With sufficient details to completely fabricate and install the element of work • On standard paper sizes, typically A1, A3, or A4	• In the order the Engineer receives them • In the sequence specified by the Contractor when several drawings or calculations are presented simultaneously or at the Engineer's discretion if no sequence is specified. • Within 14 calendar days for the first item, and within 14 additional calendar days for each additional item submitted simultaneously

Shop drawings and design calculations shall be:
* Lead structural Engineer shall have at least 10 years of experience, and/ or otherwise have a license to practice structural Engineering in their country of origin, and shall be approved by the Engineer.

Contractor shall comply with all submittal requirements that are applicable to each wall and shall not begin wall construction activities, including access construction, excavation, and precast fabrication, until receiving the Engineer's approval of all submittals that are applicable for that wall. Approval of the Contractor's proposed wall construction details and methods shall not relieve the Contractor of its responsibility to construct the walls in accordance with the requirements of these Specifications.

In addition to the submittals described in the following subsections, the Contractor shall submit excavation shoring drawings to the Engineer for approval, in accordance with Article 2.4.2.11 of Chapter 2, Earthworks, and formwork drawings in accordance with Section 1.20.8 of Chapter 1, General Requirements.

a. Shop Drawings and Design Calculations Submittals

For each wall, the Contractor shall submit to the Engineer for approval working drawings, details, and design calculations that provide all of the information needed to fabricate wall elements and install the wall in conformance with the Contract plans, these Specifications, and the direction of the Engineer.

Any particular requirements of the approved detailed specifications for any approved proprietary systems shall govern over conflicting or incompatible requirements contained within this section of the specifications.

Work on an individual wall shall not commence until the Engineer has approved the required shop drawings and design calculations for that wall. Testing of soil nails or permanent ground anchors shall not commence until the Engineer has approved the load cell, jack, pressure gauge, and master pressure gauge calibrations.

Shop drawings for each wall shall include, but not by way of limitation, the Contractor's proposed methods and materials for all applicable items identified below:

1. Shapes and dimensions of wall elements
2. Construction sequence and method of forming precast wall elements
3. Material specifications
4. Size, quantity, and details of the following:
   i. Reinforcing steel
   ii. Lifting hardware, with the manufacturer's recommended safe working capacity, including support point locations
   iii. Additional reinforcement provided at lifting and support locations
   iv. Railing and coping
   v. Pads, fillers, and filter fabric, with manufacturer identified
   vi. Support footings
5. Joint and joint filler details
6. Surface finish details
7. Erection block outs
8. Numbered panel layout showing horizontal and vertical alignment of the walls with existing and proposed ground lines

9. Elevation view showing the following:
    i. Elevation at the top of the wall, at all horizontal and vertical break points, and at least every 15 m along the wall
    ii. Elevations at the base of welded wire mats or the top of levelling pads and foundations, and the distance along the face of the wall to all steps in the welded wire mats, foundations and levelling pads
    iii. Designation of the type of panel, block, or module
    iv. Location of the original and final ground line
    v. Length, size, and number of geogrids or mesh or strips, and the distance along the face of the wall to where changes in length of the geogrids or mesh or strips occur
    vi. Length, size, and wire sizes and spacing of the welded wire mats and backing mats, and the distance along the face of the wall to where changes in length, size, and wire sizes and spacing of the welded wire mats and backing mats occur
10. Plan view showing the following:
    i. Offset from the construction centreline to the face of the wall at all changes in horizontal alignment
    ii. Limit of the widest module, geogrid, mesh, strip, or welded wire mat
    iii. Centreline of any drainage structure or drainage pipe which is behind or passes under or through the wall
    iv. Actual lengths proposed for the reinforcing layers and the locations of each product proposed for use in each of the reinforcing layers
11. General notes required for design and construction of the wall
12. All horizontal and vertical curve data affecting wall construction
13. Summary quantities of those items on the elevation sheet of each wall, including incidental items
14. Cross sections showing limits of construction. In fill sections, the cross section shall show the limits and extent of select granular backfill material placed above original ground
15. Limits and dimensions of reinforced soil volume
16. Contractor's proposed wall construction method, including proposed forming systems, types of equipment to be used, proposed erection sequence and details of how the backfill will be retained during each stage of construction
17. All details needed to do the following:
    i. Incorporate or connect to coping, railing, drainage features, conduit, sign, signal, luminaire or other required elements
    ii. Bend steel reinforcing bar, per Section 5.4.1 of Chapter 5, Reinforcing Steel.
    iii. Construct foundations and levelling pads, including details for steps in the foundations or levelling pads, as well as allowable and actual maximum bearing pressures for AASHTO load groups I and VII
    iv. Construct all modules and facing elements. Details shall show all dimensions necessary to construct the element, all steel reinforcing bars in the element, and the location of reinforcement element attachment devices embedded in precast units
    v. Traffic or pedestrian barrier at the top of the wall, if shown in the Contract plans, including interaction with bridge approach slabs

18. Method and equipment used to support precast wall elements during storage, transporting, and erection
19. Erection sequence, including method for lifting panels, placing and adjusting panels to proper alignment and grade, and supporting panels during bolting, grouting, and backfilling operations
20. Levelling pad elevations, which may vary from the elevations shown on the Contract plans. Unless otherwise indicated, at least 300 mm of cover from the top of the levelling pad to finished grade shall be provided
21. Shop drawings for all structural steel wall elements, including steel soldier piles and permanent ground anchors
25. Rate of placing concrete so as to prevent cold joints, considering the wall thickness, height, and volume of concrete to be placed

Design calculations for each wall shall include, but not by way of limitation, all items that apply to the following:

1. Calculations for precast wall elements
2. Calculations for the connection between the precast wall elements and the cast-in-situ footing
3. Calculations for modifications to the cast-in-situ footing details as shown in the Contract plans
4. Calculations for the range of heights and loading conditions on the Project
5. Calculations for internal and external stability as described in the Contract plans
6. Summary of all design parameters used
7. Material types, strength values, assumed allowable loads and loading combinations
8. Factor-of-safety parameters

b. Wall Access Plan Submittals

If construction of a wall requires access for work activities, then the Contractor shall submit to the Engineer for approval a wall access plan, which shall include, but not by way of limitation, the following:

1. Locations of access to the wall construction sites
2. Method, materials, and equipment used to construct the access, remove the access, and recontour and reseed the disturbed ground

c. Shaft Installation Plan Submittals

For construction of walls with shafts, the Contractor shall submit a shaft construction plan to the Engineer for approval at least 14 days in advance of the proposed start of work. Shaft installation shall not begin until the Engineer's approval of the shaft installation plan is received.

Submittals shall comply with the applicable requirements of Chapter 17, Drilled Piles, and Chapter 18, Driven Piles, of these standard specifications.

d. Manufacturer's Certificate of Compliance

Unless acceptance of materials is defined otherwise in these specifications, the Contractor shall furnish to the Engineer a manufacturer's certificate of compliance with each shipment of materials, certifying that the materials conform to the specified material requirements. A copy of all test results necessary to assure compliance with the Specifications, shall be submitted to the Engineer along with each manufacturer's certificate of compliance.

7.3.1.2 Shaft Foundations

Shaft foundations shall comply with the requirements of Chapter 17, Drilled Piles, and Chapter 18, Driven Piles, of these standard specifications.

7.3.2 Boundary Walls

7.3.2.1 Description

This work constructs boundary walls, also called perimeter walls or privacy walls, including the following different types:

1. Reinforced concrete walls (refer to Chapter 4, Concrete Works, of these Standard Specifications)
2. Precast post and panel walls, which use precast grooved posts with precast panels slid into the post grooves after the posts are erected, or use of a tilt-up-type panel construction where the posts are cast-in-situ after the panels are set upright
3. Reinforced posts and upper frame with concrete block infill and plastered decorative finish
4. Walls with openings having decorative aluminised grill panel

Boundary walls, as addressed in this section of these standard specifications, are not retaining walls. Boundary walls that are required to retain material shall be constructed as retaining walls in accordance with Chapter 20, Earth Retaining Systems, of these Standard Specifications.

Decorative lighting for boundary walls shall conform to the requirements of Particular Specifications.

7.3.2.2 Materials

Concrete shall be of the compressive strength shown on the Contract plans and shall conform to the applicable requirements of Chapter 4, Concrete Works, unless otherwise shown on the Contract plans.

1. Concrete for precast wall panels shall be Class C30/20.
2. Concrete for shafts shall be Class C30/20P.
3. Concrete Class C30/20W shall be used for shafts placed in water.
4. Concrete for trench, grade beam, or spread footing foundations shall conform to Class C30/20.

Materials shall conform to the requirements of the Contract plans, as approved by the Engineer, and these Specifications, including those sections specifically noted in Table 7-9. Other materials required shall be as specified in the Particular Specifications.

Table 7-9: Materials for boundary walls

Material	Specifications Requirements
PCC and its constituent materials; steel reinforcing bar; premoulded joint filler and waterstops.	Section 4.3 of Chapter 4, Concrete Works, and Section 5.3 of Chapter 5, Reinforcing Steel
Bolts and nuts shall be stainless steel.	ASTM F738M
Paints.	Chapter 24, Painting
Gravel backfill.	Section 2.5 of Chapter 2, Earthworks
Pipe underdrains.	Section 12.1.3 of Chapter 12, Stormwater Drainage
Decorative wall finishes.	Section 7.8

7.3.2.3 Construction Requirements

Excavation and backfill shall be in accordance with the requirements of Articles 2.4.2.11 and 2.5.2.4 of Chapter 2, Earthworks. If shafts are required, they shall be constructed in accordance with the shaft installation plan, as approved by the Engineer and the requirements of Chapter 17, Drilled Piles, and Chapter 18, Driven Piles.

a. Trench, Grade Beam, or Spread Footing Construction

Footing construction shall conform to the requirements of Table 7-10.

Table 7-10: Requirements for trench, grade beam, or spread footing construction

Boundary Wall Foundations Description	Specifications Requirements
Below the existing ground line	Article 2.4.2.11 of Chapter 2, Earthworks, to the limits and construction stages shown in the Contract plans; Article 2.4.2.5 of Chapter 2, Earthworks, for removal of unsuitable soils.
Above the existing ground line	Place and compact backfill material in accordance with Article 2.5.3.2 of Chapter 2, Earthworks.

To retail their configuration during concrete placement, the steel reinforcing bar cage and the boundary wall anchor bolts shall be installed and rigidly braced prior to grade beam and spread footing concrete placement. Contractor shall not place individual or loose steel reinforcing bars and anchor bolts and shall not install anchor bolts during or after concrete placement.

b. Cast-in-situ Concrete Panel Construction

Construction of cast-in-situ concrete panels for boundary walls shall conform to Chapter 4, Concrete Works. Formwork shall comply with the requirements of Section 1.20.8 of Chapter 1, General Requirements.

Cast-in-situ concrete panel tops shall conform to the top of the wall profile shown in the Contract plans and the relevant tolerances included in Table 20-6 of Chapter 20, Earth Retaining Systems. Where a vertical step is constructed to provide elevation change between adjacent panels, the dimension of the step shall be 0.5 m. Each horizontal run between steps shall be a minimum of 15 m long.

c. Precast Concrete Panel Fabrication and Erection

Precast concrete panels shall be fabricated and erected by the Contractor in accordance with Section 4.4.8 of Chapter 4, Concrete Works, and the additional requirements of this section.

An experienced supervisor shall be provided by the Contractor for panel construction and erection having at least 2 years of successful experience in the proposed construction methods, similar to the size and amount required for the project. Personnel may, at the Engineer's option, be required to demonstrate technical competence by performing sample work or by displaying their qualifications or certificates at no additional cost to the Owner.

Unless otherwise noted in the Contract plans and the particular specifications, concrete surfaces shall receive a Class 2 finish in accordance with Section 4.4.3 of Chapter 4, Concrete Works.

Precast concrete panels shall be cast by the Contractor horizontally, with the traffic side surface cast against the form liner on the bottom. These panels shall be fully supported to avoid bowing and sagging surfaces. Formwork shall comply with Section 1.20.8 of Chapter 1, General Requirements.

After receiving the Engineer's approval of the shop drawings, the Contractor shall cast 1 precast concrete panel to be used as the sample panel, which shall be constructed in accordance with the procedure and details specified in the shop drawings approved by the Engineer. These sample panels shall be made available by the Contractor to the Engineer for approval.

Upon receiving the Engineer’s approval of the sample panel, the Contractor shall continue production of precast concrete panels for the boundary wall. All precast concrete panels will be evaluated against the sample panel for the quality of workmanship exhibited. Sample panels shall be retained at the fabrication site until all precast concrete panels have been fabricated and have received the Engineer’s approval. After completing precast concrete panel fabrication, the Contractor may utilise the sample panel in production.

Precast concrete panels for boundary walls shall not exceed the scalar tolerances described in Table 7-11

Table 7-11: Construction tolerances for boundary walls

Parameter	Tolerance
Height of precast boundary wall panel	±3 mm per 1.5 m, not to exceed 6 mm total
Width of precast boundary wall panel	±3 mm per 1.5 m, not to exceed 6 mm total
Thickness of precast boundary wall panel	±6 mm
Difference between the measurement of the diagonal of the faces of the panels	< 13 mm
Offset of precast concrete wall stem panels (Deviation from a straight line extending 1.5 m on each side of the panel joint) - Across panel face - Across top of wall	 ±10 mm ±10 mm
Joint space tolerances	As shown in the Contract plans
Position of wall	10 mm
Alignment of wall	2 minutes
Average levels of wall	+10 mm
Verticality of wall	±10 mm
Surface regularity of wall	3 mm

Precast concrete panels shall not be erected until the foundations for the panels have attained a minimum compressive strength of 24 MPa. Wall panels shall be adequately supported to prevent overturning and to prevent collapse until permanent connections are completed.

Bolts connecting the precast concrete panels to their foundation shall be tightened to snug tight, which is defined as the tightness reached by either a few blows from an impact wrench or the full effort of a person using a spud wrench. If the Contract plans call for welded connections, the Contractor shall meet the structural welding requirements of ACI 551.1R.

Joints between precast concrete panels shall be sealed with a backer rod and sealant system as specified on the Contract plans. Both sides of the joint’s full length shall be sealed.

Precast concrete panel tops shall conform to the top of wall profile shown in the Contract plans. Where a vertical step is constructed to provide an elevation change between adjacent panels, the dimension of the step shall be 0.5 m. Each horizontal run between steps shall be a minimum of 15 m long.

d. Tilt-up Wall Construction

Tilt-up wall construction shall be done as shown on the Contract plans and approved shop drawings. Precast concrete wall panels shall be cast-in-situ, in close proximity to their permanent locations. Sequence for this type of precast construction shall be as follows:

1. Erect the wall panels in place by tilting them up to their permanent location
2. Temporarily brace the panels in place
3. Complete the permanent connections required to secure the precast tilt-up panel
4. Remove the temporary supports

A levelling pad shall be constructed for wall panels using high-strength mortar so that the panel in place will have a level tolerance within 1 to 500. Levelling pads and foundations shall be inspected and any errors, such as levelness or embedded article locations, shall be corrected prior to lifting the wall panels into place.

Contractor may use spreader bars, chockers with equaliser sheaves, adjustable bracing, and other erecting accessories, as required, to place panels in their permanent locations. Bracing equipment must meet applicable codes.

Panels shall be tilted from the casting platform to slope within 1 horizontal to 6 vertical. Their initial setting shall be plumb within 75 mm of true vertical with adjustable braces to vertical tolerance of 1 to 500. Contractor shall leave the braces in place until panels are secured in their final location.

Panel erection shall not commence until representative concrete test cubes have a minimum compressive strength as specified on the Contract plans and Section 4.4.8 of Chapter 4, Concrete Works.

Pickup points in concrete panels shall be located so that concrete tensile stresses during erection do not exceed 10 % of the cylinder compressive strength at time of erection.

Panels may be connected to steel columns, precast concrete columns, or cast-in-situ concrete columns. Details of connecting panels to supporting structures must be indicated on the Contract plans or shop drawings. For cast-in-situ columns, horizontal reinforcing rods at the sides of panels shall extend a minimum of 200 mm into column forms.

Panels shall be bolted to the supporting structure with high-strength bolts that meet the requirements of ASTM A325, Type 1, and then panels shall be welded to the supporting structure.

Joints between wall panels and foundation and joints between wall panels and columns shall be packed with mortar of the class shown in the Contract plans and meeting the requirements of Article 4.3.15.6 of Chapter 4, Concrete Works.

Holes in panels left after lifting rigging has been removed shall be packed with nonshrink mortar meeting the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works, and finished to match adjacent surfaces.

e. Masonry Wall Construction

Construction requirements for masonry boundary walls shall be in accordance with Chapter 6, Masonry.

f. Access Doors and Concrete Landing Pads

Access doors and door frames shall be installed by the Contractor as shown on the Contract plans, with the access doors opening toward the roadway side. Door frames shall be set in place with grout conforming to the requirements for grout for anchor bolts as defined in Article 4.3.10.4 of Chapter 4, Concrete Works, with the grout completely filling the void between the door frame and the boundary wall panel.

Required coats of paint shall be applied by the Contractor, as specified in the Particular Specifications and applicable requirements of Chapter 24, Painting, to all exposed metal surfaces of access doors and frames, except for stainless steel surfaces.

Concrete landing pads shall be constructed on the roadway side of each access door location by the Contractor, as shown in the Contract plans. Concrete shall be Class C25/20.

g. Finish Ground Line

Ground lines on both sides of the boundary wall shall be contoured and dressed by the Contractor to the following specifications:

- Provide the minimum cover over the foundation as shown in the Contract plans
- Ensure good drainage away from the barrier

After the access roads are no longer needed for boundary wall construction activities, the Contractor shall restore the area to the original condition. Access roads shall be recontoured to match the surrounding ground levels, as approved by the Engineer.

7.3.3 Shotcrete Facing

7.3.3.1 Description

This work constructs shotcrete facing, also called pneumatically placed concrete, as shown in the Contract plans.

Shotcrete facing consists of mortar or concrete conveyed through a hose and pneumatically applied to prepared surfaces with reinforcing material in place, using either the dry- or wet-mix processes.

Dry-mix processes consist of thoroughly mixing a proportional combination of dry-fine aggregate and cement and conveying the mixture through a delivery hose to a special nozzle where water is added and mixed with the other materials immediately prior to its discharge from the nozzle.

Wet-mix processes consist of premixing, by mechanical methods, a proportional combination of cement, aggregate, and water required to produce mortar or concrete; conveying the mortar or concrete through the delivery hose to the special nozzle where additional compressed air is added at the nozzle prior to its discharge.

7.3.3.2 Materials

Materials shall conform to the requirements of the Contract plans, these Specifications and as approved by the Engineer, including those sections specifically noted in Table 7-12. Other materials required shall be as specified in the Particular Specifications.

Table 7-12: Materials for shotcrete facing

Material	Specifications Requirements
Shotcrete and its constituent materials; Steel reinforcing bar; Preformed joint filler; Waterstops.	Article 4.3.10.5 of Chapter 4, Concrete Works Chapter 5, Reinforcing Steel Article 4.3.15.2 of Chapter 4, Concrete Works Section 4.3.16 of Chapter 4, Concrete Works
Gravel backfill	Section 2.5 of Chapter 2, Earthworks
Pipe underdrains	Section 12.1.3 of Chapter 12, Stormwater Drainage

Shotcrete shall be proportioned to produce a 30 MPa compressive strength at 28 days, in accordance with Article 4.3.10.5 of Chapter 4, Concrete Works.

7.3.3.3 Construction Requirements

Prior to construction of any shotcrete facing, the Contractor shall do the following:

- Submit and receive the Engineer's approval for shotcrete mix design, proposed methods and equipment to finish and cure the shotcrete, and documentation of the nozzle operators' experience in applying shotcrete per Sub-article a, of Article 7.3.1.1.
- Finely grade, and thoroughly compact, all surfaces on which shotcrete is to be placed to the lines and grades shown on the Contract plans or established by the Engineer
- Uniformly water all surfaces on which shotcrete is to be placed so that water will not be drawn from the freshly placed shotcrete.
- Remove any curing compound on previously placed shotcrete surfaces by sandblasting.
- Install reinforcement of the shotcrete as shown in the Contract plans
    i. Wire reinforcement shall be securely fastened to the steel reinforcing bars so that it will be 25 mm to 38 mm from the face of the shotcrete at all locations, unless otherwise shown in the Contract plans
    ii. Wire reinforcement shall be lapped 1.5 squares in all directions, unless otherwise shown in the Contract plans
- Install noncorroding alignment wires and depth gauges every 2 m longitudinally and transversely, with no less than 2 gauges per increment of surface area to receive the shotcrete, to establish thickness, and plane surface of the completed facing.
- Install alignment wires at corners and offsets not established by formwork. Contractor shall ensure that the alignment wires are tight, true to line, and placed to allow further tightening.
- Complete and receive the Engineer's approval for preconstruction testing.

If forms are used, they shall be plywood sheathing or other suitable material, true to line and grade, and sufficiently rigid to resist deflection during shotcrete placement. They shall be constructed to permit the escape of air and rebound during the gunning operation.

a. Equipment

Equipment to be used shall be approved by the Engineer prior to placement of slope protection. Contractor shall furnish the Engineer with 2 copies of the manufacturer's specifications and operating instructions for the equipment used.

Equipment shall deliver a continuous, smooth stream of uniformly mixed material accurately and at the proper velocity, to produce a uniform shotcrete facing that meets the additional criteria of these specifications. Equipment used with the wet-mix process shall be the pneumatic feed type, unless the Engineer provides written approval of a positive displacement feed type.

For dry-mix shotcrete, the following is required:

1. Nozzle shall be equipped with a manually operated water ring for directing an even distribution of water through the fine aggregate-cement mixture
2. Nozzle water ring shall provide ready adjustment to vary the quantity of water

For wet-mix shotcrete, the following is required:

1. Nozzle shall be fitted with an air ring for injecting additional compressed air into the premixed material flow.
2. Size of delivery hose shall be 32 mm to 64 mm.

3. Air compressors shall have ample capacity to furnish an adequate supply of clean dry air to maintain required nozzle velocity for all phases of the work and simultaneously operate a blow pipe for removing rebound.
4. Air hose shall be equipped with a filter to prevent oil or grease contamination of the shotcrete.

Constant air pressure shall be maintained in the placing machine when using the dry-mix process, or at the nozzle when using the wet-mix process. Minimum required air pressure shall be at least 550 kPa for hoses shorter than 30 m and shall increase by 35 kPa for each additional 15 m of hose or fraction thereof.

b. Testing

A 300-mm by 300-mm shotcrete test panel shall be prepared in accordance with AASHTO T 24M to evaluate shotcrete quality, strength, and aesthetics. Both preproduction and production test panels shall be prepared.

At least 3 cores shall be removed from the preconstruction panels and at least 3 cores from the production panels. All cores obtained for the purpose of shotcrete strength testing shall comply with the following:

1. Core diameter shall be at least 3 times the maximum aggregate size and a minimum of 50 mm
2. Core height shall be a minimum of 1.5 times the core diameter
3. Cores removed from the panels shall be immediately wrapped in wet burlap and sealed in a plastic bag
4. Cores shall be clearly marked to identify from where they were taken and whether they are for preproduction or production testing. For production testing, the section of the wall represented by the cores shall be clearly marked on the cores
5. Cores shall be delivered to the Engineer within 2 hours of coring.

Remaining test panels shall be the property of the Contractor.

c. Preproduction Testing

At least one 300-mm by 300-mm test panel shall be prepared for each mix design for evaluation and testing of the shotcrete quality and strength, and at least one 1.25 m by 1.25 m qualification panel for evaluation and approval of the proposed method for shotcrete installation, finishing, and curing.

All test panels shall be constructed using the same methods and initial curing proposed to construct the shotcrete facing, except that the 300-mm panel shall not include wire reinforcement and shall be constructed to the minimum thickness necessary to obtain the required core samples. Nozzlemen proposed for production shotcreting shall also apply the shotcrete for the preproduction panels.

Qualification panels, measuring 1.25 m in size, shall be constructed to the thickness of the production facing.

Test data and a visual description shall be submitted by the Contractor of each core to the Engineer for approval. Submittal shall include the following:

1. Details concerning presence of voids, sand pockets, lamination, and other inadequacies. Visual quality of the cores shall not be lower than grade 2 according to shotcrete grading requirements of ACI 506.2.
2. Sample identification, including mix designs and test panel numbers and orientation.
3. Date and time of sample preparation, including curing conditions and sample dimensions
4. Date, time, and type of test
5. Complete test results, including load and deformation data during testing, sketch of sample before and after testing, and any unusual occurrences observed
6. Name and signature of person performing the test

7. Location of steel reinforcement, if used, covered by shotcrete
8. Name and experience qualifications of the nozzleman

Production shotcrete work shall not begin until satisfactory test results are obtained and the preproduction panels are approved by the Engineer.

d. Production Testing

Testing of shotcrete shall meet the applicable requirements of Article 4.3.10.5 of Chapter 4, Concrete Works, and as specified herein.

At least one 300 mm by 300 mm panel shall be made for each section of facing shotcrete, where a section is defined as 1-day's placement. Panel thickness shall be as thick as the structure being constructed but not less than 75 mm.

Panels shall be prepared by applying shotcrete mix to a piece of plywood that is true and not warped, bowed, or deformed in any way using the same methods and initial curing used to construct the shotcrete wall; except that production panels shall not have wire reinforcement. Panels shall be constructed to the minimum thickness necessary to obtain the required core samples.

Cores shall be obtained from the panels and tested in accordance with the requirements of AASHTO T 24. Cores shall have a minimum diameter of 75 mm and a length to diameter ratio of at least 1.

Cut surfaces of the test specimens will be carefully examined for soundness and uniformity of the material and shall be free from laminations and sand pockets.

If the production shotcrete is found unsuitable based on the results of the test panels, the sections of the wall represented by the test panels shall be repaired or replaced to the satisfaction of the Engineer at no additional cost to the Owner.

e. Qualifications of Contractor's Personnel

All nozzle operators shall have at least 1-year's experience in the application of shotcrete. Each nozzle operator will be qualified, by the Engineer, to place shotcrete, after successfully completing 1 test panel for each shooting position and surface type expected to be encountered. Satisfactory evidence of such experience shall be provided to the Engineer for approval when requested.

Qualification will be based on a visual inspection of the shotcrete density, void structure, and finished appearance along with a minimum seven-day compressive strength of 17.5 MPa determined from the average test results from two cores taken from each test panel.

Notification shall be provided by the Contractor to the Engineer not less than 2-days prior to the shooting of a qualification panel. Mix design for the shotcrete shall be the same as that planned for the wall being shot.

Shotcrete shall be placed only by personnel qualified by the Engineer. If shotcrete finish Alternative B or C is specified, per Table 7-13, evidence shall be provided that all shotcrete crew members have completed at least 3 projects in the last 3 years where such finishing, or sculpturing, and texturing of shotcrete was performed.

f. Shotcrete Application

Nozzlemen who created acceptable test panels shall be used for production shotcrete application.

During construction, the Contractor shall protect all retaining walls, columns and structures from concrete splash or overspray. Suitable covering shall be provided if such protection is deemed necessary by the Engineer.

Shotcrete shall be applied within 45 minutes of adding cement to the mixture. As shotcrete leaves the nozzle, its velocity shall be maintained uniform and at a rate approved by the Engineer for the given job conditions. Rebound or previously expended material in the shotcrete mix shall not be used in any portion of the work. All rebound shall be removed prior to final set and before placement of the shotcrete on adjacent surfaces.

Shotcrete shall not be applied during any precipitation of sufficient intensity that can cause the in-place shotcrete to run or during wind conditions that can cause separation of the nozzle flow.

A clean, dry supply of compressed air that is sufficient for maintaining adequate nozzle velocity for all parts for the work and for simultaneous operation of a blow pipe for cleaning away rebound shall be maintained at all times. Thickness, method of support, air pressure, and rate of placement of shotcrete shall be controlled to prevent sagging or sloughing of freshly applied shotcrete. If the shotcrete must be applied in 2 layers to achieve the required thickness without sagging or sloughing, an initial layer of shotcrete may be placed, broomed, or scarified, and allowed to harden. Surfaces may then be dampened and an additional layer applied.

Shotcrete shall be applied from the lower part of the area upwards. Surfaces to be shot shall be damp, but free of standing water. Nozzles shall be held at an angle approximately perpendicular to the working face and at a distance that will keep rebound at a minimum and compaction will be maximised, typically 600 mm to 1,500 mm. Shotcrete shall emerge from the nozzle in a steady, uninterrupted flow.

If, for any reason, the flow becomes intermittent, the nozzle shall be diverted from the work until a steady flow resumes. Surface defects shall be repaired as soon as possible after initial placement of the shotcrete. All shotcrete that lacks uniformity, which exhibits segregation, honeycombing, or lamination — or which contains any dry patches, slugs, voids, or sand pockets — shall be removed and replaced with fresh shotcrete by the Contractor, to the satisfaction of the Engineer and at no cost to the Owner.

Premolded expansion joint material measuring 13 mm thick and conforming to the requirements of Article 4.3.15.2 of Chapter 4, Concrete Works, shall be placed at 18 m intervals on all shotcrete or concrete bank protection. Weakened plane joints, or scoring, shall be at 4.5 m intervals between expansion joints. All expansion joint material shall extend the full depth of the concrete being placed and shall be flush with the top of the finished surface; furthermore, expansion joint material shall be supported, prior to the placement of the concrete, as to ensure tight joints. Reinforcing material shall be cut at all expansion joints.

Construction joints in the shotcrete shall be uniformly tapered over a minimum distance of twice the thickness of the shotcrete layer. Surface of the joints shall be cleaned and thoroughly wetted before adjacent shotcrete is placed. Shotcrete shall be placed in a manner that provides a finish with uniform texture and colour across the construction joint. Square construction joints shall not be used.

When shotcrete is specified in the Contract plans as the final fascia finish, the curing requirements specified in Section 4.4.2 of Chapter 4, Concrete Works, shall apply. For intermediate shotcrete surfaces, or if a stained or finished final surface is required, liquid membrane-forming curing compound method of curing shall not be used. Shotcrete shall be cured by applying a clear liquid membrane-forming curing compound in accordance with Article 4.4.2.3 of Chapter 4, Concrete Works. Curing compounds shall be applied immediately after final gunning. Two coats of curing compound shall be applied to the shotcrete surface immediately after finishing.

If field inspection or testing, by the Engineer, indicates that any shotcrete produced fails to meet the requirements, the Contractor shall immediately modify procedures, equipment, or system, as necessary — and as approved by the Engineer — to produce material that meets requirements. All substandard shotcrete already placed shall be repaired by the Contractor, to the satisfaction of the Engineer, at no additional cost to the Owner. Such repairs may include removal and replacement of all affected materials.

Contractor shall remove alignment wires after facing construction is complete.

A written report shall be prepared and submitted by the Contractor to the Engineer within 24 hours of shotcrete production and application for each shift. Report shall include the following:

1. Quantity and location of shotcrete applied, including sketches of the areas placed
2. Observations of success or problems of equipment operation, application, final product condition, and any other relevant issues during production and application

3. Batch numbers, if applicable
4. Name of nozzleman
5. Names and signature of person performing the observation

g. Shotcrete Finishing

After the shotcrete has been placed as nearly as practicable to the required thickness and shape outlined by forms and ground wires, the surface shall be checked with a straightedge and any low spots or depression shall be brought up to proper grade by placing additional shotcrete in such a manner that the finished surface shall be smooth and uniform.

When the shotcrete facing is an interim coating to be covered by a subsequent shotcrete coating or a cast-in-situ concrete fascia later under the same Contract, the Contractor shall strike-off the surface of the shotcrete facing with a roughened surface as specified in Section 4.4.4 of Chapter 4, Concrete Works. Grooves of the roughened surface shall be either vertical or horizontal.

When the shotcrete facing provides the finished exposed final surface, the shotcrete face shall be finished using the alternative aesthetic treatment shown in the Contract plans. Alternatives are described in Table 7-13. Shotcrete surfaces shall have a natural gun finish, unless otherwise shown on the Contract plans or specified in the Particular Specifications, as approved by the Engineer.

Table 7-13: Aesthetic alternatives for shotcrete facing

	Description
A	After the surface has taken its initial set (crumbling slightly when cut), the surface shall be broom finished to secure a uniform surface texture.
B	Shotcrete shall be applied in a thickness a fraction beyond the alignment wires and forms. Shotcrete shall stiffen to the point where the surface does not pull or crack when screeded with a rod or trowel. Excess material shall be trimmed, sliced, or scraped to true lines and grades. Alignment wires shall be removed and the surface shall receive a steel trowel finish, leaving a smooth uniform texture and colour. Once the shotcrete has cured, pigmented sealer shall be applied to the shotcrete face. Shotcrete surface shall be completed to within a tolerance of 13 mm of true line and grade.
C	Shotcrete shall be hand-sculptured, coloured, and textured to simulate the relief, jointing, and texture of the natural backdrop surrounding the facing. Ends and base of the facing shall transition in appearance as appropriate to more nearly match the colour and texture of the adjoining roadway fill slopes. This may be achieved by broadcasting fine and coarse aggregates, rocks, and other native materials into the final surface of the shotcrete while it is still wet, allowing sufficient embedment into the shotcrete to become a permanent part of the surface.

7.3.4 Gravity Walls

7.3.4.1 Description

This work shall consist of furnishing and installing units for gravity walls in accordance with the details shown on the Contract plans as required herein or as described in the Particular Specifications, as approved by the Engineer. Gravity walls retain earth by virtue of their mass, without reinforcement that extends into the retained earth. Types of gravity walls are described herein, as follows:

- Rock wall, Article 7.3.4.2
- Concrete block wall, Article 7.3.4.3
- Gabion wall, Article 7.3.4.4

7.3.4.2 Rock Wall

a. Materials

Rock for rock walls and chinking material shall consist of hard, sound, and durable material, free from seams, cracks, and other defects that can destroy its resistance to weather, and shall meet the minimum requirements of Table 7-14.

Table 7-14: Requirements for rock for rock walls and chinking material

Test	Test method	Requirements
Specific gravity	AASHTO T 85	2.55 minimum
LA wear	AASHTO T 96	50 % maximum
Absorption	AASHTO T 85	3 % maximum

Rock for rock wall sizes are approximately as described in Table 7-15. Minimum average dimension of chinking material shall be 100 mm.

Table 7-15: Sizes of rock for rock wall

Rock size	Rock Weight (kg)	Average Dimension (mm)
One man	20 to 90	300 to 450
Two man	90 to 300	450 to 700
Three man	300 to 900	700 to 925
Four man	900 to 1,800	925 to 1,225
Five man	1,800 to 2,700	1,225 to 1,375
Six man	2,700 to 3,600	1,375 to 1,525

Backfill for rock walls shall be crushed gravel measuring between 50 mm and 150 mm in size. Acceptance shall be determined by visual inspection by the Engineer.

Gabion cribbing, wire mesh fabric, polyvinyl-chloride coating for welded-wire mesh fabric, gabion basket fasteners, and stone shall be as described in Sub-article b, of Article 7.3.4.4. Construction geotextile shall be as defined in Article 2.5.2.9 of Chapter 2, Earthworks.

b. Construction Requirements

Completed wall shall meet the tolerances of Table 7-16.

Table 7-16: Geometric tolerances for rock walls

Wall Dimension	Tolerance
Wall batter	6:1 or flatter as specified in the Contract plans
Exterior slope plane and grade	±150 mm
Maximum void between adjacent rocks	150 mm, as measured at the smallest dimensions of the void within the thickness of the wall

Excavation shall conform to the requirements of Article 2.4.2.11 of Chapter 2, Earthworks, of these standard specifications, and to the limits and construction stages shown on the Contract plans. Excavation limits shall be restricted by the Contractor to the length of rock wall that can be constructed in one day of work, except as otherwise noted. Excavation beyond these limits may be permitted by the Engineer provided the Contractor either demonstrates that the excavation will remain stable until the rock wall is completed, or the Contractor shores the excavation in accordance with Article 2.4.2.11 of Chapter 2, Earthworks.

Slope above the rock wall shall be established prior to excavating for the wall. For rock walls constructed in fills, the fill shall be overbuilt and cut back to construct the wall.

An L-shaped sample section of wall shall be constructed at least 1.5 m high and 2.5 m long, demonstrating construction of the following elements:

- Face wall
- Top wall
- Method of turning corners
- Method of forming joints

Prior to rock placement, the foundation, if not in rock, shall be compacted as approved by the Engineer. Any foundation soils found to be unsuitable shall be removed and replaced in accordance with Article 2.4.2.7 of Chapter 2, Earthworks.

Geotextile placement shall be as shown on the Contract plans.

Rocks shall be placed to conform to the following requirements:

1. Foundation masonry may be constructed at any time
2. Bottom course of rocks shall be in full contact with the foundation soils. If necessary, the excavation shall be shaped to fit the rocks. Rocks may be dropped to shape the ground provided the rocks do not crack. Cracked rocks shall be replaced and the foundation regraded to fit the replacement rock
3. There shall be no continuous joint planes in either the vertical or lateral direction
4. Face stones shall be set in random bond to produce the effect shown on the Contract plans and to correspond with the approved sample section
5. Each rock shall bear on at least 2 rocks below it, where possible
6. Each face stone shall bond with all contiguous face stones at least 150 mm longitudinally and 50 mm vertically
7. Rock orientation shall consist of the following:
   i. Maximise flat surface contact points between adjacent rocks
   ii. Minimise point-to-point contact between adjacent rocks
   iii. Arrange natural irregularities in the rocks so as to key the rocks together and to key the courses together

In constructing rock masonry walls, the Contractor shall not do the following:

- Construct any masonry other than foundation masonry until the sample is approved
- Extend beds in an unbroken line through more than 5 rocks
- Extend joints through more than 2 rocks
- Construct so that the corners of four stones are adjacent to each other
- Group small rocks or rocks of the same size, colour, or texture

Rocks shall increase in size from the top of the wall to the bottom at a uniform rate. Minimum rock sizes, as referenced from the top of the wall, shall be as in Table 7-17.

Table 7-17: Minimum rock sizes

Depth from Top of Wall (metres)	Minimum Rock Size at Depth from Top of Wall
Top of wall	Two man or larger
6	Three man
9	Four man
12	Five man

Where voids larger than 150 mm are present, chinking rock shall be keyed between the rocks to fill the void. Backfill for the rock wall shall be placed behind each course and tamped to provide a stable condition prior to placing rocks for the next successive course.

Where headers are required, the Contractor shall distribute headers uniformly throughout the walls of structures to form at least 20 % of the faces.

Individual rocks composing the backing and heart shall be bonded with the rocks in the face wall and with each other, where applicable, per the wall design shown on the Contract plans. All openings and interstices in the backing shall be filled completely with mortar or with quarry spalls surrounded completely by mortar.

Copings shall be constructed as shown on the Contract plans. Where coping is not required, the top of the wall shall be finished with rocks measuring 0.5 m to 1.5 m long, at least 150 mm high, and wide enough to cover the top of the wall. Rock heights shall be random for the top course, and rocks shall be laid such that the top course is an integral part of the wall, pitched to line in both vertical and horizontal planes.

Parapet walls shall be constructed with selected stones, squared, and pitched to line, with heads dressed in the ends and in all exposed angles and corners. Headers shall be interlocked with as many headers as possible, extending entirely through the wall. Both the headers and stretchers shall be interlocked in the 2 faces of the wall. Headers and stretchers shall comprise nearly the whole volume of the wall. All interstices and spalls shall be completely filled with mortar.

Weep holes shall be installed for all walls and abutments at the lowest points where free outlets can be obtained. Weep holes shall be spaced no more than 3 m centre-to-centre.

7.3.4.3 Concrete Block Wall

a. Description

Concrete block walls are defined as a wall of modular blocks acting as a gravity wall to retain soil or act as a boundary wall. Modular blocks may have features designed to interlock the blocks together. However concrete block walls shall not include reinforcement of the retained soil, nor any reinforcement connection between the modular blocks and the retained soil. Concrete block walls shall be constructed as shown in the Contract plans and as specified in the Particular Specifications.

b. Materials

Materials for concrete blocks and mortar shall conform to the requirements of Section 6.2.2 of Chapter 6, Masonry.

c. Construction Requirements

Construction requirements shall conform to Section 6.2.3 of Chapter 6, Masonry.

7.3.4.4 Gabion Wall

a. Description

Gabion walls consist of flexible galvanised or aluminised steel-wire mesh baskets or mattresses, called gabion cages, filled with stone. Gabion cages shall be constructed from wire of a specified thickness with uniform openings and coated as the Contract plans and these Specifications require. For gabion walls, earth is retained by virtue of the weight of the filled wire baskets.

b. Material

Materials shall conform to the specific requirements of this section, and additional materials shall be as specified in these Specifications. Of particular note are the materials in Article 2.5.2.9 of Chapter 2, Earthworks, specifically: geotextile fabric, backfill, and base course.

1. **Gabion Baskets and Mattresses**

Gabion cages shall be either baskets, typically used for wall applications, or mattresses, which are typically used as single-layer aprons for revetments or channel lining type applications. Dimensions shall be as shown on the Contract plans or as approved by the Engineer. Typical dimensions for each shall be as in Table 7-18. Gabions shall be furnished in the required dimensions, ±5 %.

Table 7-18: Typical gabion basket and gabion mattress dimensions

Dimension	Basket	Mattress
Length	1 m, 2 m, 3 m, and 4 m	6 m
Width	1.0 m	2.0 m
Depth	0.3 m, 0.5 m, and 1 m	0.2 m, 0.3 m, and 0.5 m
Diaphragm spacing	1.0 m	0.6 m or 1.0 m

Wire for the construction of gabions shall be either galvanised steel wire conforming to ASTM A 641M, Class 3, soft temper, or aluminised steel wire conforming to ASTM A809, soft temper. Wire shall have a minimum tensile strength of 415 MPa when tested in accordance with ASTM A370. Properties of gabion baskets shall conform to Table 7-19. Only one type of mesh and protective coating shall be used throughout a structure. Tolerance on the specified diameter of all wire shall be ±2.5 %.

Table 7-19: Requirements for gabion baskets

Property	Requirement for baskets	
	≥ 300 mm in the vertical dimension	< 300 mm in the vertical dimension
Nominal dimensions of the mesh openings	≤ 115 mm	≤ 85 mm
Maximum area of any mesh opening	≤ 65 cm^2	< 39 cm^2
Hexagonal twisted wire mesh		
Nominal wire size (galvanized or aluminized)	3 mm	2.2 mm
Minimum selvedge wire diameter	3.8 mm	2.7 mm
Welded wire mesh		
Diameter of galvanized steel wire for fabricating mesh	2.7 mm	2.0 mm

Property	**Requirement for baskets**	
	≥ 300 mm in the vertical dimension	**< 300 mm in the vertical dimension**
Size of rectangular openings	75 mm by 75 mm	38 mm by 75 mm
PVC coating, if required		
Nominal thickness	0.55 mm	0.55 mm
Minimum thickness	0.38 mm	0.38 mm

Gabion baskets shall be either hexagon-twisted wire mesh or welded wire mesh with the following properties, as applicable:

i. Hexagon twisted wire mesh, per ASTM A 975:

a) Formed from galvanised or aluminised wire

b) Uniform hexagonal pattern with nonravelling double twist

c) Perimeter edges of the mesh for each panel tied to a selvedge wire that is the same composition as the body mesh

ii. Welded wire mesh, ASTM 974:

a) Fabricated from galvanised steel wire, galvanised before fabrication

b) Uniform rectangular pattern with a resistance weld at each connection in accordance with ASTM A 185M

c) PVC coating, if required, fusion bonded to the welded wire mesh

A manufacturer's certificate of compliance stating that wire baskets or mattresses, stiffeners, lacing wire, and spiral connectors conform to the requirements established herein shall be provided by the Contractor to the Engineer.

Wire mesh shall be fabricated in a manner to be nonravelling, meaning the wire mesh shall resist pulling apart at any of the connections forming the mesh when a single strand in a section of mesh is cut.

PVC coating shall apply to welded wire mesh only and PVC-coating material shall be accepted by certified test reports of an independent laboratory. Initial properties of PVC-coating material shall have a demonstrated ability to conform to the requirements of Table 7-20.

Table 7-20: Material requirements for PVC coating

Property	**Test Method**	**Requirement**
Specific gravity	ASTM D792	1.2 to 1.4
Tensile strength	ASTM D638	≥ 15.75 MPa
Modulus of elasticity	ASTM D638	≥ 13.65 MPa at 100 Strain
Shore A-hardness	ASTM D2240	≥ 75
Brittleness temperature	ASTM D746	≤-9.4° C

Property	Test Method	Requirement
Salt spray exposure and ultraviolet (UV) light exposure	ASTM B117	PVC shall show no effect after the following: 3,000 hours of salt spray exposure; and, 3,000 hours of UV light exposure using apparatus Type E, 63° C, and ASTM D1499. After the salt spray test and UV light exposure specified above, the PVC coating shall not crack, blister, split, nor exhibit visible change in colour, and material properties shall be within the following: ±6 % of original specific gravity. ±25 % of original tensile strength. ±25 % of original modulus of elasticity. ±10 % of original resistance to abrasion.

Where selvedge is not woven integrally with the mesh but has to be tied to the cut ends of the mesh, it shall be attached by tying the cut ends of the mesh to the selvedge, so that a force of not less than 8.5 kN applied in the same plane as the mesh at a point on the selvedge of a mesh sample of 1m in length will be required to separate it from the mesh.

Diaphragms and end panels require selvedge on the top and vertical sides only. End panels shall be attached by the cut ends of the mesh wires at the bottom of the panel being twisted around the selvedge on the base of the gabion. Similarly, diaphragms shall be attached by the cut ends of the mesh being twisted to the joints of the mesh in the base of the gabion. In all cases, at least 6 kN/m of force shall be required to separate panels from the base.

2. Fasteners for Basket Assembly

Fasteners shall consist of one or more of the following materials:

- Lacing wire, nominal sized 2.2 mm galvanised steel wire or aluminised steel wire, with the same coating as the basket mesh
- Spiral binders, for welded wire panels, nominal diameter 2.7 mm steel wire with a 75mm pitch having the same specifications and coating as the wire mesh
- Alternate fasteners must remain closed when subjected to a 2.67 kN tensile force when confining the maximum number of wires to be confined. Installation procedures and test results for alternate fasteners shall be submitted for approval. Alternate fasteners shall be approved by the Engineer prior to use

Internal connecting wires shall be the same as required for lacing wire. Alternate stiffeners may be used with the gabion manufacturer's approval.

3. Fabrication of Baskets

Gabions shall be made so that the sides, ends, lid, and diaphragms can be assembled into rectangular baskets of the required sizes at the work site. Common wall construction may be used in gabion structures up to 4 m high. Common wall construction includes any basket that uses its top to serve as the bottom of the one above it, or where one wall also serves as a wall to an adjacent basket. When gabion structures are more than 4 m high, the baskets shall have independent sides, ends, top, and bottom.

Each gabion shall be divided by diaphragms into cells the same length as horizontal basket width. Diaphragms shall be made of the same mesh and gage as the basket body. All perimeter and diaphragm edges shall be laced or clipped together so that joints are at least as strong as the body of the mesh itself. Ends of the lacing shall be anchored by three tight turns around the selvage wire.

Strength and flexibility at a point of connection shall be at least equal to that of the mesh.

4. Stone

Gabions shall be filled with clean, hard, durable stone as approved by the Engineer. Stone shall be free of shale, caliche, or other soft particles and shall be dense enough to pass the unit weight test described in the construction requirements of this section while meeting the requirements for gradation in Table 7-21.

Table 7-21: Gradation and fracture requirements of stone for filling gabions

Sieve size	Percent passing
200 mm square	100
150 mm square	75 to 90
100 mm square	0 to 10
Percent fracture	75 minimum

c. Construction Requirements

1. Foundations

Before placing any gabion cribbing, the Contractor shall excavate the foundation or bed to the specified width, line, and grade in accordance with Article 2.4.2.11of Chapter 2, Earthworks. Foundation soils found to be unsuitable shall be removed and replaced in accordance with Article 2.4.2.7 of Chapter 2, Earthworks. Excavation for toe or cut-off walls shall be made to the neat lines of the wall.

For rocky foundations, 200 mm of aggregate material meeting the requirements of Table 2-4 of Chapter 2, Earthworks, shall be placed under the wall base elements.

Where required, a foundation trench along the toe of the revetment or wall shall be excavated to the dimensions shown on the Contract plans or indicated by the Engineer.

Where geotextile filter fabric is required, it shall be placed as shown on the Contract plans with minimum overlaps of 300 mm by 1,000 mm. Its movement shall be prevented during filling of the gabion cages by a method acceptable to the Engineer.

2. Baskets

Gabion baskets and mattresses may be fabricated from either woven or welded steel wire, but, a gabion structure shall not include both. Baskets may be assembled with fasteners that meet the requirements of Sub-article b, of Article 7.3.4.4, but a perimeter or diaphragm edge shall not include both lacing wire and clip fasteners.

During basket assembly, structure erection, cell filling, or backfilling, the Contractor shall take care not to damage wire coatings. Any damage shall be repaired to the satisfaction of the Engineer, or the damaged portion removed and replaced at no additional cost to the Owner. Basket panels shall be rotated into position and the vertical edges joined with fasteners. Temporary fasteners may be used for basket assembly, if they are supplemented during structure erection with permanent fasteners. Diaphragms shall be rotated into position and joined along the vertical edges.

All perimeter edges of gabions are to be securely selvaged or bound so that the joints formed by tying the selvages have at least the same strength as the body of the mesh.

3. Filling Baskets

Kinks and folds in the wire mesh shall be removed prior to filling the gabion cages, which shall be aligned per the Contract plans and then filled with stone placed and compacted to meet the unit weight requirements of Paragraph 4 below.

Stone shall be placed in compacted layers not more than 350 mm deep then tamped or vibrated. If cross-connecting wires are required, the Contractor shall adjust the number and depth of layers so that wires occur between the compacted layers of stone. Internal connecting wires shall be placed in each unrestrained exterior basket cell greater than 0.3 m high, including interior basket cells left temporarily unrestrained. Internal connecting wires shall be placed concurrently with rock placement.

Stone shall be placed in close contact in the unit to minimise voids. Gabion cages may be filled by machine with sufficient hand work to accomplish requirements of this specification. Exposed face or faces shall be hand-placed using selected stones to prevent bulging of the gabion cell and to improve appearance.

Care shall be taken to protect the vertical panels and diaphragms from being bent during filling operations. Last lifts of stone in each cell shall be level with the top of the gabion to properly close the lid and provide an even surface for the next course.

4. Unit Weight Requirements and Test

One unit weight test shall be conducted by the Contractor to test for each 380 m3 of gabions placed. Specified frequencies of the provided tests may be reduced by the Engineer, provided the specified minimum unit weight has been consistently achieved.

Either of the following unit weight tests shall be conducted to prove the density of completed gabions:

i. A filled gabion basket shall be selected from the completed structure and weighed

ii. A gabion basket shall be filled with stone from a loaded truck that has been weighed. After filling, the truck and unused stone shall be weighed again. Differences between the weights shall be used to determine the weight per m^3 of the stone in the gabion.

Minimum unit weights of the filled gabion basket shall be 1,600 kg/m3. Should the unit weight be less than required, the Engineer shall reject the gabion and require the Contractor to pass additional unit weight tests before completing other gabions.

5. Gabion Basket Erection

Empty gabion baskets shall be placed on the foundation and adjacent baskets interconnected along the top and vertical edges using permanent fasteners. Where lacing wire is used, wire shall be wrapped with alternating single and double loops every-other mesh opening, and not more than 150 mm apart. Where spiral binders are used, ends shall be crimped to secure the binders in place. Where alternate fasteners are used, they shall be spaced in every mesh opening and not more than 150 mm apart.

Each row or tier of baskets shall be reasonably straight and shall conform to alignment and grade. Hexagonal mesh baskets shall be stretched endwise before filling. Each basket shall be filled completely so that the secured lid rests upon layer of stones. Each basket shall be laced securely to all adjacent baskets and its lid then laced or clipped to the sides, ends, and diaphragms, in the manner described above.

Gabion cage corners shall be securely wired together to provide a uniform surface and ensure that the surface does not resemble a series of blocks or panels.

All selvage wires at the end of adjacent baskets shall be laced together. Bottom selvage of the basket being constructed on a previously constructed basket shall be laced to the top of that basket. Empty gabions stacked on filled gabions shall be laced to the filled gabion at the front, side, and back. Vertical joints between baskets of adjacent rows and layers shall be staggered by at least one cell length.

After filling the baskets, the Contractor shall secure the lids to the sides, ends, and diaphragms in the manner described above. All exposed basket surfaces shall be smooth and neat with no sharp rock edges projecting through the wire mesh.

Backfilling behind or around gabions shall conform to Section 2.5 of Chapter 2, Earthworks, using an acceptable, lightweight mechanical or vibratory compactor within 1-m of the gabion baskets. Fine grained soil backfill shall be separated from the stone filled baskets by a layer of geotextile fabric and aggregate material meeting the requirements of Table 2-4 of Chapter 2, Earthworks, unless otherwise shown on the Contract plans or approved by the Engineer.

All necessary bolts, nuts, and hardware shall be supplied by the Contractor for complete assembly of the units into a continuous wall of connected units. Gabion walls shall be erected according to the fabricator's or manufacturer's instructions. On curves, the proper curvature for the face shall be obtained by using shorter stringers in the front or rear panels. Walls shall be constructed to within ±25 mm from the lines and elevations shown on the Contract plans.

6. Gabion Mattress Erection

Gabions forming aprons and revetments shall be filled by random stones packed in the first layer and selected stones used for the top layer, so as to resemble normal stone riprap. Least dimension of stones for gabion mattress applications shall be as shown on the Contract plans, typically 75 mm to 300 mm.

7.4 Slope Protection

This work shall consist of preparing the foundation and applying materials to protect a slope in accordance with the Contract plans, Particular Specifications and requirements of these Specifications, as approved by the Engineer. Work shall conform with the locations, lines, grades, and dimensions as shown on the Contract plans or as staked by the Engineer or any other innovative but economical solution not mentioned herein but approved by the Engineer and the DoT/ Mnucipalities at no extra cost to client. Various approaches to slope protection are discussed herein and as follows:

- Slope paving, Section 7.4.1
- Wire mesh slope protection, Section 7.4.2
- Riprap slope protection, Section 7.4.3
- Coarse aggregate covering, Section 7.4.4

7.4.1 Slope Paving

7.4.1.1 Description

This work consists of covering a graded slope with cast-in-situ-reinforced concrete, brick, precast concrete blocks, grouted rock, or cellular concrete blocks.

7.4.1.2 Materials

Materials shall conform to the requirements of the Contract plans, the Engineer, and these Specifications, including those sections specifically noted in Table 7-22. Other materials required shall be as specified in the particular specifications.

Table 7-22: Materials for concrete slope paving

Material	Specifications Requirements
Bedding course Gradation Liquid limit	 AASHTO T 27, AASHTO T 11 AASHTO T 89
Concrete and its constituent materials	Section 4.3 of Chapter 4, Concrete Works
Grout	Article 4.3.10.4 of Chapter 4, Concrete Works
Shotcrete for slope paving Cement, water, aggregate; Wire mesh reinforcement	Article 4.3.10.5 of Chapter 4, Concrete Works Section 4.3 of Chapter 4, Concrete Works Section 7.4.2
Concrete masonry blocks, precast concrete blocks, brick, cellular concrete blocks, mortar	Section 6.2.2 of Chapter 6, Masonry
Rock* and mortar for rock masonry	Section 6.3.2 of Chapter 6, Masonry
Geotextile for separation or soil stabilization	Article 2.5.2.9 of Chapter 2, Earthworks
Topsoil	Article 2.2.2.5 of Chapter 2, Earthworks
*Rock for slope paving shall conform to the requirements of Article 6.3.2.1 of Chapter 6, Masonry, unless otherwise shown on the Contract plans or directed of the Engineer.	

7.4.1.3 Construction Requirements

a. Footing and Preparation of Slope

Surfaces requiring slope protection shall be thoroughly compacted and neatly trimmed to conform to the line, grade, and detail in the Contract plans. Minimum required compaction for slopes where bedding course is installed shall be 3 passes of a lightweight mechanical tamper, roller, or vibratory system.

Excavation and backfill for the slope foundation shall be constructed in accordance with Article 2.4.2.11of Chapter 2, Earthworks. Footings, if required, shall be unreinforced concrete, as shown in the Contract plans. No curing or strength testing of the footing concrete is required, and a wood float finish is acceptable. Footing costs shall be incidental to the slope protection with no separate measurement or payment.

When required, geotextile shall be placed per Section 2.7 of Chapter 2, Earthworks. Ends of the geotextile shall be buried for anchorage. Strips shall be pinned at 1.5 m intervals to hold the geotextile lap in place until concrete is placed. Any torn or punctured geotextile shall be repaired or replaced in accordance with Section 2.7.3 of Chapter 2, Earthworks.

b. Installing Brick, Precast Concrete Blocks, and Grouted Rock

Brick, precast concrete blocks, or rock shall be placed in the following manner:

- In a uniform plane

- Starting at the bottom of the slope
- Such that they rest firmly and evenly against the slope with no rocking
- In horizontal parallel courses with the longest dimension placed parallel to the bottom of the slope and flat faces along the plane of the finished slope protection
- Such that joints in successive courses do not align with joints in the preceding course

After each brick or block is placed, mortar shall be applied on the exposed sides in such quantities that when the adjacent brick or block is placed and rammed into position, the mortar is within 13 mm of the surface and not protruding above the top.

Brick and masonry block joints shall be 13 mm wide, or less. Grouted rock joints shall be 25 mm wide, or less. All mortar stain shall be cleaned from the surface.

For grouted rock installation, rocks shall be placed as described above, and then grouted in sections. A heavy flat steel sheet dropped from a height of 2 m may be used to flatten and level the rock surface after placement of the rock and prior to grouting.

c. Architectural Grouted Rock Placement

Work shall be performed as described in Sub-article b, of Article 7.4.1.3, with the following additional requirements:

1. Rock shall conform to one of the classes of masonry work defined in Section 6.3.3 of Chapter 6, Masonry
2. Grout shall be Class G6, meeting the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works
3. Rock shall be installed by masons experienced in the work. Documentation of each mason's experience shall be provided by the Contractor upon request of the Engineer
4. Rock shall be selected for appearance; colour; grain pattern; and smooth, large, flat surfaces to be placed on top. Rock selection shall be in accordance with the Contract plans and the direction of the Engineer
5. Rock shall be placed on a mortar bed conforming to the thickness requirements in Section 6.3.3 of Chapter 6, Masonry. Unless otherwise shown on the Contract plans, mortar shall meet the requirements of Section 6.3.2 of Chapter 6, Masonry, and may be preblended or mixed on-site. Mortar beds shall not lay longer than 45 minutes or until mortar begins to set before placing rock.
6. Freshly placed rock shall be damp cured for at least 72 hours prior to grouting.
7. Pointing and grouting material shall be the same as for the mortar bed.
8. Test sections shall be prepared for approval of the Engineer regarding colour, shape, smoothness, technique, and overall aesthetic. Test sections shall be required for each set of different sizes or colours or patterns, as required on the Contract plans or the Particular Specifications.
9. Test sections shall be either of the following:
    - Placed on the worksite. In this case, acceptable test sections may be incorporated into the works after approval by the Engineer, and unacceptable test sections shall be removed and replaced until the test section is approved by the Engineer
    - Placed on test panels measuring at least 3 m on a side. Backings shall be either plywood or existing ground at a location outside the worksite. In this case, test sections shall be removed and redone, if unacceptable
10. Acceptable test sections shall be preserved and protected from damage, including sunlight, until all permanent installations have received the Engineer's approval

d. Placing Cellular Concrete Blocks

Cellular concrete blocks shall be placed according to the Contract plans, starting in a trench or against a suitable anchorage at the bottom of the slope. Each block shall be laid perpendicular to the slope and bed firmly against adjoining blocks. Misaligned joints or breaks at slope changes shall be filled with grout. Individual blocks shall not be grouted to each other.

Topsoil shall be spread loosely over the cellular block slope paving, partially filling the cell openings. If required, turf establishment shall be performed as shown on the Contract plans.

e. Cast-in-situ Reinforced Concrete

Prior to concrete placement, surfaces shall be damp, but application shall not be made on any surface on which freestanding water exists.

Wire mesh reinforcement shall be placed continuously through joints with minimum laps of one mesh spacing, or 150 mm, whichever is greater. Laps shall be securely fastened at the ends. During the placement of the concrete, the reinforcement shall be secured so as to provide at least 30 mm of cover.

Concrete placement shall begin at the bottom of the slope. Methods for depositing and compacting concrete shall result in a compact, dense, and impervious concrete with a uniform plane surface. Horizontal joints shall be parallel to the bottom of the slope. Vertical joints shall be perpendicular to the horizontal joints. Cold joints shall not require filler.

Newly constructed concrete shall be finished per Article 7.6.4.4 with additional details as shown in the Contract plans. Outside edges of the slab and all joints shall be finished with a 6 mm radius edging tool.

Curing shall be performed in accordance with Article 3.8.3.8 of Chapter 3, Pavement.

Additional requirements for poured concrete slope protection shall be as follows:

- Concrete shall be the class shown in the Contract plans, or Class C15/20, in conformance with Chapter 4, Concrete Works.
- Toe walls shall be constructed as necessary or indicated on the Contract plans or at the direction of the Engineer.

For shotcrete slope protection, the Contractor shall comply with the requirements of Section 7.3.3.

7.4.2 Wire Mesh Slope Protection

7.4.2.1 Description

This work constructs wire mesh slope protection in accordance with these Specifications and the details, lines and dimensions shown on the Contract plans, as approved by the Engineer.

7.4.2.2 Materials

All metal material used in the construction of wire mesh slope protection shall be new and galvanised. Imperfectly galvanised material or material upon which serious abrasion of galvanising occurs will not be acceptable. Materials shall further conform to the requirements of Table 7-23 and Table 7-24.

Wire mesh for slope protection shall be either diamond chain-link or hexagonal double-twisted, conforming to the respective requirements of Table 7-23. Wire shall be galvanised prior to weaving and mesh shall be of nonraveling construction. Edges shall be selvedged so as to prevent unraveling and develop the full strength of the mesh.

Table 7-23: Material requirements for wire mesh reinforcement

Property	Requirements for Diamond Chain-Link	Requirements for Hexagonal Double-Twisted
Meeting the requirements of:	AASHTO M 181	ASTM A641M, Class 3, finish 5, soft temper
Steel wire diameter	3.8 mm	3.0 mm**
Galvanizing*	ASTM A392, zinc coating shall be ≥250 g/m^2 uncoated wire surface	Zinc coating ASTM A641M tested in accordance with ASTM A370. High grade or special high grade in accordance with ASTM B6, Table 1. Weight determined by ASTM A90.
Size of opening in mesh	90 mm by 140 mm	85 mm by 115 mm, about 60 cm^2
Selvedges Nominal diameter	Knuckled 3.9 mm	 3.9 mm
Lacing wire Diameter	N/A	Same type as for mesh 2.2 mm**
Minimum tensile strength per ASTM A370	N/A	415 MPa
*Galvanizing shall be done before weaving. **After galvanising.		

Acceptance of all materials shall be based on certificates of compliance submitted to the Engineer for approval.

Table 7-24: Material requirements for wire mesh slope protection components

Material	Requirement
Wire Rope Material Diameter Standard	 Zinc-coated steel structural wire rope 15.9 mm ASTM A603, Class A, ASTM A475
Hardware Rings Lightweight wire rope thimbles Wire rope clips Galvanizing Rings, thimbles, wire rope clips, U-bolts Castings Forgings	 Drop-forged steel, heat treated after forging Approximately 6.3 kg per 100 Drop-forged steel or cast steel AASHTO M 232M, Class C AASHTO M 232M, Class A AASHTO M 232M, Class B
Hog rings and tie wire	Manufactured from 2.9 mm of steel wire meeting Federal Specification QQ-W-461H, AISI numbers

Material	Requirement
	1010 and 1015, finish five; of medium hardness and tensile strength; Class 3 coating
Grout for anchors	Class G3, per Article 4.3.10.4 of Chapter 4, Concrete Works
Anchor rods	
Material	ASTM A36M
Eye construction	Drop-forged or formed with a full-penetration weld and shall develop 100 % of rod strength
Galvanization	ASTM A153M

7.4.2.3 Construction Requirements

a. Anchors

Contractor shall install anchors of the type shown in conformance to the layout shown in the Contract plans. Spacings and numbers of the anchors and wire ropes, as shown in the Contract plans, are approximate only, and the Engineer will give the Contractor the required spacing to hold the wire mesh against the slope. Backfill material shall be thoroughly compacted.

b. Wire Rope Assembly

Wire rope assembly shall be in place before the wire mesh is attached. Bottom wire rope shall not be tensioned. No wire rope splicing will be allowed.

c. Wire Mesh

Wire mesh shall be fastened to the completed wire rope assembly as shown in the Contract plans.

Hog rings on the vertical lap splices shall be placed in a single row centred on the splice.

Horizontal splices joining 2 rolls of mesh shall be made by removing a horizontal end wire and reweaving through the ends of the fabric to form a continuous mesh.

All top and bottom laps shall be made by folding the mesh to the outside, away from the slope, to avoid the possibility of falling material hanging up in the folds.

Bottom of the mesh shall be located so that material dislodged under the mesh can drain freely from the bottom, yet will not flow or bounce onto the roadway. Ends of all tie wires shall be secured to the mesh with a minimum of 1.5 turns.

Wire mesh shall not be tensioned in any direction, but is to remain loose so as to increase its dampening effect on rolling rocks. Any mesh or wire rope damaged due to the Contractor's operations shall be replaced by the Contractor at no expense to the Owner.

7.4.3 Riprap Slope Protection

7.4.3.1 Description

This work furnishes and places riprap for slope protection, as shown on the Contract plans. Riprap shall consist of broken stone, broken concrete rubble, or concrete in sacks. Riprap classes shall be as defined herein.

7.4.3.2 Material

Riprap rock shall be hard, durable, angular rock that is resistant to weathering and water action and free of organic or other unsuitable material as approved by the Engineer. Shale, rock with shale seams, or other fissile or fissured rock that may break into smaller pieces in the process of handling and placing shall not be used. Riprap rock shall conform to the gradations in Table 7-25. Grading of the riprap shall be determined by the Engineer by visual inspection of the load before it is dumped into place; or, if so ordered by the Engineer, by dumping individual loads on a flat surface and sorting and measuring the individual rocks contained in the load.

Table 7-25: Classes of riprap, defined by gradation

		Percent of Rock by Mass			
		20 %	**30 %**	**40 %**	**10 %***
Class 1	Mass (kg) [Size (mm)**]	10 to 15 [150 to 200]	5 to 10 [125 to 150]	0.5 to 5 [50 125]	0 to 0.5 [0 to 50]
Class 2	Mass (kg) [Size (mm)**]	25 to 50 [200 to 250]	10 to 25 [150 to 200]	1 to 10 [75 to 150]	0 to 1 [0 to 75]
Class 3	Mass (kg) [Size (mm)**]	100 to 150 [350 to 400]	50 to 100 [250 to 350]	5 to 50 [125 to 250]	0 to 5 [0 to 125]
Class 4	Mass (kg) [Size (mm)**]	250 to 350 [450 to 500]	100 to 250 [350 to 450]	10 to 100 [150 to 350]	0 to 10 [0 to 150]
Class 5	Mass (kg) [Size (mm)**]	700 to 1,000 [650 to 700]	350 to 700 [500 to 650]	25 to 350 [200 to 500]	0 to 25 [0 to 200]
Class 6	Mass (kg) [Size (mm)**]	850 to 1,600 [700 to 850]	500 to 850 [550 to 700]	50 to 500 [250 to 550]	0 to 50 [0 to 250]
*Spalls and rock fragments graded to provide a stable dense mass shall be furnished by the Contractor. **Approximate cubic dimension. Volume of a rock with these cubic dimensions has a mass approximately equal to the mass specified. Rock with breadth and thickness at least one-third its length shall be furnished.					

Quarry spalls shall consist of broken stone or broken concrete rubble. Riprap and quarry spalls consisting of broken stone or concrete rubble shall be free from segregation, seams, cracks, and other defects tending to destroy its resistance to weather and shall conform to Table 7-26.

Table 7-26: Quality requirements for riprap and quarry spalls

Aggregate property	Test Method	Requirement
Los Angeles wear, 500 Rev.	AASHTO T 96	50 % maximum
Specific gravity	AASHTO T 85	2.55 minimum
Absorption	AASHTO T 85	4.2 % maximum
Coarse durability index	AASHTO T 210	50 minimum

Should the riprap contain insufficient spalls, the Contractor shall furnish and place supplementary spall material from a source approved by the Engineer, at the Contractor's expense.

Grout shall meet the requirements set out in Article 4.3.10.4 of Chapter 4, Concrete Works, and grout and shall be of the class specified in the Contract plans.

a. Hand-placed Riprap

Hand-placed riprap shall be as nearly rectangular as possible, and 60 % of the stones shall have a cubic dimension of not less than 300 mm. No stone shall be used that is less than 150 mm thick.

b. Sack Riprap

Sack riprap shall consist of concrete placed in sacks made of at least AASHTO M 182, Class 3 burlap, having a capacity of approximately 0.05 m^3. Each sack shall be filled with concrete.

Concrete for sack riprap exposed to fresh water and salt water shall be Class C20. Aggregate gradation for sack riprap shall conform to the following, or as approved by the Engineer:

- 100 % passing the 50-mm sieve
- 45 % to 89 % passing the 6-mm sieve
- 0 % to 12 % passing the 0.075-mm sieve

c. Quarry Spalls

Quarry spalls shall meet the requirements for grading in Table 7-27.

Table 7-27: Quarry spalls gradation

Sieve Size	Percent Passing
200 mm	100 %
75 mm	≤40 %
18 mm	≤10 %

7.4.3.3 Construction Requirements

a. Excavation and Preparation for Riprap

Foundations for riprap shall be excavated below probable scour, or to the elevation shown in the Contract plans, and no rock shall be laid nor concrete placed until the footing is approved by the Engineer.

Excavation below the level of the intersection of the slope to be protected and the adjacent original ground or the channel floor or slope shall meet the requirements for ditch excavation in accordance with Article 2.4.2.9 of Chapter 2, Earthworks. All excavation or backfill above the level of the intersection described above and all dressing of the slope to be protected shall be included in the Contract price for the class of riprap to be placed. Before placing riprap, the slopes shall be dressed to the lines and grades as staked.

Where required, geotextile fabric shall be placed loosely, not stretched, prior to riprap placement as shown on the Contract plans and in accordance with Section 2.7 of Chapter 2, Earthworks. Strips of fabric shall overlap at least 600 mm at each joint. On horizontal joints, the uphill strip shall overlap the downhill strip. On vertical joints, the upstream strip shall overlap the downstream strip.

Geosynthetic fabric shall be protected at all times during construction from exposure to sunlight, and total exposure shall not exceed 14 calendar days.

When the maximum size of the rock to be placed on fabric exceeds 450 mm, the fabric shall be protected during the placement of the rock by a layer of bedding material spread uniformly on the fabric to a minimum depth of 150 mm. Compaction of the bedding shall not be required. Rocks shall be placed carefully on the bedding material and fabric in such a manner as not to damage the fabric. If, in the opinion of the Engineer, the fabric is damaged or displaced to the extent that it cannot function as intended, the Contractor shall remove the rock; regrade the area, if necessary; and replace the fabric at no additional expense to the Owner.

b. Loose Riprap

Loose riprap shall be placed in such a manner that all relatively large stones are essentially in contact with each other, and all voids filled with the finer materials to provide a well graded compact mass.

Stone shall be dumped on the slope in a manner that will ensure the riprap attains its specified thickness in one operation. When dumping or placing, the Contractor shall use care to avoid disturbing the underlying material.

Placing in layers parallel to the slope will not be permitted. A 300-mm tolerance for loose riprap will be allowed from slope plane and grade line in the finished surface. Hand placing or rearranging of individual rock may be necessary to obtain the specified results.

c. Hand-placed Riprap

Stones shall be laid by hand on prepared slopes to such thickness as may be ordered by the Engineer. Riprap shall be started at the toe of the embankment by digging a trench and placing a course of the largest stones therein. Each stone shall be placed so that it rests on the slope of the embankment and not wholly on the stone below, and it shall be thoroughly tamped or driven into place. Exposed face of all hand-placed riprap shall be made as smooth as the shape and size of the stones will permit and shall not vary more than 75 mm from a plane surface on the required slope.

d. Keyed Riprap

Keyed riprap, also called plated riprap, is rock placed on a prepared surface and set into place by impact pressure to seat the rocks together and form a relative flat and uniform rock surface. Rock shall first be placed per Sub-article b, of Article 7.4.3.3. Then, the riprap is set into place by exerting impact pressure with a hydraulic-powered bucket or an approximate 2,000 kg flat-faced mass. Impact shall be repeated until the rock is firmly seated and forms a reasonably uniform surface without reducing the effective sizes of the rocks. Levelling or plating process shall not be to an impact force that breaks the rock.

e. Sack Riprap

Sack riprap shall be deposited in the trench and on the slope of the embankment to be protected in accordance with the Contract plans or as ordered by the Engineer. Concrete shall be placed in the sacks to a uniform volume leaving sufficient room for effectively tying the sacks.

Sacks shall then be placed in longitudinal rows in the trench and on the slope to lie parallel with the slope. In placing the sacks on the slope, their outside faces shall be laid against a heavy timber header or screed so that each layer will be true to the line and grade. Tied ends of the sack shall be turned under and the sack firmly pressed into place against the header or screed.

Sacks in longitudinal rows shall be placed with the bottom of one sack adjacent to the top of the next sack. Joints shall be staggered in successive rows.

f. Quarry Spalls

Quarry spalls shall be placed in ditches and on slopes to be protected, in accordance with the Contract plans or as directed by the Engineer. After placement, the quarry spalls shall be compacted to be uniformly dense and unyielding.

g. Filter Blanket

When required, a filter blanket shall be placed on the prepared slope or area to the full thickness shown on the Contract plans using methods that will not cause segregation of particle sizes within the bedding. Surfaces of the finished layer shall be even and free from mounds or windrows. Additional layers of filter material, when required, shall be placed using methods that will not cause mixing of the materials in the different layers.

h. Grouted Riprap

Grouted riprap is rock placed or keyed on a prepared surface with the voids filled with grout. Rock shall first be placed in accordance with Sub-articles b or d, of Article 7.4.3.3. Then, the Contractor shall thoroughly moisten the rocks and wash excess fines from the riprap or to the underside of the riprap. Grout shall be placed to prevent segregation, beginning at the lowest elevation of the riprap. All voids shall be filled without unseating the rocks.

Grout may be delivered to the place of final deposit by any means that will ensure uniformity and prevent segregation of the grout. If penetration of grout is not obtained by gravity flow into the interstices, the grout shall be spaded or rodded to completely fill the voids in the rock blanket. Pressure grouting shall not unseat the stones, and during placing by this method, the grout shall be spaded or rodded into the voids.

Penetration of the grout shall be to the depth shown on the Contract plans. When a rough surface is specified, stone shall be brushed until 25 % to 50 % of the depth of the maximum size stone is exposed. For a smooth surface, grout shall fill interstices to within 13 mm of the surface.

Curing of the grout shall be in accordance with the requirements of Sub-article f, of Article 7.3.3.3 . At the option of the Contractor, shotcrete conforming to the requirements of Article 4.3.10.5 of Chapter 4, Concrete Works, may be furnished in lieu of grout.

Each layer of grouted riprap shall be 1.5 m or less in thickness. Contractor shall allow 3 days curing time before adding the next layer of riprap and grout. Weep holes shall be provided through the grouted riprap, as required by the Contract plans or the Engineer. Grouted riprap shall be cured by placing wet blankets to keep it moist for 3 days after the work is completed.

7.4.4 Coarse Aggregate Covering

This work consists of a layer of coarse aggregate placed to a uniform depth to the limits and for the depth shown on the Contract plans as approved by the Engineer.

Selection of aggregate sizes and colour requirements — or other required architectural attributes — shall be as shown in the Contract plans or as directed by the Engineer. Unless otherwise indicated, coarse aggregate shall be size 4 coarse aggregate as defined in Article 4.3.7.3 of Chapter 4, Concrete Works. Course aggregate used for surface covering shall be approved by the Engineer prior to installation.

Areas on which the coarse aggregate covering is to be placed shall be shaped to a reasonably true surface prior to placement. Coarse gravel shall be spread by any suitable means that shall not crush it and shall be shaped to a smooth uniform finished grade.

7.5 Concrete Kerbs, Gutters, Parapets, and Barriers

7.5.1 Description

This work constructs reinforced concrete kerb, kerb and gutter, gutter, parapet, median barrier, and side barrier to the type, dimensions, and details shown in the Contract plans or directed by the Engineer. This work includes both temporary and permanent applications. Barrier, parapet, kerb, and gutter may be on grade or structures. Construction shall conform to the details, lines and grades shown on the Contract plans, as required in these Specifications, and as may be required in the Particular Specifications, as approved by the Engineer. Construction methods shall be one of the following:

- Cast-in-situ fixed-form
- Cast-in-situ slip-form
- Precast

This work may also include the removal, storage, and resetting of temporary barrier at the locations shown on the Contract plans or as approved by the Engineer.

7.5.2 Materials

Unless otherwise specified in the Contract plans or by the Engineer, materials shall conform to the requirements of Table 7-28.

Table 7-28: Material requirements for concrete barriers, parapets, kerbs, and gutters

Material	Requirement Specifications
Concrete and its constituent materials; premolded joint filler; joint sealer; water-reducing admixture Reinforcing steel	Section 4.3 of Chapter 4, Concrete Works Chapter 5, Reinforcing Steel
Paint formulas	Articles 8.2.2.7 or 8.2.2.8 of Chapter 8, Traffic Markings and Signs.
Water-repellent compound	Table 24-13 of Chapter 24, Painting
Wire rope Material Galvanization Weave Minimum diameter Minimum breaking strength	Class 6 x 19 Improved plow steel ASTM A603 Right regular lay and fibre core 16 mm 13.6 metric tons
Anchor bolts Nuts for anchor bolts Lubrication Washers for anchor bolts	ASTM F1554 and S2, S3, and S4*; Grade 105 AASHTO M 291M, Grade DH AASHTO M 291M, and S2(*)(**) ASTM F436
Unfinished bolts Nuts for unfinished bolts Washers for unfinished bolts	ASTM A307 Grade A or B ASTM A563 Grade A ASTM F844
Grout for permanent precast barrier	Meet the requirements for grout for ground anchors, Article 4.3.10.4 of Chapter 4, Concrete Works
*Supplemental requirements are designated with an S prefix. **Documentation shall include the name, method of application, and dilution of the lubricant applied to the nuts.	

All hardware shall be galvanised per AASHTO M 232M, tested by the manufacturer, marked or identified per the relevant specification, and inspected prior to shipping to the site of the works.

A manufacturer's certificate of compliance that demonstrates conformance to these specifications and the applicable standards referenced herein shall be submitted by the Contractor to the Engineer for approval. A sample of the anchor bolt, nut, and washer shall be provided by the Contractor for testing, if requested by the Engineer.

Minimum concrete strengths for various applications shall be as described in Table 7-29.

Table 7-29: Minimum required concrete strengths for kerb, gutter, parapet, and barrier

Application	Minimum Concrete Requirements
Cast-in-situ kerb, kerb and gutter, gutter not at driveway entrances	Class C20
Cast-in-situ kerb, kerb and gutter, gutter along driveway entrances	Class C30
Precast kerb, parapet, and barrier	Class C30
All barriers and parapets	Class C30
Pavement, cap, or slab between concrete barriers	Class C15

For precast kerb, cement content shall be at least 400 kg/m^3, and the aggregate gradation shall meet the requirements for nominal maximum size 19 mm aggregate as shown in Article 4.3.7.4 of Chapter 4, Concrete Works.

7.5.3 Construction Requirements

Unless otherwise indicated on the Contract plans or specified in the Particular Specifications, kerbs, gutters, kerb and gutter, parapets, and barriers shall conform to the following:

- Constructed in straight line segments
- Cast-in-situ, if located on superstructures or approach slabs, and constructed after the deck is complete and all post-tensioning has been accomplished
- Cast-in-situ using fixed forms if installed in conjunction with light standard foundations and sign bridge foundations

Maximum allowable deviation from a 3 m straightedge held longitudinally on all surfaces shall be 6 mm. For single sloped barrier the maximum allowable deviation from a straightedge held along the vertical sloped face of the barrier shall be 6 mm.

Segments of cast-in-situ barrier, parapet or kerb may be joined to precast barrier, parapet or kerb where transitions, split barriers or gaps shorter than 3 m require it. At each joint of this type, the cast-in-situ segment shall include hardware that ties both its ends to abutting precast sections.

7.5.3.1 Preparation of the Foundation

Foundations for kerb, gutter, kerb and gutter, parapet, and barrier shall be either prepared subgrade or pavement. Subgrade shall be firm, unyielding material that consists of the following:

- Shaped to the line, grade, and cross section shown in the Contract plans
- Thoroughly compacted
- Watered thoroughly, leaving no standing water just before concrete is placed

Prepared subgrade surfaces shall be proof-rolled to check for unstable areas and areas requiring additional compaction. Unsuitable material shall be removed per Article 2.4.2.7 of Chapter 2, Earthworks. Any excavated surfaces for the concrete bedding shall be watered and compacted to a minimum of 95 % maximum density.

Clamps, spreaders, and braces shall be used where required to insure rigid forms. When the roadway section slopes away from the gutter, the slope of the gutter shall be formed to match the roadway cross slope.

All old pavements and any portion of new pavements constructed under this Contract, which are covered with oil or grease within the kerb limits, shall be further cleaned as follows:

1. Pavement shall be flushed with water
2. Where patches of oil, tar, or grease occur, these areas shall be scrubbed with a solvent-type cleaner and brush or broom
3. Pavement surfaces shall then be thoroughly rinsed

7.5.3.2 Kerb Painting

Kerb painting shall be accomplished in accordance with Sub-articles 8.2.3.3b, 8.2.3.3e and 8.2.3.3h of Chapter 8, Traffic marking and Signs. Kerbs along main roads, sector roads, and parking areas shall be painted as shown on the Contract plans. Lengths for each band shall be 1.20 m. Paint shall be on the exposed kerb surfaces after kerb and pavement are in place or as directed by the Engineer.

All kerb paint shall be applied to a minimum dry film thickness of 150 microns (in 2 coats) and achieve a minimum tensile adhesion of 2.0 MPa.

In accordance with the TCDM, kerb painting treatment in Abu Dhabi denotes parking classifications and restrictions. The colours used indicate the following:

- Kerbs painted grey - standard kerb
  -new kerbing is not to be painted
- Kerbs painted blue and black -standard parking charges apply
- Kerbs painted blue and white -premium parking charges apply
- Kerbs painted yellow and grey -parking prohibited
  -to be applied at sectors where paid parking is operated
- Kerbs painted yellow -visibility marking (junctions, entry/exits, intersections, roundabouts, and traffic separation islands)
- Kerbs painted red -parking prohibited (adjacent to fire hydrants)
- Kerbs painted blue -parking for disabled persons

7.5.3.3 Cast-in-situ Fixed-form

a. Formwork

Forms shall be steel or plywood that is coated with plastic. Formwork and details, including form liners, shall comply with the requirements of Section 1.20.8 of Chapter 1, General Requirements, and shall be capable of being removed without injuring the green concrete. Forms used more than once shall be thoroughly cleaned and any forms that have become worn, splintered, or warped shall not be used again.

Side forms shall rest throughout their length on firm ground. Top of any form or the Contract face of a straight form shall not vary from a true plane by more than 6 mm in 3 m. Forms for use on curves shall be capable of installation to within 12 mm of the true curve and if the radius is less than 50 m, shall be either flexible material or shaped to fit the curve. Forms shall be designed so that they may be securely fastened together in the correct position.

Formwork shall be properly cleaned and oiled prior to the placement of concrete. Formwork, in general, shall remain in place for at least 12 hours after concrete placement, except that formwork shall be removed as required to permit texturing.

Forms may be placed using machine methods, if approved by the Engineer, provided that the Contractor consistently produces an acceptable finished product, true to line, grade and cross section.

Removal of forms shall be by a method acceptable to the Engineer and shall be performed to avoid excessive shock and straining of the concrete.

b. Concrete Placement

Concrete placement and vibration shall conform to the requirements of Section 4.4.1 of Chapter 4, Concrete Works.

Small amounts of consolidated concrete totalling not more than 0.06 m^3 in volume, and spaced at least 3 m apart, may be used to support reinforcing steel within barrier forms, and they shall provide 50 mm minimum clearance to the outside face of the barrier.

Edge chamfers shall be formed by attaching chamfer strips to the forms.

c. Expansion and Dummy Joints

Expansion joints shall be placed as shown on the Contract plans and at the following locations:

1. Beginning and ends of kerb returns

2. Kerb abutting drainage structures
3. Kerb abutting bridges
4. Radius points
5. Cold joints with existing kerbs and gutters
6. Every 4.5 m or less for kerb, gutter, and kerb and gutter
7. Every 30 m for barriers with dummy joints every 3 m

Expansion joints shall cover the full cross section with 10 mm premoulded joint filler, except between kerb or gutter and cement concrete pavement. Expansion joints shall be a 6 mm-thick, 150 mm deep premoulded joint filler placed between the surfaces to prevent cracking.

Contraction joints shall be placed every 3 m, except where closure requires a lesser interval, but they shall not be closer than 1.2 m. They may be formed with forms or by sawing or by using sheet metal templates, with the following requirements:

1. Sheet metal templates:
   - Shall be of the dimensions, and set to the lines, shown in the Contract plans
   - Shall hold firmly during concrete placement
   - Shall remain in place until the concrete has set sufficient to hold its shape
   - Shall be removed while the forms are still in place
2. Sawn joints shall be completed:
   - As soon as the concrete has hardened to the degree that excessive ravelling will not occur
   - Before shrinkage cracking begins

d. Curing and Finishing

Curing for barriers shall conform to Method A, supplying continuous moisture, per Article 4.4.2.1 of Chapter 4, Concrete Works, and the additional requirements or exceptions of this section. Membrane curing compound shall not be used on barriers.

Kerb, gutter, and kerb and gutter shall be cured for at least 72 hours by one of the methods specified for cement concrete pavement curing in Article 3.8.3.8 of Chapter 3, Pavement.

Exposed kerb and gutter surfaces shall be finished with a trowel and edger. Within 24 hours after concrete placement, forms on the roadway face of kerbs shall be removed, and the concrete treated with a float finish. Tops and faces of the kerbs shall receive a light brush finish, and the top of the gutters shall receive a broom finish. Minor defects shall be filled with Class M6 mortar per Article 4.3.10.4 of Chapter 4, Concrete Works. Plastering shall not be allowed on the face of the kerb.

To finish cast-in-situ, fixed-form barriers, the Contractor shall complete the following procedure:

While the forms are in place, the Contractor shall:

1. Brush the top surface with a fine bristle brush
2. Cover the top surface with heavy, quilted blankets
3. Spray water on the blankets and forms at intervals short enough to keep them thoroughly wet for 72 hours

After removing the forms, the Contractor shall:

1. Remove all lips and edgings with sharp tools or chisels
2. Fill all holes with mortar
3. True up corners of openings

4. Remove concrete projecting beyond the true surface by stoning or grinding

After removing the forms, the Contractor shall cover the barrier with heavy, quilted blankets, not burlap, and keep the blankets continuously wet for at least 7 days. During this time, the Contractor may perform the required finishing work if the entire structure is kept covered and wet except the immediate work area. Otherwise, no finishing work may be done until at least 10 days after pouring.

After the 10-day curing period, the Contractor shall remove all form-release agent, mud, dust, and other foreign substances from the structure by either light sandblasting and washing with water, or by spraying with a high-pressure water jet. Water jet equipment shall use clean fresh water and shall produce at least 105 kg/cm^2 at the nozzle with a discharge of at least 11 litres per minute. Water jet nozzles shall have a 25-degree tip and shall be held no more than 230 mm from the surface being washed.

After cleaning, the Contractor shall use brushes to rub Class M6 mortar into air holes and small crevices on all surfaces, except the brushed top. As soon as the mortar takes its initial set, the Contractor shall rub it off with a piece of sacking or carpet. Structure shall then be covered with wet blankets for at least 48 hours.

Completed concrete surfaces shall be even in colour and texture with a uniformly smooth, dense surface, no rock pockets, and no holes larger than 6 mm across.

7.5.3.4 Cast-in-situ, Slip-formed Kerb, Parapet, and Barrier

Slip-formed, also called extruded, cement concrete kerb, gutter, kerb and gutter, parapet, and barrier shall conform to the applicable requirements of Chapter 4, Concrete Works, for materials, placement and testing. Slip-formed work shall be placed, shaped, and compacted to the required line and grade as shown in the Contract plans or as directed by the Engineer with approved equipment. When placing of concrete is suspended for more than 45 minutes, a construction joint shall be formed and its location shall not be at a Contraction joint.

A trial slip form placement for each type of kerb, parapet, or barrier shall be performed for acceptance by the Engineer to demonstrate the adequacy of the slip-form equipment and the Contractor's operation. Trial sections may be included as part of the finished work and left in place if accepted by the Engineer. Otherwise trial sections shall be broken up, removed, and disposed of, as approved by the Engineer.

Slip-form equipment shall be approved by the Engineer prior to use and shall consist of the following:

a. Self-propelled
b. Capable of shaping and thoroughly compacting concrete to the required cross section
c. Easily adjustable vertically during the forward motion of the machine to provide variable heights necessary to conform to the required grade
d. Capable of continually comparing the slip-form work to the grade guideline by way of a pointer or gauge attached to the machine

If required by the Engineer, the Contractor shall demonstrate that the specific slip-form equipment proposed for use can satisfactorily place the concrete mix. If, at any time, the placement results are not satisfactory to the Engineer, the use of the slip-form equipment shall be discontinued. Additional equipment and small tools necessary for completing the work shall be provided by the Contractor. Supply of concrete to the machine shall be sufficient for uninterrupted placement to the full width and depth of the mould on the slip-form machine.

A water-reducing admixture may be used in the concrete mix, provided the finished kerb and gutter retain the required line and shape.

Cement concrete kerb on pavement shall be anchored to the existing pavement by steel tie bars placed 300 mm on each side of every joint. Tie bars shall meet the dimensions shown in the Contract plans. Joints in the kerb shall be spaced at 3-m intervals. Joints shall be cut vertically and to the depth shown in the Contract plans.

Kerb openings at driveways and sidewalk ramps shall be constructed by the Contractor as shown on Contract plans and as directed by the Engineer.

Formwork, expansion joints, curing, and finishing shall be completed in accordance with the requirements of Article 7.5.3.3, with the following exceptions:

1. Surfaces shall be finished immediately after slip-forming
2. Foundation pavement shall be dry and cleaned of loose and deleterious material prior to slip-form kerb placement
3. Placing concrete on an unstable, saturated base will not be permitted. If required, the base shall be damped with water prior to placing concrete

In constructing the slip-form work, the Contractor shall do the following:

a. Consolidate concrete so as to be free of honeycomb
b. Provide concrete of a consistency that will maintain the shape of the barrier, parapet, kerb, or gutter without support
c. Minimise starting and stopping of the slip-form operation by ensuring a continuous supply of concrete.
d. Provide a wire line or laser guided controls to maintain vertical and horizontal alignment of the slip-form machine
e. Operate the slip-form machine within the manufacturer’s recommended speed
f. Provide rails or supports at the required grade instead of sensor controls, at the Contractor’s option

Curing shall conform to Article 4.4.2.5 of Chapter 4, Concrete Works.

7.5.3.5 Precast Kerb, Parapet and Barrier

Units shall be precast in sections per the Contract plans and as directed by the Engineer. Unless the Engineer agrees otherwise, the manufacturer shall be a company with at least 3 years experience in fabricating precast concrete units. Precast sections shall be 6 m or less in length with end faces perpendicular to their bases. Casting method shall be either one of the following, as approved by the Engineer:

- By hydraulically pressing concrete
- Per Section 4.4.8 of Chapter 4, Concrete Works

Requirements for each casting method are described in the following subsections. Additional requirements shall be as follows:

- No concrete barrier shall be shipped until test cylinders made of the same concrete and cured under the same conditions show the concrete has reached 30 MPa
- No concrete kerb shall be shipped from the manufacturing plant prior to 21 days after manufacture, however, shorter period may be accepted, if approved by engineer, but shall not be less than 14 days in all cases. If Type III cement has been used, the units may be shipped 14 days after manufacture.

All barriers in the same project, except end sections and variable-length units needed for closure, shall be the same length. All barriers shall be new, unused, and true to the required dimensions within the tolerances established in Table 7-30. Any damage or distortion from fabrication shall be the responsibility of the Contractor.

Table 7-30: Tolerances for precast barrier

Dimension	Tolerance

Length	±25 mm
Insert placement	±13 mm
Horizontal alignment	±3 mm per metre of length
Horizontal skew at end	±6 mm
Vertical batter	±3 mm per 300 mm of depth

Tolerances for precast kerb sections shall be ±3 mm in any dimension.

Precast concrete units damaged in the process of fabricating, curing, handling, or placing shall be repaired or replaced by the Contractor, as directed by the Engineer.

a. Hydraulically Pressed Precast Method

Precast kerb, gutter, kerb and gutter, parapet, and barrier shall consist of hydraulically pressed precast products manufactured in a fully automatic batching plant and comply with the requirements of BS EN 1340, except as modified herein, as approved by the Engineer. Units shall be fabricated by the manufacturer using steel or other approved moulds, in compliance with the approved manufacturing and testing procedures.

Unless otherwise approved by the Engineer, precast kerbs shall be 900 mm long for straight line applications or as short as 200 mm long for curves, depending on the radii of the curves. Quality control recommendations and dimensional tolerance shall be in accordance with BS EN 1340.

If required by the Engineer, testing for compressive strength shall conform to the following procedure:

1. Sample size shall consist of 3 products from a consignment of up to 1,000 products.
2. 2-100-mm-diameter cores shall be cut from each of the 3 samples.
3. Cores shall be tested in accordance with BS 1881: Part 120.
4. Mean compressive strength of 2 cores shall be reported as the compressive strength of that product.
5. Average compressive strength of 3 products shall not be less than 35.05 N/mm^2.
6. Mean water absorption of cubes, per BS EN 1340, shall not exceed 3.0 %.

b. Standard Precast Method

When kerb, kerb and gutter, gutter, parapet, or barrier are cast in accordance with Section 4.4.8 of Chapter 4, Concrete Works, then curing, shipping, and handling shall be per the same section, as approved by the Engineer. Forms shall be steel.

Test results from the manufacturer’s testing shall demonstrate compliance to the consistency, temperature, and time of placement; air content; and compressive strength requirements of Chapter 4, Concrete Works.

c. Curing and Finishing Precast Units

Immediately after each unit has been cast, it shall be cured by one of the following:

- Low-pressure steam
- Steam vapour
- Radiant heat and moisture
- Other similar process, as approved by the Engineer

Radiant heat and moisture shall be provided by water sprays and a relative humidity at least 90 % with a temperature between 16^{O} C and 38^{O} C.

Each unit shall remain in the curing room for at least 10 days, or at least 5 days if Type III cement is used.

Exposed surfaces of kerb, parapet, and barrier shall be smooth with uniform colour and appearance. Finish on the bottom of precast kerbs shall prevent mechanical interlocking of the mortar bed and the kerb bottom or anchor groove.

After release, barriers shall be finished to an even, smooth, dense surface, free from any rock pockets or holes larger than 6 mm across. Towelling shall remove all projecting concrete from the bearing surface of the barrier. Barriers shall be cured in the forms until test cylinders that have been cured under the same conditions as the barrier indicate the concrete has reached a compressive strength of a least 15 MPa. No additional curing is required once the barrier is removed from the forms.

d. Surface Treatment and Marking of Kerbs

After installation of units on site, the exposed surfaces of all precast and cast in-situ concrete kerbs, which will not to be painted for parking classifications (turquoise, black, white) or restrictions (yellow, grey) as per clause 8.2.3.3 (b), shall receive 2 brush or roller-applied coats of a water-repellent compound, meeting the requirements of Table 24-13 of Chapter 24, Painting. When the first coat has dried, the second coat of water-repellent compound shall be applied.

At the manufacturing plant, each piece of kerb shall be marked in black paint on the back or end of the unit with the date of manufacture, length, and identification number corresponding to the detail layout. Alternatively, each bundle of precast kerbs shall have a robust tag attached to it with the aforementioned information printed on the tag.

Rejected kerb shall be marked on the back or end to identify each cause of rejection.

e. Placing Concrete Kerb

Kerb shall be constructed as shown on the Contract plans, to be placed on top of the pavement base courses or on a separately cast concrete footing. At time of placement, kerb shall be firmly bedded for its entire length and breadth on either a wet concrete base or a mortar bed composed of Class M6 mortar per Article 4.3.10.4 of Chapter 4, Concrete Works, 25 mm thick, placed on approved sub-grade. Dimensions of the base and haunching shall be as shown on the Contract plans. Concrete base shall be constructed with Class C20 concrete. Kerb placement will be inspected and approved by the Engineer prior to placement of the concrete kerb haunching or other work adjacent to or against the freshly placed kerb line.

Anchor grooves in the bottom of the kerb shall be entirely filled with the mortar. Before the cement mortar bed is laid, all dirt shall be cleaned from the pavement surface by washing.

Expansion joints, consisting of approved joint filler 10 mm thick, shall be placed every 9 m, or as shown on the Contract plans or otherwise approved by the Engineer. Filler shall extend through the kerbs, bed, backing, and gutter and shall be trimmed to the finished slope of the kerb and gutter.

All joints between adjacent pieces of kerb, except expansion or drainage joints, shall adhere to the following:

- Measure 4 mm or less in width
- Be filled with joint mortar meeting the requirements for M1 in Article 4.3.10.4 of Chapter 4, Concrete Works, with one-fifth part hydrated lime and sufficient water to make the mixture plastic and easily smoothed. A grooving tool shall be used to produce a smooth, circular section groove not more than 3 mm deep in all joints.

Alignment and the top surface of adjoining sections of kerb shall be true and even with a maximum tolerance of 1.5 mm.

Unless otherwise indicated, after kerb units have been laid, a continuous backing of Class C20 concrete shall be poured. No pavement layers shall be laid against kerbing until such time as the backing is complete, back filled and approved by the Engineer.

Immediately after any concrete is in place and for seven days thereafter, the kerbs, base backing and mortared joints shall be fully cured and protected from drying out and against the harmful effects of weather, including rain and rapid temperature changes. Concrete not properly cured and protected will be rejected and shall be removed from the works.

Nosing pieces, connecting dividers, and radial sections for kerbs shall be as detailed in the Contract plans and will be required at the ends of the kerb lines, at transitions between different kerb types, and kerbs with radii less than 3 m. Bull noses and curved faces shall be of constant radius with a smooth change from radius to plain face.

For sloped mountable kerb installed in curves, the units shall be either curved blocks precast to the radii shown in the Contract plans or tangent blocks sawn to the dimensions shown in the Contract plans to conform to the specified radii.

At the end of any kerb run, the end element shall be sloped down to ground level and angled away from the road at 30 degrees.

f. Placing Precast Barrier

Precast barrier lengths shall be as shown on the Contract plans, except that the Contractor may use one short section to adjust a line for length. Creating a short section by cutting or breaking a section will not be allowed. Short sections shall be manufactured to meet the material requirements as otherwise specified. Hardware identical to that used with other sections shall interlock such a section with adjacent precast sections.

Precast concrete barrier shall rest on a paved foundation shaped to a uniform grade and section. Foundation surfaces shall meet the following test for uniformity:

When a 3 m straightedge is placed on the surface parallel to the centreline for the barrier, the surface shall not vary more than 6 mm from the lower edge of the straightedge.

Precast segment joins shall be aligned so that they offset no more than 6 mm transversely and no more than 18 mm vertically. Grouting to correct alignment is not permitted. If foundation grade and section are acceptable, the Engineer may permit the Contractor to obtain vertical alignment of the barrier by shimming. Shimming shall be done with a polystyrene, foam pad measuring 300 mm by 600 mm under the end 300 mm of bearing surface.

Barrier connection voids for permanent installations of precast barrier shall be filled with grout.

g. Rejecting Precast Kerb, Gutter, Parapet, and Barrier

Precast units shall be uniform in colour; free from cracks, flaws, or other defects; and shall have well-defined edges.

Excessive cracking, surface checking, broken or rounded corners, air holes, or lines of discolouration due to a damaged mould are cause for rejection or repair of precast concrete kerb, gutter, parapet, or barrier. An air hole shall be defined as any hole measuring 3 mm or larger in diameter or depth that is visible on the surface or appears when the surface is struck with a rubber hammer. A crack is defined as any separation of the concrete of a continuous length greater than 75 mm.

A piece of kerb, gutter, parapet, or barrier shall be rejected for any of the following conditions:

1. Variation in dimensions, alignment, or surface contour exceeding ±6 mm in length and ±3 mm in alignment
2. Failure to comply with the Contract plans, Specifications, or instructions of the Engineer
3. Evident cracking immediately after removal from the moulds.
4. Surface checking within the first 5 days after manufacture

5. Excess honeycombing in the back, unless the Engineer states it is not detrimental
6. More than 2 % of the top area is deemed defective.
7. More than 5 % of the total length of the top corners of reflecting faces is broken or rounded
8. More than 40 holes in any linear 250 mm
9. Sum of the length of lines of discolouration exceeds 50 % of the length of the unit.
10. Any single line of discolouration exceeds 450 mm long

For the total amount of precast units of a single type installed in the works, 75 % of each total shall be entirely free from lines of discolouration, and 90 % of the total laid shall demonstrate the following:

- Less than 0.2 % of the top area is deemed defective
- Less than 0.5 % of the total length of the top corners of reflecting faces is broken or rounded
- Less than 4 holes in any 250 mm length

Totals shall be taken by type of precast unit, including total kerb, total gutter, total parapet, or total barrier. Failure to reject a unit at the time of manufacture will not ensure its final acceptance.

h. Repairing Precast Kerb, Gutter, Parapet, and Barrier

Precast units having defects that are not sufficient cause for rejection shall be neatly repaired immediately after removal from the moulds in a manner subject to the approval of the Engineer. No patching or repairs shall be made without the permission of the Engineer.

Chipped or broken moulds shall be repaired such that broken or chipped areas will not be apparent on the precast units made in those moulds. Heat shall not be used to obliterate lines of discolouration. Processes used to obliterate lines of discolouration shall be subject to the approval of the Engineer.

Patches shall be undercut if, in the opinion of the Engineer, this operation is necessary to achieve a satisfactory patch.

All holes larger than a 1.5 mm diameter in the exposed surface of acceptable kerb or buttons shall be filled with cement mortar.

i. Sampling and Inspection of Precast Kerb, Gutter, Parapet, and Barrier

An advanced sample of precast kerb, gutter, parapet, and barrier that demonstrates the required colour, texture, and bottom finish shall be submitted to the Engineer for approval. No repairing of any kind shall be done on the advance sample.

Upon approval, the advance sample shall be stored at the plant or site of manufacture in a location readily accessible to the Engineer where there is adequate daylight for examination. Advance samples shall be protected from damage and discolouration and shall be used as a standard of comparison for colour, surface texture, and bottom finish. All precast units furnished to the worksite shall be equivalent to the advance sample in the foregoing respects.

Inspections at the plant will be made just prior to shipment, at which time examination will be made of the alignment, contour, colour, cracks, surface damage or discolouration, broken corners or edges, and any other defects that may have developed; and to check the laboratory test reports for strength. Intermediate inspections may be made to determine surface checking and hidden air holes, if examination for these defects is impractical at the final inspection.

j. Removing and Resetting Permanent Concrete Barrier, Parapet, and Kerbs

Contractor shall reset concrete barrier, parapet, or kerb if the Contract plans or the Engineer require. If resetting is impossible immediately after removal, the Contractor shall store the units at Engineer-approved locations and protect them from damage.

k. Temporary Concrete Barrier

Temporary concrete barrier shall be new or used precast barrier complying with the requirements of the Contract plans for precast barrier, except the following:

- Lengths may differ from those shown in the Contract plans
- Permanent lifting holes less than 100 mm in diameter may remain
- Lifting loops are permitted
- A stamp or stencil reading “temporary” shall be visible on each barrier segment

Permanent barriers that will be removed and reset per the Contract plans or the direction of the Engineer may be used as temporary concrete barrier without being stamped or stencilled “temporary.” Any permanent barrier damaged during its use as a temporary barrier will become the property of the Contractor and be replaced with an undamaged permanent barrier at no expense to the Owner when the permanent barrier is reset to its location.

All barrier shall be in good condition, without cracks, chips, spalls, dirt, or traffic marks. If any barrier segment becomes damaged during or after placement, the Contractor, at no expense to the Owner, shall immediately repair it to the Engineer’s satisfaction or replace it with an undamaged section.

As soon as the temporary barrier is no longer needed, the Contractor shall remove it from the site of the works. Owner-furnished barrier shall remain Owner property, and the Contractor shall deliver it to a stockpile site noted in the Contract or to locations approved by the Engineer. Contractor-furnished barrier shall remain the property of the Contractor.

As an alternative to precast temporary barrier, and only with the approval of the Engineer, the Contractor may use a quick-change moveable barrier (QMB) system with a QMB machine, both of which shall be installed and operated by the Contractor in accordance with the manufacturer’s instructions.

7.6 Sidewalks

7.6.1 Description

This work constructs sidewalks in accordance with lines, grades, and details shown in the Contract plans and these standard specifications or as established by the Engineer. Types of sidewalk consist of the following:

- Cement concrete sidewalks
- Pervious concrete sidewalks
- Pavers sidewalks
- Tile sidewalks
- Architectural concrete sidewalks

7.6.2 Materials

Materials shall meet the requirements of Table 7-31. Concrete for cement concrete sidewalks shall be Class C20/20 concrete that meets the requirements of Chapter 4, Concrete Works.

Table 7-31: Material requirements for sidewalks

Material	Specifications Requirements
Concrete and its constituent materials; premolded joint filler; curing materials	Section 4.3 of Chapter 4, Concrete Works

Concrete pigment; decorative finishes; concrete stain	Section 7.8
Geotextile fabric	Article 2.5.2.9 of Chapter 2, Earthworks
Pervious concrete	Article 4.3.10.6 of Chapter 4, Concrete Works, and Section 7.6.5
Adhesives for tiles Epoxy-resin-base adhesive	BS EN 12004:2007 ASTM C881M

For the purpose of examining and sampling the materials, the Engineer shall have access at all times to the place where paving blocks and other items and their constituent materials are manufactured and stored.

Before the Contractor may begin the work, the Engineer must approve all materials.

7.6.2.1 Quarry Tiles

Quarry tiles shall be standard grade per the minimum grade specifications established by the Tile Council of North America (TCNA) and in compliance with the following standards:

- BS EN 14411
- ANSI A 137.1

Materials shall match the Engineer's samples. Quarry tiles shall be manufactured from fine stoneware clay mixed with 15 % chamotte, which is burnt klinker fragments and fired in a kiln with a minimum temperature of 1,200 ^{0}C. Quarry tiles shall also meet the materials specifications of Table 7-32.

Table 7-32: Required physical properties for quarry tiles

Property	Standard	Requirement
Material		Burnt (kiln fired), extruded clay tile, unglazed, with ribbed underside and coloured throughout.
Dimensions		240 mm by 115 mm by 13 mm, ±5 %
Density		2200 kg/m^3 to 2500 kg/m^3
Water absorption		6 % maximum
Flexural strength		27 N/mm^2 minimum
Scratch hardness		6 – 7 hardness according to Moh's scale
Coefficient of thermal expansion		4.0 by 10^{-6}
Chemical resistance	ASTM C650	No visible change
Static coefficient of friction Walkways and steps Ramps	ASTM C1028	 Minimum 0.6 Minimum 0.8

Materials for quarry spalls shall additionally conform to Section 4.3 of Chapter 4, Concrete Works, including, but not by way of limitation, cement, sand, joint filler, and sealer for expansion joints. Sealer colours shall match that of the grouted tile joints. Other materials shall be used only with the approval of the Engineer. Manufacturer specifications and installation instructions for materials to be used shall be submitted to the Engineer for approval prior to start of the work.

Contractor shall obtain each material required for any type and colour of tile work from a single source, so as to minimise variations in appearance and quality. Tile shall be factory-blended and packaged accordingly, so that tile units taken from one package show the same range in colours as those taken from other packages and match approved samples. If the tiles have not been factory blended, the Contractor shall either return them to the manufacturer or blend tiles at the site of the works before installing, to the satisfaction of the Engineer.

Packaged materials shall be delivered and stored in original containers with seals unbroken and labels intact until time of use. Labels shall comply with ANSI A 137.1. Damage or contamination to materials by water, foreign matter, or other causes shall be prevented. Handle tile with temporary protective coating on exposed surfaces to prevent coated surfaces from contacting backs or edges of other units. If despite these precautions coating does contact bonding surfaces of tile, the Contractor shall remove coating from bonding surfaces before setting tile.

Adhesives formulated for tile and recommended by their manufacturer shall by used for the application indicated. Materials for setting the tiles shall conform to the following requirements:

1. For thick bed applications: Latex-Portland cement mortar per ANSI A 118.4 with liquid-latex additive such as Laticrete 3701 or approved equal
2. For thin-set applications and slurry bond coats at mortar and bed applications: a mixture of dry-mortar mix and latex additive such as Laticrete 4237 or an approved equal

Grout shall be as recommended by the manufacturer for the type of tiles. Latex-portland cement grout shall meet the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works.

7.6.2.2 Precast Tile Blocks

Precast tile blocks consist of a precast concrete base and quarry tiles specified in Article 7.6.2.1. Precast tile blocks shall be furnished as shown on the Contract plans to the lines and grades approved by the Engineer. Installation of precast tile blocks shall likewise comply with the Contract plans, these Specifications, as approved by the Engineer.

Quarry tile shall be per Article 7.6.2.1. Latex-portland cement mortar shall meet the latex manufacturer's recommendations. Concrete shall be Class C25/20 and its reinforcing shall conform to ASTM A185M.

Precast tile blocks shall be constructed as follows:

1. Precast tile blocks shall be installed, where quarry tiles cross service reservations and ducts are not provided, to the lines and grades determined by adjacent quarry tiles
2. Construction of the precast concrete base shall be as shown on the Contract plans using Class C25/20 concrete
3. Placement of quarry tiles shall be on a 5-mm-thick latex portland cement mortar in accordance with ANSI A 108.5 and ANSI A 118.5 and shall match the pattern and colour of quarry tiles elsewhere in the project
4. Pointing and grouting material shall be latex portland cement mortar

7.6.3 Construction Requirements

7.6.3.1 General

Sidewalks shall be installed to the lines, grades, and details shown on the Contract plans, as may be required by the Particular Specifications, as approved by the Engineer. Geotextile fabric shall be used where shown on the Contract plans, as approved by the Engineer. Except as otherwise approved in writing by the Engineer, the following standards shall be met for all new sidewalk installations:

- Detectable warning strip extending the width of the ramp and 600 mm from the kerb flow line shall be installed per the details provided on the Contract plans
- Abrupt changes in sidewalk elevation shall not exceed 6 mm
- Cross slope of the sidewalk shall not exceed 2 %
- Kerb ramp grades shall not exceed 8.3 %
- Sloped flares adjacent to the kerb ramps shall not exceed 10 % slope

Where a sidewalk crosses a concrete driveway, the sidewalk depth and reinforcement shall not be less than the driveway cross-sectional details shown on the Contract plans.

Completed sidewalks shall demonstrate a well-compacted mass, a surface free from voids and honeycombs, and dimensions true-to-line shape and grade.

Unless otherwise shown on the Contract plans or required by the Particular Specifications, sidewalks shall typically be 100 mm thick, or 150 mm thick where they parallel depressed kerbs or cross driveway entrances.

Sidewalks on bridge decks shall not be constructed until prestressing is complete, formwork has been removed, and the bridge deck has been surveyed to establish final lines and levels.

7.6.3.2 Preparation of the Foundation

Excavations shall be made to the required depth and to a width that will permit the installation and bracing of the forms. Foundations shall be shaped and compacted to a firm-even surface conforming to the section shown in the Contract plans. Foundation materials shall be compacted to a density of not less than 95 % of the maximum density.

All soft and yielding material shall be removed and replaced with acceptable material at least 150 mm deep, per Article 2.4.2.5 of Chapter 2, Earthworks. If borrow is required, it shall conform to 2.5.2.2 of Chapter 2, Earthworks. If bedding aggregate is required, it shall be placed in layers of not more than a 100-mm compacted thickness. Each layer shall be compacted with at least 3 passes of a lightweight mechanical tamper, roller, or vibratory system. If a base course of concrete is required, it shall be Class C15 concrete.

After the forms have been set to line and grade, the foundation shall be brought to the required grade. Prior to concrete placement, the Contractor shall thoroughly wet the foundation. At the time of concrete placement, the forms shall contain no extraneous material or standing water.

Existing concrete surfaces shall be free of loose or foreign material, scrubbed with wire brooms, and kept wet before new concrete is placed. Immediately before placement, the old surface shall be thinly coated with a Class M5 mortar meeting the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works.

7.6.3.3 Formwork

Formwork shall comply with Section 1.20.8 of Chapter 1, General Requirements, and extend for the full depth of the concrete.

Forms shall be of wood or metal in accordance with Article 1.20.8.2 of Chapter 1, General Requirements, and shall extend for the full depth of the concrete. All forms shall be straight, free from warp, and of sufficient strength to resist the pressure of the concrete without springing. Bracing and staking of forms shall be such that the forms remain true to the required alignment, horizontal and vertical, until their removal.

Clamps, spreaders, and braces shall be used, where required, to insure rigid forms.

7.6.3.4 Screed Rail Supports

Screed rail supports, if used, shall be placed 600 mm on centres.

Before concrete operations are started, the screed shall be operated over the full length of sidewalk to be constructed and the depth of construction shall be checked. Screed rails shall be adjusted, as needed, to install sidewalks as shown on the Contract plans, as approved by the Engineer.

7.6.3.5 Acceptance

Completed sidewalks shall have clean planar faces, be free of segregation, honeycombing, pits, broken corners or other defects, and show no evidence of external rendering.

After curing, the Contractor shall wash the surface with brush and water to remove all laitance and cement from the exposed, coarse aggregate.

Before acceptance of the work, all sidewalks shall be cleaned of all discolouration resulting from the Contractor's operations, including, but not limited to, dirt, stains, bitumens, and equipment tire marks. Cleaning may be by abrasive blast methods or by other methods approved by the Engineer.

Concrete sidewalk surfaces shall be tested with a 3-m straightedge. Any deviation in excess of 6 mm shall be corrected by the Contractor to the satisfaction of the Engineer at no additional expense to the Owner.

7.6.3.6 Kerb Ramps

Kerb ramps shall be of the type specified in the Contract plans. Along kerb ramps, the kerb, including the bed backing, shall be dropped to show a face of 25 mm or less, or as otherwise designated.

Kerb ramps shall be cast-in-situ. Forms shall meet the requirements of Article 7.6.3.3 and Section 1.20.8 of Chapter 1, General Requirements.

Expansion joints shall be placed in all concrete sections larger than 3 m in any direction as well as between existing concrete works and the new concrete. New concrete shall be tied to adjacent existing concrete by drilling and epoxying dowels into the existing concrete face where any of the following conditions are met:

- Excessive load transfers are possible
- Foundation for the ramp provides only marginal support capability

Ramp finishes shall be as shown on the Contract plans and in conformance with the requirements of the applicable section of these specifications. For instance, a sidewalk finish, a tile finish, or other finish may be specified. Exposed ramp surfaces shall be protected by a clear, penetrating sealant meeting the requirements of Section 29.6.1 of Chapter 29, Miscellaneous Items for Structures.

A detectable warning pattern shall be required for all new sidewalk ramp installations. Detectable warning patterns shall have a truncated-dome shape and may be installed using a manufactured material before or after the concrete has cured, or by installing masonry or ceramic tiles. Embossing or stamping the wet concrete to achieve the truncated-dome pattern or using a mould into which a catalyst hardened material is applied shall not be allowed. When masonry or ceramic tiles are used to create the detectable warning pattern, the Contractor shall block out the detectable warning pattern area to the depth required for installation of the tiles and finish the construction of the concrete ramp. After the concrete has set and the forms have been removed, the Contractor shall install the tiles using standard masonry practices.

Dimensions and details of the detectable warning pattern area on the ramp shall be as shown on the Contract plans. Unless otherwise shown on the Contract plans, colour shall be yellow and match Federal Standard 595C, colour number 33538.

7.6.3.7 Ramp Detectable Warning Retrofit

Where shown in the Contract plans, the Contractor shall retrofit existing cement concrete sidewalk ramps by installing a detectable warning pattern having a truncated-dome shape and in conformance to the details shown on the Contract plans. Warning patterns shall be the width of the ramp and cover the bottom 600 mm of the ramp. Truncated-dome patterns shall be perpendicular to the long axis of the ramp.

Warning patterns shall be capable of being bonded to an existing cement concrete surface. Surface of the warning pattern, excluding the domes, shall not be more than 10 mm above the surface of the concrete after installation.

7.6.4 Cement Concrete Sidewalks

7.6.4.1 Concrete Placement, Finishing and Texturing

Concrete shall be mixed and placed in accordance with Sections 4.3 and 4.4 of Chapter 4, Concrete Works. Sidewalks may be constructed either by the use of conventional fixed forms or by slip-form machines.

Slip-form equipment shall comply with the requirements established in Article 7.5.3.4, for slip-form equipment. All applicable requirements of sidewalk construction by use of fixed forms shall apply to the use of slip-form equipment.

After placement in the forms, concrete shall be struck off or screeded with approved equipment. During the placing and finishing of concrete, premolded joint filler for expansion joints shall be restrained in its proper position.

Concrete shall be thoroughly worked so that the coarse aggregate is below the surface and the mortar comes to the top.

7.6.4.2 Joints

Expansion, Contraction, and construction joints shall be constructed in the locations, at the intervals, and to the thicknesses shown on the Contract plans. All free mortar and concrete shall be removed from the joints.

Expansion joints shall be placed vertically across the full cross section of the sidewalk at the following locations, unless otherwise shown in the Contract plans or directed by the Engineer:

1. At locations that match the spacing of expansion joints in adjacent kerb, kerb and gutter, or pavement.
2. At tangent points or kerb returns
3. Between the sidewalk and all structures and foundations.
4. At a maximum of 12-m intervals.
5. Between sidewalks and driveways.
6. Around poles, posts, boxes, and other fixtures that protrude through the sidewalk.

Workday production shall be terminated at an expansion joint.

Contraction joints shall be formed with a jointing tool or sawed, and shall consist of the following:

a. Constructed vertically
b. Installed at locations shown on the Contract plans or indicated by the Engineer
c. Sawed to a depth of 50 mm or one-third the thickness of the concrete, whichever is greater
d. Formed by parting the large aggregates in the fresh concrete with a straightedge to a depth of 50 mm
e. Constructed at a maximum of 4.5 m intervals
f. Placed at locations that match the spacing of expansion joints in adjacent kerb, kerb and gutter, or pavement

Longitudinal Contraction joints shall be constructed in the centre of sidewalk having a width greater than 2 m and parallel to or concentric with the lines of the work.

Where scoring lines are indicated, they shall measure at least 6 mm deep with a 3-mm radius.

Final joint finishing shall be accomplished with a jointer tool having a radius of 6 mm and leaving a finished joint depth of at least 19 mm. If indicated on the Contract plans or by the Engineer, joints shall be sealed with a sealer that meets the requirements of Section 4.3.15 of Chapter 4, Concrete Works.

Contraction joints shall be formed around all appurtenances, such as manholes, utility poles, buildings, bridges, and where abutting an existing or separately placed kerb.

7.6.4.3 Curing

Concrete sidewalks shall be cured for at least 72 hours using Method A or Method C, as described in Articles 4.4.2.1 and 4.4.2.3 of Chapter 4, Concrete Works.

During the curing period, all traffic, both pedestrian and vehicular, shall be excluded. Sidewalks shall be protected from pedestrian traffic for at least 72 hours and from vehicular traffic for at least 7 days.

7.6.4.4 Finishing

Type of finish shall be as shown on the Contract plans, as approved by the Engineer.

Broom finishes shall be constructed in the following manner:

1. Strike-off the surface using a strike board and then float the surface
2. Using a steel trowel, smooth the surface as soon as it can be worked
3. Brush the walking surfaces of the sidewalk and ramps in a direction perpendicular to the centreline with a stiff bristled broom. Broom from edge to edge with adjacent strokes slightly overlapped to produce regular corrugations not more than 3 mm deep without tearing the concrete
4. While the concrete is plastic, correct porous spots, irregularities, depressions, small pockets, and rough spots
5. Install the Contraction joints or perimeter edging, using an approved grooving tool
6. Tool all exposed edges, including those at expansion joints, using an edging tool with a 6 mm radius, or as indicated on the Contract plans

Exposed aggregate finish shall be accomplished as follows:

a. Strike-off the surface using a strike board and then float the surface
b. As soon as the concrete hardens sufficiently to prevent particles of gravel from being dislodged, broom the surface with stiff brooms approved by the Engineer in the following manner:
    1. Broom transversely across the pavement
    2. Pull the loosened semi-stiff mortar entirely off the pavement
    3. Remove the mortar from all adjacent pavements
    4. Broom parallel to the pavement centreline
    5. Repeat this operation to expose the required amount of coarse aggregate
c. Exercise care to prevent marring of the surface and cracking or chipping of slab edges or joints
d. If approved by the Engineer, apply a light spray of retardant to the unfinished surface to facilitate this work

e. Other methods of aggregate exposure, such as using a water spray attachment on a special exposed aggregate broom, will be permitted if satisfactory results are demonstrated and the Engineer provides written approval

f. Install the Contraction joints or perimeter edging, using an approved grooving tool

g. Tool all exposed edges, including those at expansion joints, using an edging tool with a 6 mm radius or as indicated on the Contract plans.

7.6.5 Pervious Concrete Sidewalks

Concrete for pervious concrete sidewalks shall meet the requirements of permeable concrete, as specified in Article 4.3.10.6 of Chapter 4, Concrete Works.

Pervious concrete sidewalks shall be constructed in careful compliance to the Contract plans, the Particular Specifications, and these Specifications. Pervious concrete shall be properly mixed, placed, and compacted, as approved by the Engineer, to be effective. Documentation that proves the following shall be provided by the Contractor to the Engineer:

a. Pervious concrete supplier, the Contractor, and each individual responsible for the installation of pervious concrete have successfully completed at least 3 pervious concrete installations within the past 3 years

b. Contractor has at least 3 years of competent work with pervious concrete

c. Any applicable test results from previous jobs, if so requested by the Engineer

Alternately, the Engineer may approve the Contractor for pervious concrete sidewalk installation based on his successful performance of mixing and placing of trial sections of sidewalk as required below.

Preparation for the Engineer’s inspection and approval of a test panel shall be done at the Contractor’s expense.

Construction of pervious concrete sidewalks shall not commence until the Contractor has successfully produced a test panel meeting the following requirements:

1. Test panels shall measure at least 9 m^2 and be of the same depth as the proposed sidewalk
2. Test panels shall be prepared with the same materials and means, and on the same sub-base, that the Contractor proposes for use in the final product
3. Test panel shall be marked for identification of batch number and date
4. There shall be no skin of cement or mortar at the bottom or top of the pavement. Such skin could prevent passage of water through the slab at its designed percolation rate
5. Concrete void spaces shall be 15 % to 20 %
6. Unit weight shall be within ±5 % of the mix design unit weight
7. Using a permeameter, or a procedure that the Engineer and the Contractor agree upon, the Contractor shall demonstrate that the pavement has a percolation rate of at least 5 m per hour

Preparation of the foundation shall be per Article 7.6.3.17.6.3.2, except that no organic material, clay, or organic sludge shall be allowed to remain in the soil below subbase.

Subbases shall be installed in accordance with the dimensions, materials, and compaction shown on the Contract plans, with the additional requirement that the subbase beneath the pervious concrete must be of enough depth and properly installed to temporarily store the water while it infiltrates into the soil. If not otherwise shown on the Contract plans, the subbase depth, aggregate void ratio, aggregate sizing, and subgrade preparation shall meet the requirements of *ADQCC (WA-726) Stormwater and subsoil drainage system (Vol. 1,2,3, and 4);* for permeable pavement design. Sub-bases typically consist of at least 150 mm to 250 mm of open-graded aggregate or crushed or recycled concrete with a geotextile fabric layer between the subgrade soil and the subbase aggregate.

Prior to the placement of pervious concrete, the sub-base shall be tested for the rate of permeability by the double-ring infiltrometer, or another suitable test, as approved by the Engineer. Test borings are recommended to determine soil conditions and water table level. Borings may not be required, if undisturbed soil under the base demonstrates good permeability and stability and has not been disturbed for 3 years or more. Permeability testing and certification, if required, shall be the responsibility of the Contractor.

Forms shall be steel unless the Contractor can successfully demonstrate that reinforced plastic or plastic-coated plywood forms will not warp or move under screed vibration and compaction. Appropriate release agents shall be applied to the forms before placing concrete and rollers used in compaction. When debris or aggregate begins to stick to compaction rollers, they shall be cleaned and recoated with a release agent to prevent ravelling.

Pervious concrete shall be delivered, installed, finished, and cured in a similar manner to conventional concrete except that the requirements of Table 7-33 shall supersede any conflicting requirements for conventional concrete.

Table 7-33: Requirements for the installation of pervious concrete

Preparation of the subgrade:
• Subgrade shall be moist with no standing water immediately prior to concrete placement.
Acceptance of concrete:
• Shall be based on visual inspection of each load for consistency and aggregate coating. • Shall be based on unit weight of each load in lieu of slump tests. Pervious concrete is so stiff that slump testing does not provide meaningful quality control.
Placement:
• Pervious concrete shall not be pumped. • Discharge shall be a continuous operation completed as quickly as possible. • Concrete shall be deposited as close to its final position as practicable. • Fresh concrete shall be entered and adhere to the mass of previously placed green concrete. • Workers shall spread pervious concrete in advance of the screed without stepping in the pervious concrete because footsteps could prevent formation of a successful void structure. • A screed shall be used to level off the surface of the pervious concrete. • Vibrating screeds, manual screeds, laser screeds, or other screeds are acceptable as approved by the Engineer with the following qualifications: i. For vibrating screeds, frequency of vibration shall be low enough to avoid over-compaction or closing off of the surface. ii. Manual screeds shall be discontinued if they cause tears in the surface. • Screed shall strike-off material above the forms, typically 15 mm to 20 mm, to allow for compaction. i. This may be accomplished using temporary strips attached to the top of the form. ii. Alternatively, height-adjusting screeds may also be used. • Edges near forms shall be compacted using 300 mm by 300 mm steel tamp, or a similar device, to prevent ravelling. • Any vibration shall be shut off immediately when forward progress is halted for any reason. • An evaporation retarder may be applied before compaction to minimise surface water loss, if approved by the Engineer.
Compaction shall be complete within 15 minutes after placement:

• Pervious concrete shall be compacted by a heavy steel roller after screeding. • Unless otherwise approved by the Engineer in writing, the Contractor shall provide either slip-form or form-riding equipment with a following compactive unit that will provide a minimum of 70 kPa vertical force. • After strike-off and compaction, no other finishing operation will be allowed. Pervious concrete shall not be floated, trowelled, or worked in any other way that might cause the pavement surface to be sealed or the voids to be filled. • Proper compaction shall result in at least 15 % voids.
Curing shall begin within 20 minutes after compaction:
• After placement, pervious concrete shall be misted with water and then covered with plastic sheeting and kept damp for at least 7 days. • Curing materials shall be secured as quickly as possible. • Sheeting shall overlap all exposed concrete and film edges by at least 300 mm. • Sheeting shall be secured to the pervious surface to minimise air invasion between the sheeting and the pervious concrete. i. If the Contractor elects to use a layer of soil to secure the cover, the Contractor shall take precautions to prevent spillage or contamination of the fresh pavement in placing and removing the soil layer. Soil shall be swept off of the sheeting prior to removing the sheeting. ii. If rebar or wood are used to secure the sheeting, the Contractor shall make every effort to minimise bubbles and openings for air. • Placement and securing of plastic sheeting shall be approved by the Engineer, and the Contractor shall comply with the Engineer's direction for adjustments to curing arrangements.

Completed installation shall be the dimensions shown on the Contract plans, ±12 mm in 3 m.

During placement all tools, including screed machines, compaction rollers, rakes, trowels, and forms shall be kept clean and coated with a release agent to reduce the possibility of ravelling. Compaction rollers displaying aggregate adhesion will accelerate ravelling and disintegration.

Contraction joints shall not be installed due to the potential for excessive ravelling at the joints. Expansion joints sufficiently accommodate Contraction, and minor cracking is not detrimental to the surface aesthetic or the structural integrity of pervious concrete. Expansion joints shall be installed in the following manner:

a. At the locations and to the dimensions shown in the Contract plans or directed by the Engineer

b. At the same locations as in adjacent pavements to avoid reflective cracking

c. At intervals of 12 m to 18 m

d. Directly after consolidation using a rolling joint tool approved by the Engineer, or by driving a steel straightedge to the required depth with a hammer

e. To a depth of one-quarter the thickness of the pavement

If joints are not installed directly after compaction, they may be saw cut into the pervious pavement, preferably occurring within 4 days of completing concrete placement, and no later than 7 days after concrete placement. To perform saw cuts during the curing period, the Contractor shall sweep the plastic covering, slit it, and fold it back to accommodate the saw cut. Upon completion of the saw cut, the Contractor shall fold the plastic back over the edges, cover the slit with a new piece of plastic that overlaps each side by 300 mm or more, and secure the plastic for the remainder of the curing period.

When a pour is interrupted, it should be terminated against a form and properly compacted. A 45° groove measuring 25 mm deep shall be created adjacent to the form. When the pour is continued thereafter, a similar groove shall be formed into the joint formed by the new pour, matching the previous groove. Resulting V-shapes can then be filled with an approved joint filler.

No sand or soil shall be stored or placed directly on pervious surfaces. Contractor shall schedule pervious installation as near the conclusion of a construction project as possible. At the Engineer's request, the Contractor shall vacuum pervious concrete before opening the area to pedestrians and traffic.

7.6.6 Paver Sidewalks

Materials, tolerance, curing, and installation requirements for interlocking concrete paving blocks shall be in accordance with Section 7.9. Other type of pavers for sidewalks shall be in accordance with the requirements specified herein.

Kerbs or edging abutting the areas to be paved shall be laid in advance of paver installation.

Preparation of the foundations shall be per Article 7.6.3.17.6.3.2. Where specified, or required by the Engineer, the prepared surface shall be treated with an approved environmentally compatible herbicide and ant poison before the layer of sand for bedding is placed.

Layers of uncompacted sand shall be screeded to a depth of 50 mm over the compacted base. This layer of bedding sand shall not be used for levelling. Sand shall be spread and then left loose and protected against precompaction, including compaction by rain or dew. Any sand that has precompacted shall be loosened in advance of the laying face to the extent to which paving will be completed that day. Sand shall continue to be lightly screeded by the Contractor in a loose condition to the predetermined depth, slightly ahead of laying the paving units.

Pavers with chips, cracks, voids, discolouration, and other visible defects shall not be used. Pavers from several pallets or cubes shall be mixed as they are placed to produce a uniform blend of colours and textures. Pavers shall be cut with a motor-driven masonry saw or block splitter equipment to provide clean, sharp, unchipped edges.

When laying the pavers, the Contractor shall ensure that the blocks avoid disturbance of the sand cushion until the unit is in its correct position. Disturbances to adjacent pavers shall likewise be avoided.

Pattern for laying the paving blocks and their thickness shall be as shown on the Contract plans, as approved by the Engineer. Unbroken blocks shall first be laid and filler pieces afterwards. Filler pieces shall be neatly sawn or hewn to fit exactly into the space to be filled. Spaces of less than 25 % of a full-sized block may be filled with Class C30 concrete. Top faces of blocks shall be flush.

After each 15-m^2 to 20-m^2 area of paving blocks has been laid, the pavement shall be compacted by 2 passes of a suitable vibrating-plate compactor operating at a frequency of 65 hz to 100 hz and a low amplitude with the following requirements:

1. For 60-mm-thick blocks, the compactor shall have a centrifugal force of 7 kN to 16 kN and a plate area of 0.2 m^2 to 0.4 m^2
2. For 80-mm-thick blocks, the compactor shall have a centrifugal force of 16 kN to 20 kN and a plate area of 0.35 m^2 to 0.5 m^2

Two passes shall be made at 90 degrees of each other, and the plate compactor shall not pass closer than 1 m to a temporarily unrestrained edge during laying. No paving shall be left in an uncompacted condition overnight, except for the 1 m strip at the temporarily unrestrained edge.

After compaction of the pavement as described above, joint and Class M3 mortar, per Article 4.3.10.4 of Chapter 4, Concrete Works, shall be spread and brushed into the joints until the joints have been properly filled. After the joint material has dried, any surplus sand shall be broomed off and the pavement shall then be subjected to 2 further passes by the plate vibrator. If necessary, the joint sand shall be filled again and further passes of the plate vibrator shall be made in each direction, until the sand is no longer absorbed into the joints. Joint widths between blocks shall be per the Contract plans, typically between 2 mm and 6 mm.

Joints shall be filled as soon as practical after compaction, before the termination of each work day, before acceptance of the day's work, and before construction traffic is allowed.

Dimensional accuracy, uniformity of joint games, alignment, and squareness of the paver installation shall be checked by the Contractor after laying the first 3 rows of blocks and at regular intervals thereafter. If joints begin to open, the blocks shall be knocked together using a rubber or wooden mallet.

Completed sidewalks shall meet the requirements of the following tolerances, or the Contractor shall remove and replace, at the Contractor's expense, failing areas:

a. Surface level shall be ±5 mm of the design level
b. Maximum deviation within the compacted surface shall be 3 mm or less, as measured with a 3 m straightedge
c. Level of any 2 adjacent blocks shall not differ by more than 1 mm

Exposed paver surfaces shall be washed clean after installation. Prior to final acceptance, any loose, chipped, broken, stained, or otherwise damaged pavers shall be removed and replaced. New units that match adjoining units shall be provided and installed by the Contractor in the same manner as the original units with the same joint treatment.

7.6.7 Tile Sidewalks

Unless otherwise shown or specified, tile installation for sidewalks shall comply with applicable requirements of ANSI A 108/A 118/A 136.1 and recommendations of the TCNA Handbook for Ceramic Tile Installation, as well as the manufacturer's instructions for the installation of each material required. Tiles shall be furnished and installed as shown on the Contract plans to the lines and grades shown on the Contract plans, as approved by the Engineer. Colours, patterns, and mosaics of quarry tile shall be as shown on the Contract plans.

Tile sidewalks shall be installed by the Contractor with at least 3 years experience in the installation of materials comparable to those specified for the project.

Prior to installation of tile sidewalks, the Contractor shall submit the following to the Engineer for approval:

- Evidence of the Contractor's 3 years of experience, including contact information for the owner of each project
- Three samples of each type, class, and colour of tile for each form of construction and finish
- Detailed shop drawings showing proposed widths, lines, grades, accesses, layout of all field tiles, trim shapes, jointing patterns, and any other details necessary to properly construct the work. Contractor shall provide scale details of expansion joints, control joints, special tiles, frame and service abutments.
- Test panels, measuring not less than 300 mm on a side, shall consist of a plywood backing with tile grouted as required for installation in the works using materials indicated for the work. Engineer's approval shall be for colour, pattern, texture and joint width only. Compliance with all other requirements is the exclusive responsibility of the Contractor

No tiles shall be fabricated nor delivered before approval of shop drawings. Laying tile sidewalks shall be as follows, unless otherwise directed by the Engineer:

a. Subgrade shall be prepared in accordance with Article 7.6.3.17.6.3.2 and the Contractor shall ensure that:
    1. Substrates for setting tile are firm, dry, and clean and free from oil or waxy films or curing compounds
    2. Grounds, anchors, recessed frames, electrical and mechanical units of work, and similar items located in or behind tile have been completed before installing tile

b. Tiles shall be soaked in water a minimum of 30 minutes prior to installation

c. Base shall consist of the following:

   1. For quarry tiles, bases shall be a 100 mm thick base slab of Class C15/20 concrete complying with the requirements of Section 4.3 of Chapter 4, Concrete Works, or as otherwise shown in the Contract plans

   2. For precast tile blocks, bases shall be a 50 mm thick layer of clean coarse sand, 100 % passing a 6-mm sieve, 0 % to 35 % passing a 0.300 mm sieve and 0 % to 10 % passing a 0.150 mm sieve, shall be spread with water added and compacted to obtain the required grades before placing the precast concrete blocks

d. Quarry tiles shall be installed in accordance with ANSI A 108.1, except that the mortar bed shall be 40 mm thick, as indicated on the Contract plans and shall be Class M3 mortar with a latex additive that meets the requirements of Article 4.3.10.4 of Chapter 4, Concrete Works

e. Mortar bed shall not lay longer than 45 minutes or until mortar begins to set before placing tiles.

f. Tile shall be laid symmetrically starting at the centre of area and finishing with equally cut rows on the sides

g. Freshly placed tiles shall be damp cured for a minimum 72 hours prior to grouting

h. Pointing and grouting material shall be the same as for the mortar bed

If necessary, the Contractor may etch substrate with 10 % solution of muriatic acid, if necessary to remove curing compounds or other substances that would interfere with the proper bond of specified mortar for tiles. To remove all traces of acid and to seal the substrate with sealer, as recommended by the manufacture, the Contractor shall rinse the tiles with water.

Tile work shall be laid-out in the pattern and trim shapes as shown on the Contract plans. Tiles shall form a complete covering without interruptions, except for control and expansion joints as shown on the Contract plans and as required to comply with the manufacturer’s instructions. Edges and corners shall be neat without disruption of pattern or joint alignments. Joint widths shall be uniform.

Where required, tiles shall be cut with approved power saws. Tiles with jagged or flaked edges shall not be installed. Cutting and drilling of tile shall not mar the surface. Cut tile edges abutting trim, finish, or built-in items shall be carefully ground to create straight, aligned joints. Tile shall fit closely around penetrations.

Control or expansion joints shall be provided where shown, or required by ANSI or TCNA standards, or by job condition for proper workmanship. This process shall be as follows:

1. Install removable divider strip of proper width and depth to include tile and bed
2. Grout tiles and properly cure the work
3. Remove strips and install joint fillers and sealants of the type recommended by the tiling manufacturer

Upon completion of placement and grouting, tile surfaces shall be cleaned so they are free of foreign matter. Grout residue shall be removed from tile immediately. Unglazed tiles may be cleaned with acid solutions only when permitted by the tile and grout manufacturer's printed instructions, but no sooner than 14 days after installation. Metal surfaces, cast iron, and vitreous plumbing fixtures shall be protected from the effects of acid cleaning. Surfaces shall be flushed with clean water before and after cleaning.

Temporary protective coatings shall be removed by methods recommended by the coating manufacturer and that are acceptable to the brick and grout manufacturer. Coating shall be discarded in a manner that prevents clogging drains.

Finished installations shall be clean and free of cracked, chipped, broken, unbounded, and otherwise defective tile work. Final protection and conditions meet the requirements of the manufacturer and installer to ensure tile is without damage or deterioration at the time of substantial completion.

When recommended by tile manufacturer, the Contractor shall apply a protective coat of neutral protective cleaner to completed tile walls and floors. Installed tile work shall be protected by the Contractor with kraft paper or other heavy covering during the construction period to prevent staining, damage, and wear. Foot and wheel traffic on tiled floors shall be prohibited by the Contractor for at least 7 days after grouting is completed.

7.6.8 Architectural Concrete Sidewalks

Prior to installation, the Contractor shall prepare a 1-m by 1-m test panel, 75 mm thick, of each colour, pattern, and texture required for the Engineer's approval.

Foundations shall be prepared per Article 7.6.3.17.6.3.2 and as shown on the Contract plans. Screed concrete shall be placed to the proper grade and wood-float to a uniform surface per Article 7.6.4.1. Colourant shall be applied by the Contractor in accordance with the manufacturer's recommendations. Stain or colourant shall meet the requirements of Section 7.8.

If a dry-shake colour hardener is used, the Contractor shall apply it evenly to the plastic concrete surface per the manufacturer's directions and using at least 30 kg per 10 m^2.

Colours shall be applied in two separate applications and the Contractor shall wood-float the surface after each application. Trowelling shall occur only after the final floating.

Dyes with a repetitive pattern shall be placed on the concrete surface and hand-tamped to create the required texture or imprint shown on the Contract plans.

Coloured curing and finishing compounds shall be applied in accordance with the manufacturer's directions.

7.7 Fencing

7.7.1 Description

This work furnishes, installs, repairs, and replaces fences and gates, complete with hardware and appurtenances, as shown on the Contract plans, as specified herein, and as approved by the Engineer. Types and height of fencing shall be shown on the Contract plans. These types include the following:

- Chain-link fence, including vinyl coated chain link.
- Glare screen
- Wire fence, which may be barbed wire or include woven wire
- Temporary fence
- Sand fence

Chain-link and wire fence are typically used as animal/pedestrian barriers along highway right-of-ways. Wire fence is more generally used for right-of-way fencing in rural areas. Chain link may be also used for security or vandal protection around public restricted areas.

Glare screens typically consist of manufactured units and may be of two different general types. Type 1 is a vertical blade type usually mounted to the tops of traffic barriers to limit glare from oncoming traffic headlights, used for both permanent and temporary detour applications. Type 2 are usually constructed of a small pattern sized diamond-woven wire mesh fence or using chain-link fencing with interlocked vertical slats, manufactured from aluminium-, galvanised-, or aluminium-coated steel that is fabricated and placed to reduce glare from headlights of opposing traffic or other adjacent light sources. Type 2 glare screens can be installed for both permanent and temporary applications, and are often used as a combination glare screen and visual barrier for traffic along work zones.

Sand fences may be of two general types. Type 1 is a wire fence similar to the wire fence specified in Article 7.7.3.4, except specifically modified to be used in rural areas as a camel fence. Type 2 as specified herein, is a sand trapping fence composed of manufactured units consisting of twisted wire pairs with interwoven wooden slats specifically designed to trap and help protect the roadway from drifting, windblown sand.

7.7.2 Materials

All material used in the construction of fences and gates shall be new. Materials shall be durable and impact resistant, meeting the requirements specified herein, as shown on the Contract plans, or as may be described in the Particular Specifications and as approved by the Engineer. Iron or steel material shall be galvanised, unless specified otherwise. Material upon which serious abrasions of galvanising occurs shall not be acceptable. All fence materials, per each type and application, shall be provided from a single manufacture as approved by the Engineer.

All materials for the various types of fencing shall comply with the specified requirement of Table 7-34, including coating class, style, fabric, fittings, and hardware. Where there is a conflict between these Specifications and the referenced specification, the requirements of these Specifications shall govern.

Table 7-34: Materials requirements for fencing installations

Material	Requirement
Barbed wire	AASHTO M 280
Tension wire	AASHTO M 181
Steel woven fence wire	ASTM A116, AASHTO M 181, AASHTO M 279
Fence fittings	ASTM F626 or AASHTO M 232M
Fence posts and framework steel sections Fence post and framework steel strengths and coatings	ASTM A702, AASHTO M 181 ASTM F1043, ASTM F1083
Sampling of pipe posts for galvanizing	ASTM A53M

PVC shall mean polyvinyl chloride. GMS shall mean galvanised mild steel.

Approval of fence material shall be by manufacturer's certificate of compliance, submitted by the Contractor. This submittal shall include the following information for Engineer's approval:

- Manufacturer's name
- Product name and description
- Manufacturer's technical data
- Storage instructions
- Installation instructions

Contractor shall also provide the following to the Engineer:

a. Shop drawings showing a complete layout plan with posts, bracings, gate, and detail drawings for all connections
b. Mock-ups, as requested by the Engineer, that includes, at a minimum, a 2-m-length with typical gate hardware and connections

Samples shall be supplied by the Contractor, as requested by the Engineer, and shall include, at a minimum, the following:

1. Mesh measuring 300 mm by 300 mm
2. Line wire measuring 300 mm long
3. Tying wire measuring 300 mm long
4. Stirrup wire measuring 300 mm long
5. Barbed wire measuring 300 mm long
6. Fence fittings measuring 300 mm long
7. Post and brace of each type

Manufacturer shall be a company specialised in production of the fencing type required, with minimum of 5 years experience.

7.7.2.1 Chain-link Fence

a. Post Material for Chain-link Fence

Except as noted otherwise, base metal for the manufacturing of posts and braces shall comply with the requirements of AASHTO M 181, Type I zinc-coated steel, Grades 1 or 2; and shall include all round and roll-formed material, including brace rails, top rails, line posts, brace posts, end posts, corner posts, and pull posts — except that the carbon content of steel posts shall not be more than 0.4 %. Steel made by the oxygen furnace process will be acceptable.

Grade 1 post material shall conform to the weight per linear foot, minimum wall thickness and detail requirements of ASTM F1043. Grade 1 post material that exceeds the maximum wall thickness requirement of ASTM F1043 may be accepted, provided it does not interfere with the proper construction of the fence.

Grade 2 post material shall meet the organic exterior coatings requirements of AASHTO M 181, Section 33; and the additional requirement that the interior coated surface shall be capable of resisting 300 hours of exposure to salt fog with a maximum of 5 % red rust when tested in accordance with ASTM B117.

Round post material shall be either Grade 1 or 2.

Roll-formed post material shall be Grade 1. Roll-formed end, corner, and pull posts shall have integral fastening loops to connect to the fabric for the full length of each post. Top rails and brace rails shall be open, rectangular sections with internal flanges as shown in ASTM F1043.

Posts and braces shall additionally comply with the following requirements, unless otherwise indicated on the Contract plans.

Table 7-35: Chain-link post requirements

Location	Type	Minimum size of the greatest dimension (mm)	Minimum wt per linear metre (kgs)
End, corner, pull, and gate posts	Pipe	60.3 OD	5.43
Line posts	Pipe	48.3 OD	4.05
Braces (struts)	Pipe	42.2 OD	3.38

OD = outside diameter

Post-types used shall be the same on any one project.

Posts shall have provisions to securely hold the top tension wire in position and allow for removal and replacement of a post without damaging the top tension wire. Tubular posts shall be fitted with rain-proof tops.

Extension arms, stretcher bars, and other required fittings and hardware shall be steel or malleable iron, or wrought iron, and shall be hot-dipped galvanised.

b. Post Caps for Chain-link Fence

Malleable iron, or plastic, post caps designed to exclude all moisture shall be provided for each post. If the Contract plans show barbed wire, the Contractor shall furnish barbed wire support arms integral with the post caps. If a top rail is shown on the Contract plans, the Contractor shall furnish post caps with an opening for the top rail. Post caps must have a 50 mm skirt.

c. Chain-link Fence Fabric

Chain-link fence fabric shall consist of galvanised steel wire that complies with AASHTO M 181 and as shown on the Contract plans. Base metal shall be hot-dipped galvanised steel wire. Wire used in the manufacture of the fabric shall be 4.88 mm for all fence fabric. Wire shall be woven into 50 mm, ±2 mm, diamond mesh. Width, top, and bottom finishes of the fabric shall be as specified in AASHTO M 181.

Tie wires and post clips shall be at least 3.76 mm galvanised steel.

Turnbuckles and truss tighteners shall be fabricated of commercial quality steel, malleable iron, or wrought iron, and shall be hot-dipped galvanised. Truss tighteners shall have a strap thickness of not less than 6 mm.

Portland cement concrete shall be used for metal post, brace foundations, and deadmen; and shall comply with the requirements of Section 4.3.1 of Chapter 4, Concrete Works, for Class C20/20 concrete.

d. Gates for Chain-link Fence

Gates shall be of the sizes shown on the Contract plans, and gates wider than 2.45 m shall have a vertical member installed at the midway point of the gate.

Gate frames shall be constructed of not less than 38 mm internal diameter, hot-dipped galvanised pipe conforming to AASHTO M 181 Type I, Grades 1 or 2. Corners of the gate frame shall be fastened together and reinforced with a malleable iron or pressed-steel fitting designed for the purpose. They may also be welded in conformance to the requirements of Sections 23.4.11 and 23.6.10 of Chapter 23, Steel Structures. Paint shall be applied in conformance to the applicable requirements of Chapter 24, Painting.

Each gate shall be furnished complete with necessary hinges, latch, and a drop bar locking device designed for the type of gate posts and gate used on the project. Gates shall have positive type latching devices with provisions for padlocking. Hinges, latches, and locking devices shall be galvanised. Locks shall be supplied for each gate. Three sets of keys shall be provided for all locks.

Gates fabricated from round sections of pipe of the size and weight shown on the Contract plans shall be provided by the Contractor. These materials shall meet ASTM F1083 for all gate pipes. Chain-link fence fabric for filling the gate frame shall meet the requirements of Sub-article c, of Article 7.7.2.1, for the fence type being furnished. Cross trussing shall consist of 9-mm steel adjustable rods that have been galvanised. Chain-link fence fabric specified for the fence shall be attached to the gate frame by the use of stretcher bars and the tie wires, as specified for fence construction. Suitable tension connectors shall be spaced at approximately 300 mm intervals. For each gate, the Contractor shall include the following:

1. Corner and tee fittings of malleable iron or pressed steel with means for attaching diagonal bracing members
2. Hinges of malleable iron allowing a full 180° swing, easily operated by one person

3. Ball-and-socket-type bottom hinges that do not twist or turn from the action of the gate and prevent the closed gate from being lifted off the hinges
4. A positive stop that prevents any portion of the gate from swinging over an adjacent traffic lane.
5. At least 2 steel, or malleable iron, hinges not less than 80 mm in width to hang the gate, so designed as to securely clasp to the gate post and permit the gate to be swung back against the fence
6. A malleable iron pulley system for roll-type gates, when required.
7. Diagonal braces consisting of 9-mm-diameter cable with turnbuckles, 2 to each gate frame; and, for vehicle gates, a vertical pipe brace of the size and weight shown on the Contract plans at the centre of each gate leaf
8. Latches of malleable iron or steel for single gates with a single-fork latch and padlock eye that will keep the gate closed
9. Heavy-duty padlocks acceptable to the Engineer and master-keyed. Padlocks shall be a 51 mm, Type EPC, 5-pin tumbler mechanism, brass or bronze, solid case, with chain, unless otherwise directed by the Engineer
10. Two fork latches mounted on a centre plunger rod with a padlock eye for double-leaf gates
11. Holdbacks for each leaf of vehicular gates, with a semi-automatic holdback catch anchored at least 300 mm into a 300 mm diameter by 600-mm-deep concrete footing and a malleable iron centre rest, designed to receive the plunger rod anchored as shown on the Contract plans for all double-leaf gates

Gate frames constructed of steel sections, other than pipe, that are fabricated in such a manner as to form a gate of equal or better rigidity may be used, provided they are approved by the Engineer.

e. Tension Wire for Chain-link Fence

Tension wire shall meet the requirements of AASHTO M 181. Tension wire galvanising shall be Class 1.

f. Fittings and Hardware for Chain-link Fence

Except where indicated, fittings shall be malleable cast iron or pressed steel and shall conform to the requirements of ASTM F626 or AASHTO M 232M, whichever is applicable. Fittings for any particular fence shall be those furnished by the manufacturer of the fence.

Tension truss rods shall be 9.5 mm round galvanised rods with drop-forged turnbuckles or other approved type of adjustment. Truss tighteners shall have a strap thickness of at least 6.35 mm. Couplings for tubular sections shall be outside sleeve type and shall be at least 150 mm long.

Eye-bolts for attaching tension wire shall be 9.5 mm diameter and of sufficient length to fasten to the type of post being used. Tension bars shall be 4.76 mm by 19 mm nominal and cross sectional area shall be 90 mm^2, ±5 %.

Hog rings shall be 2.68 mm galvanised steel wire. Tie wire shall be 3.76 mm galvanised steel wire or 3.76 mm aluminium wire meeting the requirements of ASTM F626.

Structural bars, stretcher bar bands, post caps, and miscellaneous hardware shall be fabricated from commercial quality steel and shall be zinc-coated in accordance with the requirements of AASHTO M 111M. Stretcher bars shall be 4.76 mm by 19 mm steel flat bars. Stretcher bar bands shall be 3.2 mm by 25.4 mm preformed steel bands.

Barbed wire, for use with chain-link fence, shall conform to the requirements of Sub-article e, of Article 7.7.2.3, of these specifications. Barbed wire support arms shall be of the type shown on the Contract plans, shall be fabricated from commercial quality steel, and shall be zinc-coated in accordance with the requirements of AASHTO M 111M. Barbed wire shall be as specified on the Contract plans, typically 3 strands of twisted 2.51 mm barbed wire with 4-point, 2.03 mm barbs spaced approximately 125 mm, conforming to ASTM A121. Support arms typically extend at an angle of 45° from vertical, with clips for attaching 3 strands of barbed wire to each support arm and sufficient strength to support a 90 kg weight applied at the outer strand.

Contractor shall install grounding rods consisting of copper-clad steel rods at least 2.5 m long, with a minimum diameter of 16 mm, or other ground rod approved by the Engineer.

All necessary quantities of fittings and fasteners shall by furnished by the Contractor in sufficient quantities to erect all fencing materials in a proper manner. Fittings for posts shall be form-pressed or rolled steel, forged steel, malleable iron or wrought iron of good commercial quality, and spaced as shown on the Contract plans.

g. Chain-link Fence Coatings

Where shown on the Contract plans, or required in the Particular Specifications, posts, gate frames, rails, bracings, clamps, accessories and similar materials shall have a vinyl coating thickness of 0.254 mm to 0.356 mm.

Fabric shall have a vinyl coating thickness over the galvanised substrate as per AASHTO M 181.

Vinyl coating shall be continuously extruded, not sprayed or dipped, over the galvanised steel wire by the thermal extrusion process under 352 kg/cm^2 (34 MPa) pressure to ensure a dense and impervious covering free of voids, having a smooth and lustrous surface appearance.

Wire shall be vinyl-clad before weaving and shall be free and flexible at all joints.

Plasticised PVC with a low temperature -20° C, consisting of plasticiser with no fillers, extenders, or extraneous matter other than the necessary stabilisers and pigments shall be used. Colours shall be stabilised and have a light fastness that shall withstand a minimum Weather-O-Meter exposure of 10,000 hours without any deterioration per ASTM D1499, E 42, Type E.

In addition to the requirements above, Vinyl-clad wire shall meet the material requirements of Table 7-36.

Table 7-36: Requirements for vinyl coating for chain-link wire

Property	Requirement
Accelerated aging test: 10,000 hours at 62° C	No cracking or peeling
Character	Self-extinguishing
Insulation	12,000 volts
Tensile strength	190 kg/cm^2
Elongation	275 %
Specific gravity	1.30 maximum
Hardness	At least Durometer A-90, ±5
Abrasion resistance	High
U.L. Test for abrasion at 120° C under 500 g load	15 % maximum deformation
Compression cut through (Bell Laboratory Test)	105.5 kg/cm^2

Vinyl coatings shall, in addition, resist attack from prolonged exposure to dilute solutions of most common mineral acids, sea water, and dilute solutions of most salts and alkalis.

Pipe coating materials shall meet the material requirements of Table 7-37.

Table 7-37: Requirements for pipe coating materials

Property	Requirement
Specific gravity	1.32 maximum
Tensile strength	105.5 kg/cm^2 minimum
Elongation	200 %
Tear strength	381 microns = 2.4 kg
Hardness of coating	At least 80 Shore A Durometer, ±v5
Dielectric strength	1,000 volts per mil
Volume resistivity	2.0 ohm/cm by 1012 ohm/cm
Brittle temperature	-20° C (film)
Water absorption at 25°C, one week at 94°C, 2 hours	 0.70 % maximum 0.95 % maximum
Resin formulation shall meet the standard 3,000-hour Weather-O-Meter requirement	No cracking, blistering, or loss of adhesion
Impact resistance test, Gardner test method	185 cm/kg minimum
Certified abrasion resistance: withstand at least 10-minute blast, at 5.6 kg/cm^2, at 305 mm, at 25° C with S230 shot at an impingement angle of 90 degrees	Steel substrate shall not be exposed
Salt spray test (Federal Test standard 141–Method 6061) For scored samples after exposure of 1,000 hours	10,000 hours minimum with no perceptive deterioration to coating or evidence of metal corrosion for unscored samples. Undercutting shall not exceed 5 mm
Prolonged exposure at 24° C to fuses	Exhibit chemical resistance
Resist attach from prolonged exposure to dilute solutions of mineral acids, sea water, and most salts and alkaline	

All damaged areas of the coating shall be repaired in accordance with the coating manufacturer's instructions.

All fasteners, including nuts, bolts, washers, shall be stainless steel of Type 316 or A4.

All hardware, including latches and hinges, shall be GMS.

h. Motorised Gates and Accessories

1. Horizontal Sliding Type

Gates shall have a minimum clear width of 7.3 m and 1.0 m for vehicular and pedestrian entrances, respectively, and a height to match the fence height as shown on the Contract plans.

Frame, verticals, and bracings shall be of mild steel (MS) hollow sections, as detailed in the Contract plans. After fabrication, MS sections, accessories, and other components shall be hot-dipped galvanised. Finished fabricated products shall be painted using a system per applicable specifications in Section 24.4 of Chapter 24, Painting, with an approved quality primer and enamel paint, black in colour, or as otherwise shown on the Contract plans.

Motorised gates shall be remote-controlled and horizontally sliding. Systems shall be suitable to be operated under a local power supply system 220/415 V, 50 Hz. Assembly shall consist of photo-electric cells and the pressure switches connected together in series with contacts normally closed for remote operation. Assembly shall include the following:

i. Heavy gauge steel frame for pad mounting.
ii. All-weather hinged covers with provision for padlocking
iii. Adjustable safety friction clutch.
iv. Adjustable limit switches, rotary type
v. Magnetic solenoid locking brake
vi. Emergency disconnect for manual operation in case of power failure
vii. Magnetic reversing starter, of size 1 contactor type, with overload and under voltage protection.
viii. Factory prewired electrical system
ix. Permanent lubricated heavy-duty bearings and heavy-duty roller chain
x. Removable hood for the motor.
xi. Operator shall be suitable to withstand the local weather conditions IP54.
xii. Motor shall meet the international standards, IEC, and shall be suitable for remote operation
xiii. Electric gate operator shall include electric gate operator to be located as indicated on the Contract plans. Operator shall have parallel 3-button illuminated control stations for open, stop, and close. Electrical conduit, switches, wiring, and connections specified under the applicable electrical sections shall be provided
xiv. Pedestrian gates shall be of manually operated type
xv. Padlock with 3-sets of master keyed keys for each gate.

2. Stop Bar

Stop bars, or traffic barriers, shall be designed for a 100 % duty cycle. Barriers shall be equipped with a torque motor that lifts the boom arm through a sinusoidal level system that allows the boom arm to be locked in both the up and down positions. All the electronic equipment shall be manufactured to ISO 9002 standards. Boom arms shall lift up to at least 85° in the event of power failure. At least 4 tension springs shall be available for counter balancing. Left- and right-hand barriers shall be provided, as required, with round or octagonal boom arms. Barriers shall be design to require minimum maintenance.

Boom arms shall be available to at least 6 m long and made from extruded aluminium tubing powder-coated in white with red reflective tape. Boom arms shall be joined to the boom adapter so that the attachment will sheer in case of accidental collision and prevent damage to the barrier and boom arm. Jack knife kits shall be provided, if required, for height restricted areas for up to 4.5 m boom arms.

Left- and right-hand boom arm configurations shall be available. Rubber buffers shall be used for dampening on the down position to eliminate bouncing. A minimum 60 w, 220 v AC, 50 hz motor gear box shall be provided, and shall include 100 % duty cycles. An instant reverse torque drive motor with a minimum design operating temperature of 50° C shall be provided. Booms shall open to 90° under power and at least 85° on power failure.

Cabinets shall be an IP54 enclosure, manufactured from a minimum 1.6-mm 3CR12 stainless steel. Cabinets shall be powder-coated in any RAL colour selected by the Engineer. Operating speeds shall be from 2 seconds to 4 seconds from horizontal to vertical position.

Modular electronics with plug-in attachments shall be used for control. Large, lockable, hinged doors shall be provided for easy access.

7.7.2.2 Glare Screens

Glare screens may be of two types, as shown on the Contract plans and as discussed below.

a. Type 1: Glare screen shall consist of a multipiece vertical blade delineator system used along medians. They are the type positioned on the top of median barriers to create a visual shield for the length of the median. They can be used for both temporary detours and permanent medians. Salient features of the Type 1 glare screens shall be as follows:

   1. Modular, with components consisting of a vertical blade, base and horizontal base rails. Vertical blades shall be of sizes as shown on the drawing, but typically are available in 60 mm through 1000 mm heights.
   2. Durable manufactured of impact resistant, non-metallic polymeric materials. All materials shall be new. Blade, base and rail shall have sufficient strength to withstand 5 impacts beginning with 15 mph and progressing through 25, 35, 45 and 55 mph respectively. Device used for impacting the glare screen shall be a horizontal steel bar with a 400 mm by 60 mm plastic covered steel plate attached to simulate truck bumpers, trailers and wide or overhanging loads. Lowest point of impact by the steel plate will be 250 mm above the top of the barrier wall. After 5 impacts all blades shall remain attached to the system, stand erect, be serviceable, and exhibit no delaminating or cracking.

b. Type 2: Visual barrier fence which can also be installed on concrete barriers and steel guardrails or in standalone installations. They are typically used for curved roadways, access ramps, raised highways and construction lanes. Glare screen fence types and sizes shall be as shown on the Contract plans, but are typically of the general types as follows:

   1. Style A: Woven wire panels with approximately a 25 mm diamond wire mesh.
   2. Style B: Chain-link fencing with vertical wood or plastic material slats.
   3. Alternate manufactured fence panel type as may be approved by the Engineer.

All material used in the construction of the fence shall be new. Iron or steel material shall be galvanised or aluminium-coated, as specified. Imperfectly galvanised or aluminium-coated material, or material upon which serious abrasions of galvanising or aluminium coating occur, will not be acceptable.

Glare screen fence fabrics for Style A and Style B fences shall consist of diamond-woven wire mesh. Fabric wire shall be 3.76 mm iron or steel wire that shall meet all of the requirements of ASTM A392 galvanised or ASTM A491 for aluminium-coated, except that galvanising of the Style B glare screen fabric shall be not less than 305 g/m^2 and shall be done before weaving. Aluminium coating shall be Class II.

Style A glare screen mesh size shall be approximately a 25 mm diamond. Style B glare screen mesh size shall be a maximum of 90 mm vertical and 140 mm horizontal. Design of the Style B shall permit the slats to be installed in a vertical position, as shown in the Contract plans without distortion of the slats.

All fencing materials for the Type 2 glare screen fences shall meet the applicable requirements of Article 7.7.2.1 for chain-link fencing. Vertical slat materials for the Style B glare screen fence shall meet the following requirements:

1. Wood slats shall be 10 mm by 60 mm by the height designation of the fence. Material shall be finished and treated and shall be free from loose knots, cracks, or other imperfections. A dimensional tolerance of ±1.5 mm in width or thickness is allowed provided that the maximum space between slats does not exceed 19 mm.
2. Plastic slats shall be 10 mm by 60 mm by the height designation of the fence. They shall be manufactured from tubular polyethylene colour pigmented material consisting of high-density

virgin polyethylene and colour pigments, designed to retard ultraviolet penetration. These materials shall have a minimum wall thickness of 0.076 mm, ±0.0076 mm, and shall remain flexible without distortion and without becoming brittle through a temperature range of -57º C to +121º C. Tensile strength shall be at least 24,820 kPa and the melt index shall not exceed 0.25.

Plastic slats shall be retained in place by means of U-shaped retainer members at the bottom and top of the fence. Retainer members shall be of the same material as the slats. Colour for plastic slats will be approved by the Engineer from samples submitted by the Contractor or supplier.

7.7.2.3 Wire Fence

Wire fence materials shall conform to the requirements of Article 7.7.2.1. All materials used in the construction of the wire fence shall be new. All iron or steel material shall be galvanised. Material upon which serious abrasions of galvanising occur will not be accepted. Materials shall be accepted based on manufacturer’s certificate of compliance.

a. Steel Post for Wire Fence

Round post material shall conform to AASHTO M 181, Type I, Grade 1.

All angle post material shall be hot-dipped galvanised in accordance with the requirements of AASHTO M 111M, Grade 75. Galvanising shall be 541 ml/m^2 of surface area. Angle posts used for end, corner, gate, and pull posts and braces shall have a minimum weight of 4.6 kg/m.

Posts shall be not less than 2 m in length. A tolerance of -5 % on the weight of individual posts, braces or anchor plates will be permitted. One type of line post shall be used throughout the project. Line posts shall be studded, slotted, or properly adapted for attaching either wire or mesh in a manner that will not damage the galvanising of posts, wire, or mesh during the fastening. Line posts shall have a minimum weight of 2 kg/m and shall be provided with a tapered galvanised steel anchor plate. Anchor plates shall be securely attached and have a surface area of 500, ±50 mm^2, a minimum weight of 0.3 kg and 541 ml/m^2 galvanising. Only new steel shall be acceptable. Rerolled or open seam material shall not be used.

When painting is specified, the Contractor shall use an approved anticorrosive coating per applicable requirements of Section 24.3 of Chapter 24, Painting. After the installation of painted posts and braces, the Contractor shall spot-coat damaged areas with the same paint colour using paint with at least the same anticorrosive properties as the original paint. Size, weight, and area of posts, braces, and anchor plates shall be as shown on the Contract plans.

b. Wood Posts and Braces for Wire Fence

Outer bark and all inner cambium bark shall be removed by the Contractor from treated posts; however, occasional strips of bark may remain if not more than 13 mm wide or more than 75 mm long. Only sound timber that is free from decay, shakes, splits, or other defects that can weaken the posts or braces, or otherwise make them structurally unsuitable for the purposes intended, shall be used. Knots that are sound, tight, trimmed flush, and not in clusters will be allowed, provided they do not exceed one-third of the small diameter or the least dimension of the posts and braces. Spurs and splinters shall be removed and the ends cut square.

All wood posts and braces shall be treated.

Before use all materials shall be of good quality and approved by the Engineer. Peeler cores shall not be used for round posts. Wood fencing materials shall have sufficient sapwood in the outer periphery to obtain the specified penetration of preservative. Fencing materials shall be cut to the correct length before pressure treatment.

Line posts shall be 75-mm, minimum diameter round posts or nominal 75-mm by 75-mm square-sawed posts. If the posts are to be pointed for driving, they shall be pointed before treatment. Line posts shall be at least 2 m in length. Pull posts and brace posts shall be 150-mm-diameter round posts or nominal 150-mm by 150-mm material not less than 2 m long.

End, gate, and corner posts, and posts at an intersecting fence, shall be 150-mm-diameter round posts or nominal 150-mm by 150-mm material not less than 2.4 m long.

Preservatives used to pressure-treat wood fencing materials shall meet the requirements as shown on the Contract plans or as approved by the Engineer. Minimum penetration of preservative shall consist of the following:

- For material 125 mm or less: 10 mm penetration and 90 % of sapwood
- For material 125 mm or greater: 13 mm penetration and 90 % of sapwood

Retention of the preservative shall be per Table 7-38.

Table 7-38: Minimum retention in kilograms per m3

Preservative	Sawed Posts	Round Posts
Creosote	160.0	128.5
Pentachlorophenol	8.0	6.4
ACA	6.4	6.4
ACZA	6.4	6.4
CCA	6.4	6.4

c. Brace Wire for Wire Fence

Brace wire shall be 3.76-mm wire galvanised to meet the requirements of AASHTO M 279, Type Z, Class 1.

d. Staples and Wire Clamps for Wire Fence

Staples used to attach the wire fencing to wood posts shall be 3.76 mm, 38 mm long, galvanised to meet the requirements of AASHTO M 279, Type Z, Class 1. Wire clamps used to attach the wire fencing to steel posts shall be 3.06 mm wire, galvanised to meet the requirements of AASHTO M 279, Type Z, Class 1.

e. Barbed Wire Material Requirements

Barbed wire shall be furnished by the Contractor where shown on the Contract plans, as approved by the Engineer. Typical installations shall be per ASTM A121, Class 1, consisting of 3 strands of 2.51-mm gauge wire, twisted with 4-point, 2-mm barbs spaced 125 mm apart, at most.

f. Barbless Wire Material Requirements

Barbless wire shall meet the same requirements as barbed wire, except that the barbs shall be omitted.

g. Wire Mesh Material Requirements

Wire mesh shall conform to the requirements of AASHTO M 279, Type Z, and shall consist of 8 horizontal wires with vertical stays spaced 300 mm apart. Top and bottom wires shall be 3.43 mm, and the intermediate wires and vertical stays shall be 2.51 mm. Mesh shall have a total width of 0.8 m and a height as shown on the Contract plans.

Galvanising shall be Class 3. Zinc-coated wire, as represented by the test specimens, shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns per minute around a cylindrical steel mandrel having a diameter the same as the specimen being tested, without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with bare fingers.

h. Vertical Cinch Stays for Wire Fence

Vertical cinch stays shall be 3.6 mm galvanised wire meeting the requirements of AASHTO M 279, Type Z, Class 1. Minimum weights for zinc coating shall be 92 g/m^2 of uncoated wire surface. Tie wires, hog rings, and post clips shall be zinc-coated steel of good commercial quality and shall be of the same gauge as the fence fabric being fastened.

i. Miscellaneous Hardware for Wire Fence

Galvanised bolts, nuts, washers, braces, straps, and suitable devices for holding barbed wire and wire mesh firmly to metal posts shall be used. Bolts, nuts, hinges, latches, and other miscellaneous hardware shall be galvanised in accordance with AASHTO M 232M.

j. Wire Gates

Gate frames shall be constructed of galvanised pipe with a nominal diameter of not less than 25 mm. Pipes shall conform to the requirements of AASHTO M 181 Type I, Grade 1. Wire gates shall be not less than 1.2 m in height and shall be designed to fit openings of the widths called for in the Contract plans. Each gate shall be provided with 2 upright braces of the same material as the frame, spaced at quarter points in the gate. All gates shall be provided with adjustable 8-mm-diameter galvanised diagonal truss rods from corner to corner.

Gate frame shall be provided with wire mesh conforming to the requirements specified in Sub-article g, of Article 7.7.2.3, except that it shall consist of 10 horizontal wires and have a total width of 1.2 m. Each gate shall be furnished complete with necessary galvanised hinges and latches designed for use with the type of gate posts used on the project. Hinges shall be so designed as to be securely attached to the gate post and to enable the gate to swing back against the fence. Double gates shall be hinged in the same manner as single gates and shall be provided with an approved galvanised drop-bar locking device. Galvanising for hinges, latches, and locking devices shall be in accordance with AASHTO M 232M.

Gates greater than 1.5 m wide shall have a vertical member installed at the midway point of the gate. Gates shall be hung by at least 2 steel, ductile iron, or malleable iron hinges, so designed as to securely clamp to the type of gate post furnished and permit the gate to swing back against the fence. Gates shall be provided with a combination steel, ductile iron, or malleable iron catch and locking attachment that will not rotate around the latch post. Stops to hold gates open shall be provided, where required.

7.7.2.4 Temporary Fencing

The Contractor shall furnish, install, maintain and remove temporary fencing at existing utilities, services, along detour roads, as required for safety of the public, as specified herein and where directed by the Engineer.

Temporary fencing shall consist of wood fence posts a minimum of 1.5 m in length and with a minimum cross-sectional dimension of 75 mm in any direction, set 600 mm into the ground at 3 m on centres, and end struts or braces, as required. Steel fence posts may be substituted for wood, if approved by the Engineer.

Two strands of approved, brightly coloured utility type plastic warning tape shall be stapled to the wood fence posts at the top and at mid-height in a taut and workmanlike manner.

7.7.2.5 Sand Fences

Sand fences may consist of one of two types, and shall be supplied and constructed as shown on the Contract plans, and as described below:

a. Wire fences used as camel fences: Camel fences shall meet the material and construction requirements of Article 7.7.3.4 as modified by the following items:
    1. Line wires: 16 nos. line wires, 3.15 mm dia., to every post with tensile strength of 1200 N/mm^2 and galvanized according to AASHTO M 279, Type Z, Class 1.

2. Straining, start, end and corner posts: Metal posts having IPE 120 section, 3000mm long, hot dip galvanized to BS EN ISO 1461. Straining posts are installed at maximum 300 m centers. Start, end and corner posts are installed at the locations described in Sub-article a, of Article 7.7.3.4.
3. Intermediate (line) posts: Metal posts having IPE 80 section, 2900 mm long and Article 7.7.3.4. Intermediate posts are provided at every 7.5 m centers.
4. Struts (braces): Struts for straining and end posts are of IPE 80 sections and are 3000 mm long, hot dip galvanized to BS EN ISO 1461.
5. All post and strut foundations shall be concrete bedded in accordance with Article 7.7.3.2.
6. Dropper bars: 11 nos. dropper bars per bay of 7.5 m to keep the line wires in place. Droppers shall have aluminium clips to connect the bars to the line wires.

b. Sand control fences used for trapping windblown sand: Sand control fences shall be supplied and constructed as shown on the Contract plans and as approved by the Engineer. Sand control fences shall be a provided from a single manufacturer with the posts, wire and vertical slats acting as a single system. Sand control fence shall be comprised of support posts, wire, wood slats woven into the wire tension strands, fittings, braces, and all necessary hardware. Approved sand control fences shall meet the following requirements:

   1. Overall above ground height of the fence shall be approximately 2 m.
   2. Porosity of the fence system (open space between the vertical slats) to be within 40 to 60 % of the frontal fence area.
   3. Slats composed of durable wood, treated against insects, with sizes approximately 1.8 m by 40 mm by 10 mm. Slats shall be evenly spaced and fixed into the wires by twisting each tension wire pair around each slate and fixed with a galvanized steel staple. Each twist shall be not less than two 360^o twists of the wire in the weave between the slats.
   4. Galvanised steel tension wires galvanized according to AASHTO M 279, Type Z, Class 1, gauge 12 or larger, having minimum tensile strength of 1200 N/mm^2. Tension wires shall consist of a minimum of 4 no., 2-wire pairs spaced evenly over the height of the fence.
   5. Post shall be carbon steel pipes, hot dip galvanized to BS EN ISO 1461, 50 mm dia. 3 m long, placed 3 m apart, with a 4 mm wall thickness, Posts shall be have suitable wire attachment provisions meeting the requirements of Sub-article a, of Article 7.7.2.3.

7.7.2.6 Animal Grid

The Contractor shall furnish, place, and construct animal grids in accordance with these specifications and requirements of BS 4008:2006 and conforming to the details, dimensions, and locations shown in the Contract plans.

The Contractor shall provide shop drawings for the Engineer's approval prior to construction of the animal grid.

Unless otherwise specified, all structural steelwork shall be Grade S275 conforming to BS EN 10025, and shall be galvanized in accordance with BS EN ISO 1461:2009.

Unless otherwise specified, all bolts shall be Grade 4.6 conforming to BS 3692:2001.

Unless otherwise specified, all welds shall be in accordance with BS EN 1011-1:2009, BS EN 1011-2:2001, and BS EN 1011-8:2004.

Concrete and steel reinforcement for use in animal grids shall meet the applicable requirements of Chapter 4, Concrete Works, and Chapter 5, Reinforcing Steel, of these standard specifications.

7.7.3 Construction Requirements

7.7.3.1 General

Fence lines shall be cleared of all trees, brush, logs, up-turned stumps, roots of downed trees, rubbish, and debris. Minor irregularities in the path of the fencing shall be levelled-off.

Clearing width shall be approximately 3 m, or as shown on the Contract plans or approved by the Engineer.

Grubbing will not be required, except where short and abrupt changes in the ground contour will necessitate removal of stumps to properly grade the fence line. Any high points that interfere with the placing of fence fabric shall be excavated to provide the clearance shown on the Contract plans. All stumps within the clearing limits shall be removed or close cut. Grading of the fence line shall be sufficient enough to prevent short and abrupt breaks in the ground contour and improve the aesthetic appearance of the top of the fencing when installed. It is expected that in the performance of this work, machine operations will be required for chain-link fencing, and handwork will be required for wire fencing — except where sufficient widths exist for machine work.

Fences shall be constructed close to and inside the ROW line unless otherwise directed by the Engineer or shown in the Contract plans. Deviations in alignment to miss obstacles will be permitted only when approved by the Engineer and only when such deviations will not be visible to the travelling public or adjacent property owners.

Damaged fences or gates shall be repaired or replaced by the Contractor. If posts cannot be repaired by straightening, the Contractor shall remove and replace the post and foundation. When a fence installation is to be removed in its entirety and not replaced, the Contractor shall return all salvageable material to the location shown in the Contract plans and backfill all postholes with suitable material. Salvaged fence fabric shall be returned to the Owner in secured rolls not more than 15 m long. Unsalvageable materials shall be disposed of by the Contractor.

7.7.3.2 Chain-link Fence and Gate Construction

All gates, corners, and end posts shall be fitted with tops designed to fit securely over the posts. A top rail shall be fastened to the side of the gate posts, corners, and end posts; and, on the top of the line posts by steel or malleable iron or wrought iron fitting, galvanised, at each connection — all in accordance with the detail indicated on the Contract plans. All required fittings and hardware shall be fastened to the posts in the proper manner.

Changes in line where the angle of deflection is 15 degrees or more shall be considered corners and shall require the installation of corner posts. Post spacing and placement shall conform to the requirements of Table 7-39.

Table 7-39: Post spacing and placement for chain-link fence

Post type	Required spacing or placement
Line posts	3 m maximum interval
Pull posts	50 m maximum interval At each change in direction exceeding 20^{o} vertically
Corner posts	At each horizontal angle point exceeding 15^{o} At line changes amounting to 600-mm tangent offset or more between posts

Post spacing shall be measured from the centre of one post to centre of the next, and shall be parallel to the slope of the natural ground. All posts shall be placed in a vertical position. In unusual locations, the posts shall be set perpendicular to the ground surface, as approved by the Engineer.

All posts shall be set in concrete footings that comply with the details shown on the Contract plans and crowned at the top to shed water. Concrete footings shall consist of Class C25/20 concrete and shall comply with Chapter 4, Concrete works. Fence fabric or wire shall not be attached to the posts until the concrete has cured a minimum of 72 hours.

End, corner, and gate posts shall be braced to the nearest line post with galvanised diagonal or horizontal braces used as compression members and galvanised steel truss rods with turnbuckles or truss tighteners used as tension members. Line posts shall be braced horizontally and trussed in both directions at intervals not to exceed 250 m.

Excavation or filling required along fence lines shall be in accordance with the applicable requirements of Sections 2.4 and 2.5 of Chapter 2, Earthworks.

Chain-link fabric shall be fastened on the side of the posts designated by the Engineer.

Fabric shall be stretched and securely fastened to the posts, and between posts the top and bottom edges of the fabric shall be fastened to the tension wires. Tension wires shall be stretched tight. Tension wire along the bottom shall be installed on a straight grade between posts by excavating the high points of ground; and, in no case will filling of depressions be permitted.

Fabric shall be fastened to end, corner, and gate posts with a minimum 10 mm diameter steel stretcher bar and not less than 3-mm by 18 mm stretcher bar bands spaced at a maximum 300-mm intervals. Fabrics shall be fastened to line posts, top rails, and tension wires with tie wires or post clips. Fasteners shall be spaced at maximum intervals of 600 mm.

Surplus excavated material remaining after the fence has been constructed shall be disposed of in a manner approved by the Engineer.

Existing fences that are to remain in place and that have been damaged by the Contractor's operations shall be replaced or restored by the Contractor at no additional cost to the Owner.

Unless otherwise directed by the Engineer, posts shall be set in concrete to the dimensions shown on the Contract plans. All concrete footings shall be crowned so as to shed water. If the Contract plans indicate posts shall be set in undisturbed earth, the Contractor shall either drive or drill them. Driving shall be accomplished in such a manner as not to damage the post. Voids around the posts shall be backfilled with suitable material and thoroughly tamped.

Concrete footings shall be constructed to embed the line posts at grade depressions where the tension on the fence will tend to pull the post from the ground. Forms shall be used for footings where the ground cannot be satisfactorily excavated in neat lines. Forms shall remain in place for at least 24 hours after concrete placement. Footings shall be backfilled with moistened material immediately after each form is removed and materials thoroughly tamped. Concrete shall be covered with at least 100 mm of loose, moist material that is free of clods and gravel immediately after placing concrete. No other curing is required.

Excess excavated and loose material used for curing shall be spread neatly and uniformly. Excess concrete and other construction debris shall be removed from the site.

Where solid rock is encountered without an overburden of soil, line posts shall be set at a minimum depth of 360 mm; and, end, corner, gate, brace, and pull posts at a minimum of 510 mm into the solid rock. Holes shall have a minimum width of 25 mm greater than the largest dimension of the post section. Posts shall be cut before installation to lengths that will give the required length of post above ground, or if the Contractor so elects, an even length of post set at a greater depth into the solid rock may be used. After the post is set and plumbed, the hole shall be filled with Class G3 grout per Article 4.3.10.4 of Chapter 4, Concrete Works. Grout shall be thoroughly worked into the hole so as to leave no voids and crowned to carry water from the post.

Where solid rock is covered by an overburden of soil or loose rock, the posts shall be set to the full depth shown in the Contract plans unless penetration into solid rock reaches the minimum depths specified above. In this case, the depth of penetration may be terminated. Concrete footings shall be constructed from the solid rock to the top of the ground. Grouting will be required on the portion of the post in solid rock.

Steep slopes or abrupt topography may require changes in various elements of the fence. It will be the responsibility of the Contractor to provide all posts of sufficient length to accommodate the chain-link fabric and ornamental tops adapted to receive the top rail.

a. Chain-link Fence Top Rail

Top rails shall pass through the ornamental tops of the line posts, forming a continuous brace from end to end of each stretch of fence. Lengths of tubular top rail shall be joined by sleeve couplings. Top rails shall be securely fastened to terminal posts by pressed steel fittings or other appropriate means.

b. Chain-link Fence Tension Wire and Tension Cable

One continuous length of tension wire shall be used between pull posts. Sufficient tension shall be applied to avoid excess sag between the posts. Tension wires shall be tied or otherwise fastened to end, gate, corner, or pull posts by methods approved by the Engineer.

Cables shall be installed by the Contractor on all terminal posts and extended to adjacent posts. The cables shall also be installed on each side of corner and pull posts. Cables shall be installed using a 9.5-mm drop-forged, eye-and-eye, or eye-and-clevis turnbuckle, unless otherwise shown on the Contract plans.

c. Chain-link Fence Fabric

Chain-link fabric shall be placed on the face of the post away from the roadway, except on horizontal curves where it shall be placed on the side designated by the Engineer.

Chain-link fabric shall be placed approximately 25 mm above the ground and on a straight grade between posts by excavating high points of ground. Filling of depressions will be permitted only upon approval of the Engineer. Fabric shall be stretched taut and securely fastened to the posts. Fastening to end, gate, corner, and pull posts shall be with stretcher bars and fabric bands spaced at intervals of 375 mm or less or by weaving the fabric into the fastening loops of roll formed posts. Fastening to line posts shall be with tie wire, metal bands, or other approved methods — and attached at 350 mm intervals. Top and bottom edges of the fabric shall be fastened with the wires spaced at 600 mm intervals to the top rail or to top and bottom tension wires, as may be applicable.

Rolls of wire fabric shall be joined by weaving a single strand into the ends of the rolls to form a continuous mesh.

d. Chain-link Fence Gates

Motorised gates and accessories shall be installed as shown on the Contract plans and in conformance with Sub-article d, of Article 7.7.2.1, as approved by the Engineer. Shop drawings and product data shall be submitted by the Contractor for Engineer approval. Shop drawings shall include layouts for components, accessories, fittings, hardware, anchorages; height elevations of the same; and schedule of components. A copy of the manufacturer's installation instructions and any samples requested by the Engineer shall be furnished by the Contractor.

Manufacturer of motorised gates proposed for use in the works shall be a company that specialises in commercial quality motorised gates with at least 5 years experience.

Delivery, storage, and handling shall be in conformance with the manufacturer's recommendations.

Field measurements, surfaces, substrates, and conditions shall be verified to confirm readiness to receive work. All equipment shall be installed in accordance with the manufacturer's instructions and recommendations, and shall comply with the details shown on the Contract plans.

Chain-link fabric shall be fastened to the end bars of the gate frame by stretcher bars and fabric bands and to the top and bottom bars of the gate frames by tie wires in the same manner as specified for the chain-link fence fabric or by other standard methods, if approved by the Engineer.

Welded connections on gate frames where the galvanised coating has been burned shall be thoroughly cleaned by wire brushing and all traces of the welding flux and loose or cracked galvanising removed. Clean areas shall then be painted with 2 coats of galvanising repair paint, per ASTM A780 / A780M – 09.

Drop bar locking devices for the wire gates shall be provided with a 300-mm-round by 450-mm-deep footing of commercial concrete, crowned at the top, and provided with a hole to receive the locking bar. Depth of the penetration of the locking bar into the footing shall be as specified by the manufacturer of the locking device.

Gate posts shall align such that the top of all gate frames are level with the fencing top tension wire or top rail. If kerbs are shown on the Contract plans, vehicular gates that are greater in overall height than the adjacent fencing by the height necessary to extend to within 50 mm of the pavement between the kerbs shall be provided.

e. Chain-link Fence Grounding

At least one electrical ground for each 300 m of fence, located near the centre of the run, shall be installed by the Contractor. Additional grounds shall be provided directly under any point where power lines pass over the fence. Grounding rods shall be vertically driven or drilled by the Contractor until the top of the rod is approximately 150 mm below the top of the ground. A No. 6 solid copper conductor shall be connected to the rod and to the fence by an Underwriter's Laboratory listed method so that each element of the fence is grounded.

7.7.3.3 Glare Screen Construction

Construction of glare screens shall conform to the requirements of these Specifications, as shown on the Contract plans, as recommended by the manufacturer and as approved by the Engineer.

a. Vertical Vane Glare Screens

Installation of vertical vane glare screens shall be performed per the recommendations of the product manufacturer, as approved by the Engineer

b. Glare Screen Fence Fabric

Glare screen fabric shall be placed on the face of the posts designated by the Engineer. On curves, the fabric shall be placed on the face of the post that is on the outside of the curve. Fabric shall be stretched taut and securely fastened to the posts. Fastening to end, brace, and pull posts shall be with stretcher bars and fabric bands spaced at 300 mm intervals. Fabric shall be cut and each span attached independently at all pull and corner posts. Fabric shall be securely fastened to line posts with tie wires, metal bands, or other approved methods, attached at 350 mm intervals. Tops and bottoms of the fabric shall be fastened to the tension cable and tension wire with hog rings spaced at 600 mm intervals.

Rolls of wire fabric shall be joined by weaving a single strand into the end of the rolls to form a continuous mesh.

c. Glare Screen Fence Slats

Slats shall be fastened into the weave by using staples, screws, or other methods recommended by the manufacturer and as approved by the Engineer. Allowing the tension of the mesh to hold the slats in place will not be permitted. Slats broken or split during construction shall be removed and replaced by the Contractor at no expense to the Owner.

d. Glare Screen Fence Posts

Posts shall be installed in accordance with the Contract plans and shall be done per the applicable requirements of Article 7.7.3.2 . Posts for temporary glare screen fences may be installed on removable fittings mounted on heavy pre-cast concrete blocks. Blocks and fittings shall be as required on the Contract plans, or per the approved Contractor shop drawings, suitable to remain stable and upright for all weather conditions during the construction period.

All round posts shall be fitted with a watertight top securely fastened to the post. Line posts shall have tops designed to carry the top cable.

e. Glare Screen Fence Tension Wires

Tension wires shall be attached to the posts, as detailed in the Contract plans or as approved by the Engineer.

f. Glare Screen Fence Tension Cables

Tension cables shall pass through the line post top, and one continuous length of cable shall be used between the pull posts. Sufficient tension shall be applied to the cable to allow maximum sag of 6 mm between posts after the chain link mesh has been attached to the cable. A temporary bracing on pull posts shall be provided when applying tension to one length of cable at a time to prevent undue stresses on the pull post. Cables shall be fastened to the top of the pull post with an eye-bolt through the post and a turnbuckle connecting the eye-bolt to the cable. Pull posts shall be braced to the bottom of the end or anchor posts with a short length of cable or tension wire, as shown in the Contract plans. All turnbuckles shall have a minimum 25 mm take-up clearance after tensioning.

Ends of all cables shall be seized with annealed iron wire for a distance of at least 25 mm.

g. Glare Screen Fence Fittings, Attachments, and Hardware

A lead washer shall be placed against the shoulder of the eye-nut, eye-bolt, or backup nut; and, a lead washer backed by the steel washer placed between the pipe and lock washer. Nuts shall be tightened sufficiently to seal the hole in the pipe. A galvanised iron strap 6 mm in thickness by 300 mm in width, formed as shown in the Contract plans, shall be provided for the attachment of eye-bolts to the base of the H column post to take the strain of the cable tension off the web of the H column.

7.7.3.4 Wire Fence Construction

Construction of wire fence shall conform to the requirements of Article 7.7.3.2 in addition to the specific requirements identified in this Specification.

a. Wire Fence Posts

Line posts shall be spaced as shown on the Contract plans and directed by the Engineer at intervals not to exceed 4.25 m. All intervals shall be measured from the centre of one post to centre of the next. In general, when determining the spacing of posts, measurements will be made parallel to the slope of the existing ground, and all posts shall be placed in a vertical position, except where otherwise directed by the Engineer.

Fence posts shall be set by the Contractor plumb and firm at the intervals, depth, and grade shown on the Contract plans. Corner and pull posts shall be braced in two directions. End and gate posts shall be braced in one direction.

Corner posts shall be installed where the alignment changes 30° or more. At alignment angles between 15° and 30°, the angle post shall be braced to the adjacent line posts with diagonal tension wires.

Line posts may be driven in place provided the method of driving does not damage the post. Steel corner, gate, and pull posts shall be set in commercial concrete footings to the dimensions shown in the Contract plans and crowned at the top to shed water.

At grade depressions, where stresses tend to pull posts out of the ground, the Contractor shall snub or guy the fencing at the critical point with a double 3.76 mm galvanised wire. Wires shall be connected to the top horizontal line of the barbed wire or to the top and bottom wire or wire mesh fabric, and to a deadman weighting at least 45 kg. Fences shall be stretched before guying and snubbing.

Corner, end, or angle post assemblies shall be installed before stretching the wire between posts. Existing cross fences shall be connected to the new fences and corner posts at junctions with existing fences. While drawing barbed wire and wire fabric taut, the Contractor shall fasten to posts using galvanised ties or staples, or as shown on the Contract plans. Pull post assemblies shall be installed at 50 m maximum intervals for steel posts and 150 m maximum intervals for wood posts.

Metal line posts may be driven provided driving does not damage the posts. Metal corners, ends, pull posts, and braces must be set in concrete footings crowned at the top to shed water. Backfill shall be thoroughly tamped in 100 mm layers. Timber posts shall be notched as shown in the Contract plans.

Concrete footings shall be constructed to embed the lower part of steel line posts, and wood anchors shall be placed on wood posts at grade depressions wherever the tension on the line wires will tend to pull the post from the ground. Concrete footings shall be 1 m deep by 300 mm in diameter and crowned at the top.

Where solid rock is encountered without an overburden of soil, line posts shall be set a minimum depth of 360 mm and end, corner, gate, and pull posts a minimum depth of 510 mm into the solid rock. Holes shall have a minimum dimension 25 mm greater than the largest dimension of the post section to be set. Posts shall be cut before installation to lengths that will give 1.4 m of post above ground, or if the Contractor so elects, 1.8 m posts set 460 mm into the solid rock may be used.

After the post is set and plumbed, the hole shall be filled with Class G3 grout per Article 4.3.10.4 of Chapter 4, Concrete Works. Grout shall be thoroughly worked into the hole so as to leave no voids. Grout shall be crowned to carry water away from the post. Where posts are set in the above manner, anchor plates and concrete footings will not be required.

Where solid rock is covered by an overburden of soil or loose rock, the posts shall be set to the full depth of 0.75 m, unless the penetration into solid rock reaches the minimum depths specified above. In this case, the depth of penetration may be terminated. When the depth of the overburden is greater than 300 mm, anchor plates will be required on the steel line posts, and concrete footings shall be constructed from the solid rock to the top of the ground on steel end, gate, corner, and pull posts. When the depth of overburden is 300 mm or less, anchor plates and concrete footings will not be required.

Grouting will be required on the portion of the post in solid rock. Steel braces shall be anchored to soil or loose rock with a commercial concrete footing not less than 460 mm on any one side and set in solid rock to a minimum depth of 250 mm in the same manner as specified above for posts. Braces shall be set on the diagonal as shown in the Contract plans and connected to the post with an approved connection.

Wood braces shall be dapped 6 mm into the posts and shall be fastened to each post with 3 galvanised nails.

Wire braces shall consist of a 3.76 mm wire passed around the wood posts to form a double wire. Wire shall be fastened to each post with 2 staples and fastened together to form a continuous wire. Wires shall then be twisted together until the wire is in tension.

Where the new fence joins an existing fence, the two shall be attached in a manner satisfactory to the Engineer, end or corner posts being set as necessary. Pull posts shall be spaced not more than 300 m apart, but spacing shall be such as to use standard rolls of wire mesh with a minimum of cutting and waste. Changes in alignment of 30 degrees or more shall be considered as corners, and corner posts shall be installed. Where it is deemed by the Engineer that a change in alignment of less than 30 degrees will materially lessen the strength of the fence, the line post at the angle shall be supported by the addition of braces or wires in a manner satisfactory to the Engineer.

Where fence lines are interrupted by openings for gates, intermediate post assemblies shall be installed at both sides of the opening, at a distance of one panel width from the end of the opening.

b. Wire Fence Barbed Wire and Wire Mesh

After the pull posts have been placed and securely braced, the barbed wire and/or mesh shall be pulled taut to the satisfaction of the Engineer, and each longitudinal wire shall be cut and securely fastened to the pull post with devices customarily used for the purpose. Wire or mesh shall not be carried past a pull post, but shall be cut and fastened to the pull post independently for the adjacent spans. After the tensioning of the wire or mesh between 2 pull posts all longitudinal wires shall be properly fastened at proper height to each intervening line post.

Wire mesh and barbed wire shall be placed on the face of the post that is away from the highway, except that on horizontal curves, the mesh and wires shall be fastened to the face on the outside of the curve unless otherwise directed by the Engineer.

Where unusual ground depressions occur between posts, the fence shall be guyed to the ground by means of a 3.76 mm galvanised wire attached to a weight of approximately 45 kg buried 600 mm in the ground. Guy wire shall be securely attached to each strand of barbed wire and to the top and bottom wires of the wire mesh fabric in a manner to maintain the entire fence in its normal shape. If necessary to guy the fence in solid rock, the guy wire shall be grouted in a 50 mm diameter, 250 mm deep hole. Operation of guying shall leave the fence snug with the ground.

c. Wire Fence Vertical Cinch Stays

Vertical cinch stays shall be installed midway between posts on both types of fence. Wire shall be twisted in such a manner as to permit weaving into the horizontal fence wires to provide rigid spacing. All barbed wires and the top, middle, and bottom wire of the wire mesh shall be woven into the stay.

d. Wire Fence Gates

Wire mesh fabric shall be taut and securely tied to the frame and stays in accordance with recognised standard practice for wire gate construction. Welded connections on gate frames shall be treated as specified for chain-link fence gates.

Drop bar locking devices for double wire fence gates shall be provided with a footing of commercial concrete 300 mm in diameter and 300 mm deep, crowned on top and provided with a hole to receive the locking bar. Diameters and depths of footing holes shall be as specified by the manufacturer of the locking device.

7.7.3.5 Temporary Fencing Construction

Temporary fencing shall be provided by the Contractor at excavations in accordance with Section 1.16.7 of Chapter 1, General Requirements. All open excavations, and other hazardous areas that are a result of Contractor operations, shall be enclosed by temporary fencing to ensure that the public cannot gain access. Damaged sections of temporary fencing shall be repaired or replaced promptly to maintain at all times the standards of fencing and installation as initially approved. Temporary fencing shall not be removed from any location without the prior approval of the Engineer.

Temporary fencing shall be maintained by the Contractor during the works in a sound, protective condition, as approved by the Engineer.

At the completion of construction or when directed by the Engineer, the Contractor shall remove and dispose of all temporary fencing.

Temporary fencing shall have posts set in the ground or shall be freestanding and shall be located as directed by the Engineer.

Temporary fencing shall have an overall height of 2 m, and the overall design shall be such that the fencing cannot be easily displaced, toppled, scaled or crawled under.

Design, details, and locations of temporary fencing shall be submitted to the Engineer for approval.

No fabrication or installation of temporary fencing shall commence until the Engineer's approval has been obtained.

High visibility red and white markings shall be included as shown on the Contract plans and where necessary, temporary fences shall have steady state or flashing lighting units attached to them.

7.7.3.6 Sand Fence Construction

a. Camel Fence Construction

Camel fence construction shall meet the applicable requirements of Article 7.7.3.4, as per the manufacturers recommendations and as approved by the Engineer.

b. Sand Trapping Fence Construction

Installation of sand control fences shall be done in accordance with the applicable requirements of Article 7.7.3.4, in accordance with the manufacturer’s recommendations and as approved by the Engineer.

Installation shall leave a bottom gap below the slats of 10 % of the height

Posts shall be bedded in either pre-cast or cast-in-place foundations, and plumbed vertically.

7.7.3.7 Animal Grid Construction

The width of the animal grid shall be fixed by the Engineer in accordance to the width of the gate or road. The plain round bars shall be continuous over a minimum of two spans.

7.7.4 Median Fences, Steel

a. Description

The Contractor shall fabricate and erect steel median fences, Type 1 and Type 2, furnishing all materials, labour, tools, equipment and appurtenances and performing all work as indicated on the Drawings and in accordance with these Standard Specifications.

b. Materials

1. Steel for c-channels shall be to ASTM A36.
2. Steel for circular hollow sections shall be to ASTM A500, Grade A.
3. Steel for square hollow sections shall be to ASTM A500, Grade A.
4. Welded galvanized wires shall comply with ASTM A1064.
5. All sections of median fences shall be galvanized after fabrication in accordance with ASTM A123, A153 and A385, as applicable. The paint system for median fences shall consist of a zinc phosphate pre-treatment (primer) followed by super durable polyester powder coating (PE SDF), or equivalent, to a minimum thickness of 100 microns.
6. All welding shall comply with the requirements of the applicable sections of Chapter 27.
7. All base plate and post fastening hardware shall be hot-dip galvanized steel (galvanized to ASTM A153).

Alternatively, hardware may be stainless steel with non-metallic washers and sleeves. Stainless steel bolts shall comply with ASTM A193, Grade B8, Class 2; nuts shall comply with ASTM A194, Grade 8; and flat washers with ASTM A240, Type 316.

8. Elastomeric bearing pads shall comply with the requirements of Chapter 25.
9. Precast concrete foundations shall be class C25/20 concrete as per requirements of Chapter 4 and waterproofed with a rubberized bituminous coating, as indicated on the drawings, and shall meet the requirements for quality and construction as specified in Chapter 4, Concrete Works of these Standard Specifications.

c. Fabrication and Erection

All metal median fencing shall be fabricated and erected in sections to the line and grades indicated on the Drawings and shall not reflect any unevenness in the structure. Unless otherwise specified or indicated on the Drawings, all railing posts shall be vertical.

The fabrication and erection of all metal median fencing shall comply with the requirements of Chapter 23 and as specified herein.

The ends of all tubular sections shall be capped or covered with a welded steel plate.

d. Information Required

The Contractor shall supply the Engineer with detailed shop drawings in accordance with the requirements of Chapter 1 of these Standard Specifications. The shop drawings shall indicate all materials, details, and other technical information to clearly show the fabrication and erection of all median fencing sections.

7.8 Decorative Finishes for Concrete and Masonry

Decorative concrete finishes types shall be of the type as shown on the Contract plans, as may be required in the Particular Specifications and as approved by the Engineer. In general, colour coatings of concrete surfaces shall comply with the applicable material and installation requirements of Sections 24.1 and 24.7 of Chapter 24, Painting, of these Standard Specifications. Protective surface waterproofing shall meet the requirements of Chapter 28, Waterproofing.

The Contractor shall prepare and submit to the Engineer for approval trial samples of the type and colours as shown on the Contract plans or as included in the Particular Specifications. Trial sample sizes, numbers and methods shall be agreed with the Engineer prior to preparation which may require a full size trial section for final approval by the Owner.

7.8.1 Concrete Colour Pigment

Pigments for cement and cement products shall conform to the requirements of BS 1014. Dry-shake colour hardener or integral concrete colourant shall be as shown on the Contract plans and as approved by the Engineer. Pigment shall be in the form of dry, soft powder and shall not contain chemical compounds capable of affecting adversely the setting and development of strength of the cement and other properties of the finished products and shall be compatible with other admixtures used in the same mix.

Minimum pigment content shall be 5 % by weight of cement, unless otherwise approved by the Engineer.

Coloured wax meeting the requirements of ASTM C309 shall be used as a curing membrane, unless otherwise as shown on the Contract plans.

7.8.2 Plaster for Decorative Finishing

7.8.2.1 Description

This section defines a cement plaster system directly applied on concrete and concrete blocks.

7.8.2.2 General

Plaster shall comply with provisions of ACI 301, ACI 318, and CRSI *Manual of standard practice* — except where more stringent requirements are indicated.

Shop drawings showing locations and installation of control and expansion joints, including plans and elevation sections and details of component and attachments to other works shall be submitted by the Contractor.

Surfaces shall be constructed such that the maximum gap between a 3 m straightedge and any point on the surface shall be 3 mm.

Prior to installing plaster work, the Contractor shall construct panels measuring at least 3 m by 3 m and demonstrating finish and application required, aesthetic effects, and qualities of materials and execution. Test panels shall not be part of permanent works.

7.8.2.3 Materials

Plaster shall be composed of materials meeting the requirements specified in this section of these Standard Specifications, Table 7-40, the referenced standards, and any additional qualifications as stated on the Contract plans or as directed by the Engineer.

Table 7-40 Plaster material requirements

Material	Specifications Requirements
Cement	Section 4.3.1 of Chapter 4, Concrete Works; Type I
Lime	BS EN 459-1 Special hydrated lime for finishing purposes meeting the requirements of ASTM C206, Type S
Sand	ASTM C 897, graded per Table 7-41
Bonding agent	ASTM C 932 and as approved by the Engineer
Concrete pigment	Section 7.8.1

Plaster shall be tested in accordance with BS 4551, Method of testing mortars, screeds, and plasters.

Table 7-41: Sand for plaster

Sieve Size (mm)	Percent Retained by Weight
4.75	0
2.36	0
1.18	40
600 μm	65
300 μm	90
150 μm	100
75 μm	100

Plaster mixes shall meet the requirements of ASTM C926. All mix proportions included herein are suggestive, variations to meet local conditions and achieve the desired finish are permitted within the limits specified in ASTM C926.

Interior plastering shall be 20 mm thick. Proportions of mixes given are for damp, loose sand.

Table 7-42: Suggested mix proportions for interior plastering

Coat	Suggested Mix Proportions by Volume
Scratch coat on masonry or concrete	Portland cement, sand, and coarse aggregate (2.38-mm maximum), 1:1:1/4
Brown coat	Portland cement, hydrated lime, sand, 1:1/4: 3
Finish coat (skim coat)	Type N hydrated lime in putty as ASTM C206

Exterior plastering shall be 25 mm thick. Each coat of plaster shall be kept wet with water spray, 3 times a day for 4 days for curing. Final coats shall be left to dry for 30 days after the curing period and before proceeding with paint application.

Table 7-43: Suggested mix proportions for exterior plastering

Coat	Suggested Mix Proportions by Volume
Scratch coat	Cement, sand, 1:1
Brown coat	Cement, lime, sand, 1:0.25:3 350 kg cement mixed to 1 m^3 sand, add lime slurry
Final coat	Cement, lime, sand, 1:0.25:3.25 300 kg cement mixed to 1 m^3 sand, add lime slurry

Mixing shall be performed in compliance with ASTM C926 for base- and finish-coat mixes as applicable to plaster bases, materials, and other requirements indicated.

Constituents shall be measured by volume using clean gauge boxes made to size to suit volume required. Gauge boxes shall be overfilled, and the Contractor shall strike-off excess material with a straightedge. Materials shall be mixed until uniform in appearance before adding water. Contractor may then add water and mix to a consistency suitable for the work.

Batches shall not remain in mechanical mixers for longer than 3 minutes. Mixers in continuous use shall be washed out 4 times daily, and mixers shall be washed after each batch if used intermittently or used with different constituents.

Contractor shall not do the following:

- Use plaster after initial set has taken place
- Retemper or reconstitute mixes

To render the finish coat, the Contractor shall add water only and comply with manufacturer's written instructions.

7.8.2.4 Construction Requirements

Continuous, adequate ventilation shall be maintained by the Contractor commencing 1 week before starting plastering and continuing until plaster is cured to the satisfaction of the Engineer.

Existing work and approaches shall be protected with boards, dust sheets or the like. Any droppings onto finished work shall be cleaned immediately.

Independent scaffolding shall be used to avoid putlog holes and other breaks in surfaces.

Plastering work shall not begin until the following occurs:

a. Openings, chases, or other apertures required for services are formed
b. Fixings for pipes, fixing pads, and plugs have been fixed;
c. Metal lath, beads, and other plaster accessories have been fixed
d. Making-good has been completed.

Before applying plaster, the Contractor shall ensure that backgrounds comply with the following:

1. Adequately true and level to achieve specified tolerances
2. Adequately fixed
3. Free from contamination and loose areas
4. Adequately prepared to give a good bond

Beads, lath, and accessories shall be properly fixed and accurately located before applying plaster. Any which are rusted, improperly set, or otherwise defective shall be replaced prior to plaster work.

Additional specifications, as shown in Table 7-44, shall be referenced as applicable to the plaster work at hand

Table 7-44: Reference specifications for plaster works

Description	Specification
Waterproof building papers	BS EN 1521
Code of practice for external rendering	BS EN 13914-1
Code of practice for internal plastering	PD CEN/TR 15123 BS EN 13914-2 BS 8481
Specification for hydrated lime for masonry	ASTM C207
Test methods for preconstruction and construction evaluation of mortars for plain and reinforced unit masonry	ASTM C780

Contractor shall sequence plaster application with installation and protection of other work so that neither will be damaged by installation of other.

Plaster bases and substrates to receive direct application of plaster shall be cleaned and any loose material or substances that may impair the work removed. Projections and concrete fins shall be cut flush to the surface. Efflorescence, laitance, dirt and other loose material shall be removed by thoroughly dry brushing. All traces of mould oil, paint, grease, dirt and other materials incompatible with coating shall be removed by scrubbing with water containing detergent and washing off with plenty of clean water.

Ferrous surfaces shall be treated with rust-inhibitive paint where plaster will be in direct contact.

Concrete surfaces shall be roughened thoroughly and evenly to a depth of 3 mm by sand blasting, bush hammering, or abrasive blasting. Surfaces shall be cleaned by washing and brushing. Roughened, or hacked, concrete masonry backgrounds shall be wetted immediately before applying coatings.

Plaster materials, composition, and mixes shall be applied in accordance with ASTM C926. Excessive water shall not be used to mix and apply plaster materials.

Plaster shall be installed with a finished surface to a true plane to correct line and level, with all angles and corners to a right angle unless otherwise specified and with walls and reveals plumb and square. Deviations from a plane surface shall be not more than ±3 mm in 3 m from a true plane in finished plaster surfaces, as measured by a 3-m straightedge placed at any location on surface.

Plaster shall be installed flush with metal frames and other built-in metal items or accessories that act as a plaster ground, unless otherwise indicated. Where interior plaster is not terminated at metal frame by casing beads, the Contractor shall cut base coat free from metal frame before plaster sets and groove finish coat at junctures with metal.

Internal corners and angles shall be square. External corners shall be finished flush with corner beads on interior work, square and true with plaster faces on exterior work.

Curved surfaces, splayed surfaces and other irregular surfaces shall be true to profile and checked with accurate metal forms and templates.

At frames, the Contractor shall bring plaster out flush with wood and metal frames and grounds and finish each coat with a small, neat V joint where plaster finishes against frames.

At vertical surfaces, plaster shall extend full height from floor to 100 mm above the soffit of ceiling/structural soffit, unless otherwise indicated.

On a suspended ceiling, plaster shall be finished flush with system bead or angle, or 75 mm above ceiling soffit where there is a perimeter bead or angle.

Plaster bases and finish coats shall be moist-cured by the Contractor to comply with ASTM C926.

Scratch coats shall be applied with sufficient force and cement slurry (1:1) to form a good key, and shall be cured for 3 days.

Brown coat shall be applied and then the Contractor shall scratch the surface, cure for 3 days, and allow to dry for at least 24 hours. Contractor shall adjust suction by wetting immediately before applying finish coat.

Finish coats and finishes shall be applied with a steel trowel to a smooth, hard finish. Curing shall consist of a light fog spray of water for 4 days, commencing 12 hours after completion of application. Contractor shall protect against rapid drying until thoroughly cured. Final coats shall be left to dry for 30 days after the curing period and before proceeding with paint application.

Render plaster finishes shall be applied in accordance with the manufacturer's recommendations.

Defective or damaged plaster shall be corrected by the Contractor before starting decoration. Defective work may be cut or raked out, and the Contractor shall moisten backgrounds and fill with finish coat mixes and finish to match adjacent work. Contractor shall repair, point, cut, and patch plaster around work abutting, setting into, or extending into plastered surfaces, on completion of such work. Exposed block-work to receive paint finish shall be applied with cement mortar slurry and rubbed over block-work to fill joints.

Contractor shall cut, patch, replace, repair, and point up plaster, as necessary, to accommodate other work. Cracks and indented surfaces shall be repaired and the Contractor shall point-up finish plaster surfaces around items that are built into or penetrate plaster surfaces. Contractor shall repair or replace work to eliminate blisters, buckles, check cracking, dry outs, efflorescence, excessive pinholes, and as necessary to comply with required visual effects.

Temporary covering and other provisions made to minimise spattering of plaster on other work shall be removed when plaster work is complete. Plaster shall be removed promptly from door frames, windows, and other surfaces not to be plastered. Surfaces stained, marred, or otherwise damaged during plastering work shall be repaired. When plastering work is completed, the Contractor shall remove unused materials, containers, equipment, and plaster debris.

Final protection shall be provided by the Contractor and conditions shall be maintained in a manner acceptable to manufacturer and installer and that ensure plaster work is without damage or deterioration at the time of substantial completion.

7.8.3 Integral Colour Plaster

7.8.3.1 Description

This work includes the following:

1. Interior portland cement plasterwork on solid-plaster bases
2. Exterior portland cement plasterwork on solid plaster bases
3. Plaster ceilings

7.8.3.2 General

Contractor shall submit the following to the Engineer for approval:

- Product data for each type of product indicated

- Shop drawings showing locations and installation of control and expansion joints, including drawings, elevations, sections, details of components, and attachments to other work
- Samples for initial selection for each type of factory-prepared finish coat indicated
- Samples for verification for each type of factory-prepared coloured textured finish coat indicated. Samples shall measure 300 mm by 300 mm and be prepared on rigid backing

For portland cement plaster assemblies with fire-resistance ratings, the Contractor shall provide materials and construction identical to those tested in assembly indicated according to ASTM E119 by the independent testing laboratory.

Before plastering, the Contractor shall install test panels measuring at least 9 m^2 in surface area to demonstrate aesthetic effects and set quality standards for materials and execution. These test panels shall include the following:

- Install mock-ups for each type of finish indicated
- For interior plasterwork, simulate finished lighting conditions for review of mock-ups
- Incorporate approved test panels into the completed work if undisturbed at time of substantial completion. A preinstallation conference shall be held by the Contractor at the worksite

a. Materials

Materials shall be stored by the Contractor inside or under cover and shall be kept dry and protected against damage from weather, direct sunlight, surface contamination, corrosion, construction traffic, and other causes.

Contractor shall comply with ASTM C1063 and coordinate depth of trim and accessories with thicknesses and number of plaster coats required. Accessories and miscellaneous materials shall meet the requirements of Table 7-45.

Table 7-45: Requirements for accessories for integral colour plaster

Material or accessory	Requirement
Galvanized accessories:	
Foundation weep screed	Fabricated from hot-dipped galvanized steel sheet, ASTM A653M, Z180 zinc coating
Cornerite	Fabricated from metal lath with ASTM A653M, Z180, hot-dipped galvanized zinc coating
External-corner reinforcement	Fabricated from metal lath with ASTM A653M, Z180, hot-dipped galvanized zinc coating
Corner-beads Small nose corner-bead with expanded flanges Small nose corner-bead with perforated flanges Small nose corner-bead with expanded flanges reinforced by perforated stiffening rib Bull nose corner-bead, radius 19.1-mm minimum, with expanded flanges	Fabricated from zinc-coated galvanized steel Use unless otherwise indicated Use on curved corners Use on columns and for finishing masonry corners Use at locations indicated on Contract plans
Casing beads	Fabricated from zinc-coated galvanized steel square-edged style; with expanded flanges

Material or accessory	Requirement
Control joints	Fabricated from zinc-coated galvanized steel one-piece-type, folded pair of unperforated screeds in M-shaped configuration; with perforated flanges and removable protective tape on plaster face of control joint
Expansion joints	Fabricated from zinc-coated galvanized steel folded pair of unperforated screeds in M-shaped configuration; with expanded flanges
2-piece expansion joints	Fabricated from zinc-coated galvanized steel formed to produce slip-joint and square-edged reveal that is adjustable from 6.34- to-16-mm wide; with perforated flanges
Plastic trim	Fabricated from high-impact PVC
Corner-beads	With perforated flanges
Small nose corner-bead	Use unless otherwise indicated
Small nose corner-bead recommended by manufacturer for use where durable corner is required	Use on columns and for finishing unit masonry corners
Bull nose corner-bead, radius 19.1-mm minimum	Use at locations indicated on Contract plans
Casing beads	With perforated flanges in depth required to suit plaster bases indicated and flange length required to suit applications indicated
Square-edge style	Use unless otherwise indicated
Bull-nose style, radius 20-mm minimum	Use at locations indicated on Contract plans
Control joints	One-piece-type, folded pair of un-perforated screeds in M-shaped configuration; with perforated flanges and removable protective tape on plaster face of control joint
Expansion joints	Two-piece type, formed to produce slip-joint and square-edged 38 mm wide reveal; with perforated concealed flanges
Miscellaneous materials:	
Fibre for base coat	Alkaline-resistant glass or polypropylene fibres, 13 mm long, free of contaminants, manufactured for use in Portland cement plaster
Bonding compound	ASTM C932

Material or accessory	Requirement
Steel drill screws	For metal-to-metal fastening, ASTM C1002 or ASTM C954, as required by thickness of metal being fastened; with pan head that is suitable for application; in lengths required to achieve penetration through joined materials of not fewer than 3 exposed threads
Fasteners for attaching metal lath to substrates	ASTM C1063
Sound attenuation blankets	ASTM C665, Type I (blankets without membrane facing), produced by combining thermosetting resins with mineral fibres manufactured from glass, slag wool, or rock wool
Fire-resistance-rated assemblies	Comply with mineral-fibre requirements of assembly
Isolation strip at exterior walls	
asphalt-saturated organic felt	ASTM D226M, Type I (No. 15 asphalt felt), unperforated
Foam gasket	Adhesive-backed, closed-cell vinyl foam strips that allow fastener penetration without foam displacement, 3.1 mm thick, in width to suit steel stud size

Water for mixing shall meet the requirements of Section 4.3.8 of Chapter 4, Concrete Works.

Plaster materials shall meet the requirements of Table 7-46.

Table 7-46: Requirements for plaster materials for integral colour plaster

Material	Requirement
Portland cement	ASTM C150M, Type I
Colour for finish coats	Gray
Masonry cement	ASTM C91, Type N
Colour for finish coats	Gray
Plastic cement	ASTM C1328
Colourants for job-mixed finish-coats	Colourfast mineral pigments that produce finish plaster colour to match Engineer's sample
Lime	ASTM C206, Type S; or ASTM C207, Type S
Sand aggregate	ASTM C897
Colour for job-mixed finish coats	In colour matching Engineer's sample

Plaster mixes shall comply with ASTM C926 for applications indicated, and shall comply with the requirements of Table 7-47. Fibre shall be added to base-coat mixes after ingredients have mixed at least 2 minutes. Fibre quantities in mixes shall comply with the fibre manufacturer's written instructions and shall not exceed 16 kg fibre per m^3 of cementitious materials. Aggregate quantities shall be reduced accordingly to maintain workability.

Table 7-47: Integral colour plaster mixes

Mix description	**Requirements**
Masonry cement mixes:	
Scratch coat	One part masonry cement and 2.5 parts to 4 parts aggregate
Brown coat	One part masonry cement and 3 to 5 parts aggregate
Portland and masonry cement mixes:	
Scratch coat	For cementitious material, mix 1 part Portland cement and 1-part masonry cement. Use 2.5 parts to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material)
Brown coat	For cementitious material, mix 1 part Portland cement and 1part masonry cement. Use 3 to 5 parts aggregate per part of cementitious material (sum of separate volumes of each component material)
Portland and plastic cement mixes:	
Scratch coat	For cementitious material, mix 1-part plastic cement and 1 part Portland cement. Use 2.5 parts to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material)
Brown coat	For cementitious material, mix 1-part plastic cement and 1 part Portland cement. Use 3 to 5 parts aggregate per part of cementitious material (sum of separate volumes of each component material)
Base-coat mixes for use over monolithic concrete Portland cement mix Portland and masonry cement mix Plastic cement mix	Single base coats for 2-coat plasterwork For cementitious material, mix 1 part Portland cement and 0-part to three-quarters part lime. Use 2.5 parts to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material) For cementitious material, mix 1 part Portland cement and 1 part masonry cement. Use 2.5 parts to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material) Use 1 part plastic cement and 2.5 parts to 4 parts aggregate
Base-coat mixes for use over concrete masonry units Portland cement mix Masonry cement mix Plastic cement mix	Single base coats for 2-coat plasterwork For cementitious material, mix 1 part Portland cement and three-quarters part to 1.5 parts lime. Use 2.5 parts to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material) Use 1-part masonry cement and 2.5 parts to 4 parts aggregate Use 1 part plastic cement and 2.5 parts to 4 parts aggregate
Job-mixed finish-coat mixes Portland cement mix	For cementitious materials, mix 1 part Portland cement and 1.5 parts to 2 parts lime. Use 1.5 parts to 3 parts aggregate per part

Mix description	Requirements
	of cementitious material (sum of separate volumes of each component material)
Masonry cement mix	one-part masonry cement and 1.5 parts to 3 parts aggregate
Portland and masonry cement mix	For cementitious materials, mix 1 part Portland cement and 1 part masonry cement. Use 1.5 parts to 3 parts aggregate per part of cementitious material (sum of separate volumes of each component material)
Plastic cement mix	one-part plastic cement and 1.5 parts to 3 parts aggregate
Factory-prepared finish-coat mixes	For ready-mixed finish-coat plasters comply with manufacturer's written instructions

7.8.3.3 Construction Requirements

Project conditions shall meet the requirements of ASTM C926. For interior plasterwork, the Contractor shall do the following:

a. Maintain room temperatures at greater than 10º C for at least 48 hours before plaster application, and continuously during and after application
b. Avoid conditions that result in plaster drying out during curing period
c. Distribute heat evenly; prevent concentrated or uneven heat on plaster
d. Ventilate building spaces as required to remove water in excess of that required for hydrating plaster in a manner that prevents drafts of air from contacting surfaces during plaster application and until plaster is dry

For exterior plasterwork, the Contractor shall do the following:

1. Apply and cure plaster to prevent plaster drying out during curing period
2. Use procedures required by climatic conditions, including moist curing, providing coverings, and providing barriers to deflect sunlight and wind
3. Apply plaster when ambient temperature is greater than 10º C.
4. Protect plaster coats from freezing for not less than 48 hours after set of plaster coat has occurred

Contractor shall ensure that the manufacturer's written recommendations for environmental conditions are met before applying finishes. Adjacent work shall be protected from soiling, spattering, moisture deterioration, and other harmful effects caused by plastering. Solid-plaster bases that are smooth or that do not have the suction capability required to bond with plaster shall be prepared according to ASTM C926.

Before sprayed fire-resistive materials are applied, the Contractor shall attach offset anchor plates or ceiling runners (tracks) to surfaces indicated to receive sprayed fire-resistive materials. Where offset anchor plates are required, continuous plates fastened to building structure not more than 610 mm on centre shall be provided. After sprayed fire-resistive materials are applied, they shall be removed only to the extent necessary for installation of plaster assemblies and without reducing the fire resistive material thickness to less than that required to obtain fire-resistance rating indicated. Remaining fire-resistive materials shall be protected by the Contractor from damage.

Fire-resistance-rated assemblies shall be installed according to the requirements for design designations from listing organisation and publication indicated on Contract plans.

Accessories shall be installed according to ASTM C1063 and at locations indicated on Contract plans. Reinforcement for external corners shall include the following:

- Lath-type external-corner reinforcement at exterior locations

- Corner bead at interior and exterior locations.

Control joints shall be installed at locations indicated by the manufacturer subject to approval by the Engineer for visual effect as follows:

a. As required to delineate plasterwork into areas (panels) of the following maximum sizes:
   1. Vertical surfaces: 13.4 m^2
   2. Horizontal and other nonvertical surfaces: 9.3 m^2
b. At distances between control joints of not greater than 6.0 m on centre
c. As required to delineate plasterwork into areas (panels) with length-to-width ratios of not greater than 2.5:1
d. Where control joints occur in surface of construction directly behind plaster
e. Where plasterwork areas change dimensions, to delineate rectangular shaped areas (panels) and to relieve the stress that occurs at the corner formed by the dimension change

Plaster applications shall comply with ASTM C926. Finished surfaces shall not deviate more than ±6.4 mm in 3 m from a true plane, as measured by a 3 m straightedge placed on the surface. Hollow-metal frames, bases, and similar work occurring in plastered areas shall be grouted with base-coat plaster material, before lathing where necessary. Except where full grouting is indicated or required for fire-resistance rating, grout shall measure at least 152 mm at each jamb anchor. Plaster shall be finished flush with metal frames and other built-in metal items or accessories that act as a plaster ground, unless otherwise indicated. Where casing bead does not terminate plaster at metal frame, base coat shall be cut free from metal frame before plaster sets and groove finish coat at junctures with metal.

Plaster surfaces that are ready to receive field-applied finishes indicated shall be provided by the Contractor, who shall use independent scaffolding to avoid putlog holes and other breaks in surfaces.

Bonding compounds shall be applied on unit masonry and concrete plaster bases. Contractor shall apply wood or plastic float finish to achieve an even and rough Arabic texture finish.

Concealed interior plasterwork shall be constructed of the following:

a. Where plaster application will be concealed behind built-in cabinets, similar furnishings, and equipment, apply finish coat
b. Where plaster application will be concealed above suspended ceilings and in similar locations, finish coat may be omitted
c. Where plaster application will be used as a base for adhesive application of tile and similar finishes, finish coat may be omitted

Contractor shall cut, patch, replace, and repair plaster, as necessary, to accommodate other work and to restore cracks, dents, and imperfections. Work shall also be repaired or replaced to eliminate blisters, buckles, crazing and check cracking, dry outs, efflorescence, sweat outs, and similar defects and where bond to substrate has failed. Temporary protection and enclosures of other work shall be removed by the Contractor. Promptly remove plaster from doorframes, windows, and other surfaces not indicated to be plastered. Repair floors, walls, and other surfaces stained, marred, or otherwise damaged during plastering.

7.9 Interlocking Concrete Paving Blocks

7.9.1 Description

Interlocking concrete pavers shall comply with the requirements specified herein. All interlocking concrete pavers shall be from manufacturers with valid product certification as per Abu Dhabi Quality Conformity Council product conformity scheme.

A. Paver thickness shall be 60mm for pedestrian areas and 80-140 mm for vehicular areas. Dimensions are based on ASTM C936.

B. The paving block manufacturers shall achieve the desired aesthetic appearance and finish of the paving blocks by careful combination of fine and coarse aggregates within the general grading limits specified herein to ensure an acceptable smooth surface is achieved.

7.9.2 Products

7.9.2.1 Constituent Materials Specifications

The constituent materials of the interlocking concrete pavers shall comply with the requirements of the following articles.

A. Cement: The cement to be used in the manufacture of paving blocks shall be sulphate-resisting Portland cement Type-V, or ordinary Portland cement with partial cement replacement by supplementary cementitious materials such as fly ash and ground granulated blast-furnace slag (GGBS), and microsilica, etc., in accordance with ASTM C150.

B. Aggregates: The aggregates to be used in the manufacture of the paving blocks shall be from crushed rocks and from approved sources, conforming to the requirements of BS EN 12620:2002+A1:2008. The sand shall be washed and free from deleterious substances. The aggregate shall not contain harmful material such as coal, mica, shale or similar laminated materials which cause strength deterioration.

1. *Coarse Aggregate*: Coarse aggregate for paving blocks shall meet the following requirements:

Table 7-48. Coarse Aggregate for Interlocking Concrete Pavers

Properties	Test Method(1)	Permissible Limit
Particle Size Distribution	BS EN 933-1:2012	As per BS EN 12620:2002+A1:2008
Clay Silt & Dust	BS EN 933-1:2012	Max 1%
Organic Matter Content	BS 1377-3:1990	Nil
Water Absorption	BS EN 1097-6:2013	Max 1.5%
Relative Density	BS EN 1097-6:2013	Min 2.6
Shell Content	BS EN 933-7:1998	Nil
Flakiness Index	BS EN 933-3:2012	Max 25%
Elongation Index	BS 812-105.2:1990	Max 25%
Soundness (Mg SO_4) 5 cycles	ASTM C88-13	Max 5%
Sulphate Content (SO_3)	BS EN 1744-1:2009+A1:2012	Max 0.3%
Chloride Content (Cl)	BS EN 1744-1:2009+A1:2012	Max 0.20%

Table 7-48. Coarse Aggregate for Interlocking Concrete Pavers		
Aggregate Crushing Value	BS EN 1097-2:2010	Max 25%
Los Angeles Abrasion	AASHTO T 96-02	Max 25%
Note: 1) All standards refer to the latest version unless otherwise specified.		

2. *Fine Aggregate*: Fine aggregate for paving blocks shall meet the following requirements:

Table 7-49: Fine Aggregate for Interlocking Concrete Pavers		
Properties	**Test Method**	**Permissible Limit**
Particle Size Distribution	BS EN 933-1:2012	As per BS EN 12620:2002+A1:2008
Clay Silt & Dust	BS EN 933-1:2012	Max 3% passing 75 µm sieve
Organic Matter Content	BS 1377-3:1990	Nil
Water absorption	BS EN 1097-6:2013	Max 2%
Relative Density (Apparent)	BS EN 1097-6:2013	Min 2.6
Shell Content	BS EN 933-7:1998	Max 1%
Soundness (Mg SO_4) 5 cycles	ASTM C88:13	Max 5%
Acid Soluble Materials	BS EN 1744-1:2009+A1:2012	Max 0.25%
Sulphate Content (SO_3)	BS EN 1744-1:2009+A1:2012	Max 0.3%
Chloride Content (Cl)	BS EN 1744-1:2009+A1:2012	Max 0.1%

C. Water: The water to be used in mixing and curing the precast concrete blocks shall be of drinking quality, clean and free from injurious substances of sewage, oil, acids, strong alkalis, vegetable matter, clay and other such substances harmful to the finished product.

D. Pigment: Pigment shall comply to ASTM C979 to be used in manufacturing of precast concrete interlocking blocks shall be in the form of dry, soft powder of mineral oxides and shall not contain chemical compounds capable of affecting adversely the setting and development of strength of the cement and other properties of the finished products and shall be compatible with other admixtures used in the same mix. Pigments can be used throughout the concrete or for the top layer only in double mix production. Surface protection against color fading or chemical attaches are possible, but must be specifically recommended by purchaser.

7.9.3 Design Mix

The design mix shall comply with the requirements of the following articles.

A. Combined Aggregate Grading: The combined grading shall satisfy the following limits.

Table 7-50: Combined Aggregate Grading for Interlocking Concrete Pavers	
Diameter	**Limit (Percent Passing [1,2])**
8.0 mm	100%
4.75 mm	72-82%
2.36 mm	41-61%
1.18 mm	25-46%
600 µm	16-31%
300 µm	8-17%
150 µm	3-8%
75 µm	0-3%
Notes: 1. Smooth, non-gap graded curve is expected. 2. Central tendency should be attempted.	

B. Cement Content: The cement content shall be a minimum of 430 Kg/m^3.

C. Water Cement (W/C) Ratio: The water cement ratio shall be a maximum of 0.42.

D. Pigment Content: Only mineral oxide type from reputable source with test certificates. The pigment content shall not exceed 10% by mass of cement.

7.9.4 Physical & Mechanical Properties

The physical and mechanical properties of the interlocking concrete blocks shall conform to the following requirements.

A. Bulk Density (min. 48 hrs. immersion):

1. Average > 2.375 T/m^3
2. Minimum = 2.330 T/m^3

B. Bulk/Apparent Density Ratio (min. 48 hrs. immersion)

1. Average > 0.88
2. Minimum = 0.87

C. Water Absorption (min. 48 hrs. immersion, tested according to ASTM C140)

1. Maximum = 3% for aggressive exposure zones[1], and 4.5% for less aggressive exposure zones[2]

D. Compressive Strength (min. 48 hrs. Immersion, tested according to BS 6717:1993)

1. Average ≥ 55 Mpa for aggressive exposure zones, and 49 for less aggressive exposure zones
2. Minimum = 47 Mpa for aggressive exposure zones, and 44 for less aggressive exposure zones

E. Abrasion Resistance (for vehicular areas only, tested as per ASTM C418)

1. Average thickness loss < 3 mm
2. Maximum volume loss = 150 mm^3 per 500 mm^2
3. Or comply with BS EN 1338 (maximum volume loss 20,000 mm^3 per 5,000 mm^2

F. Flexural Strength (tested according to ASTM C293 / C293M: 10)

1. Average Flexural Strength > 5 Mpa (Dry)
2. Minimum Flexural Strength = 4.5 Mpa (Dry)

G. At least 4 out of 5 of all tested specimens shall meet the specified average criteria for all physical and mechanical properties specified.

H. The paving block manufacturers may achieve the physical properties specified herein for their products through various means such as addition of mineral and/or chemical admixtures to the concrete mix for the paving blocks.

I. Concrete paving blocks shall be adequately cured, as specified, so that they comply with all the physical and mechanical properties upon delivery to site.

J. Any consignments delivered to site that do not comply with the specified physical and mechanical properties shall be rejected by the Purchaser and the Manufacturer shall remove the consignment from site.

K. Durability Criteria:

1. AS/NZS 4456.10:2003, method B
2. Resistance to sodium sulphate and sodium chloride
3. Conduct the test for 40 cycles and record the total loss
4. Total loss after 40 cycles < 1% of mass of specimen

7.9.5 Dimensional Tolerance

A. The length or width of each unit shall not differ by more than ±1.6mm from the designated dimensions.

B. The height of each unit shall not differ by more than ±3% from the specified standard thickness.

[1] Aggressive exposure zones are those areas where a shallow water table is known to be present. This underground water is generally brackish, where salt and other mineral content is capable of attacking Interlocking Concrete Pavers. This type of zone is generally found in Abu Dhabi City and other coastal areas throughout the Emirate.

[2] Less aggressive exposure zones have deeper water tables, comprising more fresh water. This type of zone is generally found in regions of Al Ain and Al Gharbia.

7.9.6 References

1) ASTM C88
2) ASTM C150
3) ASTM C293
4) ASTM C418
5) ASTM C936
6) BS 812
7) BS 1377
8) BS 6717
9) BS 7533
10) BS EN 933
11) BS EN 1097
12) BS EN 12620
13) BS EN 1744
14) AASHTO T 96-02

7.10 Installation Guidelines

7.10.1 General

Interlocking concrete pavers shall comply with the requirements specified herein. Installation of interlocking concrete pavers shall be carried out only by companies with a valid certification as per Abu Dhabi Conformity Council installation guidelines conformity scheme.

A. Pavers for vehicular areas shall be manufactured in a single or double mix as required by the purchaser. Single mix shall be preferred for vehicular load applications and double mix for pedestrian areas or where decorative appearances are requested.

B. The thickness of the paving blocks shall be selected in light of the sub base material, the sub grade soil, the expected load, load frequency, and shape of the blocks as indicated on the contract document/ as applicable.

C. An edge chamfer around the wearing surface is standard. Blocks without chamfers are possible, but must be requested by the purchaser.

D. The project contractor shall provide a 10-year performance guarantee for the single and double mix paving blocks against de-lamination and colour fading beyond normal wear and tear in the emirate of Abu Dhabi environment. The 10- year (see Appendix 1) guarantee shall be back-to-back from the concrete paving block manufacturer.

7.10.2 Products & Execution

7.10.2.1 Curing & Handling

A. Following the manufacturer curing process, all consignments delivered to project site shall comply with performance criteria required on ADS 15.

7.10.2.2 Installation

The installation of interlocking concrete pavers shall comply with the requirements specified herein, and elsewhere in these specifications.

A. The subgrade and/or aggregate base course for pedestrian and vehicular concrete paving blocks shall be prepared as per the particular specifications and Contract documents, as applicable. Moreover, in absence of these document, the subgrade shall follow ASTM, ASHTO, or EN standard.

B. Installation teams are to be properly trained and to have previous experience in the installation of interlocking pavers and shall follow the requirement/ specification recommended by manufacturers, as approved by the Owner.

C. After preparation of the subgrade or aggregate base course for the concrete paving blocks, as applicable, the Contractor shall place 50mm of bedding sand complying with the grading limits specified in the table below. The bedding sand shall be crushed material.

Table 7-51: Grading for Bedding Sand for Less Aggressive Zone(1)

Sieve Size	Percent Passing for Each Sieve(2)
5 mm	89 to 100%
2.36 mm	65 to 100%
1.18 mm	45 to 100%
600 µm	25 to 80%
300 µm	5 to 48%
150 µm	0 to 15%
75 µm	0 to 5%

Notes: 1) Less aggressive exposure zones have deeper water tables, comprising more fresh water. This type of zone is generally found in regions of Al Ain and Al Gharbia.

2) As per BS 7533 Part 3 Category IV for pedestrian surface.

Table 7-52: Grading for Bedding Sand for Aggressive Zone(1)

Sieve Size	Percent Passing for Each Sieve(2)
14mm	100%
10mm	98 to 100%
6mm	85 to 99%
2mm	0 to 15%
1mm	0 to 2%
63 µm	0 to 1%

Notes: 1) Aggressive exposure zones are those areas where a shallow water table is known to be present. This underground water is generally brackish, where salt and other mineral content is capable of attacking Interlocking Concrete Pavers. This type

Table 7-52: Grading for Bedding Sand for Aggressive Zone[1]
of zone is generally found in Abu Dhabi City and other coastal areas throughout the Emirate.
2) According to BS EN 13043, category 2.8/6.3 G_c80/15.

D. The bedding sand shall be uniformly spread over the compacted subgrade or aggregate base course, as applicable for pedestrian or vehicular areas, and screed uniformly to grade approximately 5 to 10 mm higher than required. Actual height to be determined from site trial.

E. The sub base/ subgrade below the bedding aggregates to a depth of 30 cm shall have maximum acid-soluble total salt content $\leq$ 1% (according to BS 1377 Part 3)

F. Where utilities are present, preparation of subgrade and sub base should be in accordance with utility providers' requirements, including minimum depth of cover.

G. Concrete paving blocks in the approved pattern should be placed as close together as possible such that the spaces of the joints are between approximately 3 mm and 5 mm. It is important that the spaces be consistent so that the pattern will remain constant.

H. Utility chamber access openings should be integrated with the paving pattern.

I. Paving blocks should be laid from a mix of pallets to avoid any significant colour banding due to variation in batches.

J. Any necessary cutting of concrete paving blocks shall be done with a mechanical block splitter or a purpose built proprietary diamond saw. In all such situations, only cut paving units with true, even and undamaged edges shall be laid. Cut paving with ragged edges and producing voids shall not be installed. Cut pieces to be laid shall not be less than 30% of a full paving unit and where necessary the cut shall be shared uniformly with the next complete unit.

K. Dimensional accuracy, uniformity of joint gaps, alignment and squareness shall be checked after laying the first three rows of blocks and thereafter at regular intervals. If joints begin to open the blocks shall be knocked together using a rubber mallet.

L. After each 100m², or such area that has been agreed with the Owner, has been laid the blocks shall be compacted to the required levels using a plate vibrator.

M. Interlocking concrete paving blocks should be tamped with a mechanical plate vibrator equipped with a rubber pad on the tamping face (to minimize damage to the finished surface and appearance of the paving blocks), until pavers are uniformly levelled, true to grade and free of any movement. The mechanical plate vibrator shall have a plate area of 0.20 to 0.35m² and have a compaction force of 12-24 KN and a frequency of approximately 75 to 100 Hz. Compaction above and around underground chambers requires particular attention.

N. The joints in the paving blocks shall be filled with sand complying BS 7533-3:2005+A1:2009 by sweeping in the jointing sand, unless otherwise approved by project Owner. The grading limits for the jointing sand specified in BS 7533-3:2005+A1:2009 are indicated in the table below.

Table 7-53: Grading for Jointing Sand	
Sieve Size	**Percentage Passing Each Sieve**
2.36 mm	100%
1.18 mm	95-100%
600 µm	50-100%

Table 7-53: Grading for Jointing Sand	
300 µm	15-60%
150 µm	0-15%
75 µm	0-3%

P. No paving shall be left uncompacted overnight except for the 1m strip at the temporary unrestrained edge.

Q. Upon completion, the finished surface level, shall be within 5mm of the design level and the maximum deviation within the compacted surface, measured by a 3m straight edge shall not exceed 2mm. The level of any two adjacent blocks shall not differ by more than 1mm. Any areas of paving which do not comply with these tolerances shall be removed, the aggregate bedding laying course adjusted and the paving blocks re-laid to the correct levels.

R. The Contractor shall submit shop drawings indicating various patterns to the Owner for review and approval. No interlocking concrete paving blocks shall be fabricated and delivered before a specific pattern has been approved.

7.10.3 References

1) ASTM C88
2) ASTM C150
3) ASTM C293
4) ASTM C418
5) ASTM C936
6) BS 812
7) BS 1377
8) BS 6717
9) BS 7533
10) BS EN 933
11) BS EN 1097
12) BS EN 12620
13) BS EN 1744
14) AASHTO T 96-02

7.10.4 Suggested Delivery, Storage & Handling

A. Requirements of On-Site Delivery:

1. The receipts for pavers delivered for use on the Project must state the name of the Contractor, the Contract Number and the identification number of each batch/bundle delivered to the site.
2. Each delivery shall also be accompanied by copies of the In-house Certification and reports on the testing relevant to the batches delivered. The certificate shall confirm that raw material used in the mixes and finished products comply with ADS 15. On delivery of pavers to the site, originals or certified copies of these documents must be transmitted to the Owner.
3. No pavers shall be laid on site until the Owner receives and approves the aforesaid documentation.
4. The Owner shall be notified 24 hours in advance of pending paver deliveries. No truck shall be offloaded until inspected by the Owner.

5. At the Owner's option, test samples may be taken from the loaded truck and immediately checked for compressive and flexural strength at the site lab, prior to permission to off-load.
6. As per the Owner’s determination, truck loads may be rejected based on visual and immediate test observations.
7. Approval by the Owner to off load the pavers is a conditional approval, subject to the final result of the manufacture, independent and site laboratory testing, proper handling, installation, and performance.

B. Removal and Replacement of Removable Pavement: For reasons beyond the control of the Contractor, it may become necessary to remove and then replace interlocking pavers (either vehicular or pedestrian) or precast tile blocks that are in a present condition acceptable to the Owner. In such cases, the Contractor shall carry out the removal and replacement of the removable pavement in such a way that the replaced pavement meets the exact same specification requirements that governed the original placement of that pavement, including the requirements for the subgrade and base courses.

C. Removal and Transportation of Interlocking Concrete Pavers to the Owner Stores: Where existing interlocking concrete pavers in vehicular or pedestrian areas require removal to facilitate the proposed works, and are not to be reinstated, the Contractor shall carefully remove the pavers and transport them to a designated Owner storage area off the island of Abu Dhabi.

1. The work shall consist of, but not be limited to, preparing shop drawings indicating the removal limits, removal, on-site storage, loading, transporting, and unloading of the pavers selected for storage.
2. During all operations, the Contractor shall proceed with due care and attention so as not to damage the pavers. Any pavers made unsuitable for future use due to the Contractor’s actions or operations shall be deducted from the measurement for this item.
3. Pavers identified as unsuitable for future use prior to commencement of the works shall be removed and disposed of in accordance with the relevant division of these specifications.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 8 - TRAFFIC MARKINGS AND SIGNS

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 8: Traffic Markings and Signs

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8 TRAFFIC MARKINGS AND SIGNS

This work shall consist of furnishing and installing traffic markings and signs including permanent and temporary pavement marking, raised pavement markers, and permanent signing in accordance with these specifications and conforming to the Contract documents.

8.1 Reference Standards and Codes

Standards and codes for traffic markings and signs shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
TR-516	Abu Dhabi Road Structures Design Manual;
AISI	American Iron and Steel Institute;
AISI	AISI 1038, Steel Cold Drawn, 19-32 – Matweb – Division of Automation Creation;
ANSI	American National Standards Institute;
ASME	American Society of Mechanical Engineers;
ASTM	American Society for Testing and Materials;
APA	American Plywood Association Design/Construction Guide for Concrete;
BSI	British Standards Institution;
BS EN	European Standards;
CIE	Commission International de l’Eclarirage;
COFI	Council of Forest Industries ;
CSA	O121-08 – Douglas Fir Plywood;
FHWA	Department of Transportation Federal Highway Administration;
GSA	Government General Services Administration;
Henkel	Translation of German Technical Process Bulletin, Alodine, 1200 two component Brush –on Process Dusseldorf;
Kipp, AISI/Dale O	1038 Steel, cold drawn, 19-32 mm (0 75-1 25 in) round, Metal Material Data Sheets s l : MatWeb - Division of Automation Creation, Inc., 2010 AISI 1038;
MunsellStore	Munsell Sheet of Color;
NIST	Voluntary Product Standard ps 1-107 Stryctral Plywood ;
SAE	Society of Automotive Engineers;
SAE	AMS 6378 F Steel Bars, 1 0Cr - 0 20Mo - 0 045Se (0 39 - 0 48C) (4142H Modified), Die-Drawn, 130 ksi (896 MPa) Yield Strength, Free Machining Warrendale, PA : SAE International, Aerospace Material Division, 2001 AMS 6378F;
TDOT	Texas Department of Transportation;
U S Military	MIL-P-21035 (A-9-73 & X-6442) Paint, high Zinc Dust Content Galvanizing Report.

Table 8-1 and Table 8-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for Traffic markings and signs. It also includes designations and titles.

Table 8-1: Designations and titles for AASHTO and ASTM standards that apply to traffic markings and signs

AASHTO Designation	ASTM Designation	Title
	ASTM D 1729 - 96(2009)	*Standard Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials*
	ASTM D2244 – 11	*Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates*
AASHTO M 249		*Standard Specification for White and Yellow Reflective Thermoplastic Striping Material (Solid Form)*
	ASTM D570 - 98(2010)e1	*Standard Test Method for Water Absorption of Plastics*
	ASTM E1710 – 11	*Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer*
AASHTO T 250		*Standard Method of Test for Thermoplastic Traffic Line Material*
	ASTM D638 – 10	*Standard Test Method for Tensile Properties of Plastics*
	ASTM D2240 - 05(2010)	*Standard Test Method for Rubber Property—Durometer Hardness*
	ASTM D711 - 10	*Standard Test Method for No-Pick-Up Time of Traffic Paint*
	ASTM D6359-99	*Standard Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments (Withdrawn 2006)*
	ASTM E303 - 93(2008)	*Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*
	ASTM D2196 - 10	*Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer*
AASHTO M248-91		*Ready-Mixed White and Yellow Traffic Paints*
	ASTM D823 - 95 -2007	*Standard Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels*
	ASTM D 969-85(2003)e1	*Test Method for Laboratory Determination of Degree of Bleeding of Traffic Paint*
	ASTM D3718 - 85a (2010)	*Standard Test Method for Low Concentrations of Chromium in Paint by Atomic Absorption Spectroscopy*

AASHTO Designation	ASTM Designation	Title
	ASTM E1347 – 06	*Standard Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry*
	ASTM D1475 – 98 2008	*Standard Test Method For Density of Liquid Coatings, Inks, and Related Products*
	ASTM D522 - 93a (2008)	*Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*
	ASTM D3335 - 85a (2009)	*Standard Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy*
	ASTM D2369 - 10e1	*Standard Test Method for Volatile Content of Coatings*
	ASTM D1849 – 95 (2008)	*Standard Test Method for Package Stability of Paint*
	ASTM D2371 – 85 (2010)	*Standard Test Method for Pigment Content of Solvent-Reducible Paints*
	ASTM D1309 – 93 (2010)	*Standard Test Method for Settling Properties of Traffic Paints During Storage*
	ASTM D476 – 00 / (2011)	*Standard Classification for Dry Pigmentary Titanium Dioxide Products*
	ASTM D4563 – 02 (2008)	*Standard Test Method for Determination by Atomic Absorption Spectroscopy of Titanium Dioxide Content of Pigments Recovered From Whole Paint*
	ASTM D562 - 10	*Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer*
	ASTM D3960 - 2005	*Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings*
	ASTM D126 – 87 (2006)	*Standard Test Methods for Analysis of Yellow, Orange, and Green Pigments Containing Lead Chromate and Chromium Oxide Green*
	ASTM D1652 - 2004	*Standard Test Method for Epoxy Content of Epoxy Resins*
	ASTM D2074-92 (1998)	*Standard Test Methods for Total, Primary, Secondary, and Tertiary Amine Values of Fatty Amines by Alternative Indicator Method (Withdrawn 2007)*
	ASTM D4060 2010	*Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*
AASHTO M 247		*Standard Specification for Glass Beads Used in Pavement Markings*
	ASTM E1347 - 2006	*Standard Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry*
	ASTM D4280 2012	*Standard Specification for Extended Life Type, Nonplowable, Raised Retroreflective Pavement Markers*

AASHTO Designation	ASTM Designation	Title
AASHTO M 237		*Standard Specification for Epoxy Resin Adhesives for Bonding Traffic Markers to Hardened Portland Cement and Asphalt Concrete*
	ASTM C882 / C882M - 05e1	*Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear*
AASHTO T 49		*Standard Method of Test for Penetration of Bituminous Materials*
AASHTO T 53		*Standard Method of Test for Softening Point of Bitumen (Ring-and-Ball Apparatus)*
AASHTO T 316		*Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer*
AASHTO T 51		*Standard Method of Test for Ductility of Asphalt Materials*
	ASTM D3111 - 2010	*Standard Test Method for Flexibility Determination of Hot-Melt Adhesives by Mandrel Bend Test Method*
	ASTM D5167 - 10	*Standard Practice for Melting of Hot-Applied Joint and Crack Sealant and Filler for Evaluation*
AASHTO T 237		*Standard Method of Test for Testing Epoxy Resin Adhesive*
AASHTO M 111M		*Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*
	ASTM G154 - 2006	*Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*
	ASTM D 4956	***Standard Specification for Retroreflective Sheeting for Traffic Control***
	ASTM D523 - 08	*Standard Test Method for Specular Gloss*
	ASTM B308 / B308M – 10	*Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles*
	ASTM D2794 – 93 (2010)	*Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*
	ASTM D685-93 (2007)	*Standard Practice for Conditioning Paper and Paper Products for Testing (Withdrawn 2010)*
	ASTM D828-97 (2002)	*Standard Test Method for Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus (Withdrawn 2009)*
	ASTM B209 - 10:	*Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*
	ASTM D962 – 81 (2008) e1	*Standard Specification for Aluminum Powder and Paste Pigments for Paints*

AASHTO Designation	ASTM Designation	Title
	ASTM D790 2010	*Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*
	ASTM D695-2010	*Standard Test Method for Compressive Properties of Rigid Plastics*
	ASTM D732 - 2010	*Standard Test Method for Shear Strength of Plastics by Punch Tool*
	ASTM D3841-97(2008)e1	*Standard Specification for Glass-Fiber-Reinforced Polyester Plastic Panels*
	ASTM D635 - 2010	*Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position*
AASHTO M 270M		*Standard Specification for Structural Steel for Bridges*
	ASTM F468 - 10	*Standard Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use*
	ASTM A307 – 10	*Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength*
	ASTM F593 - 01	*Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs*
	ASTM A193M 11	*Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*
	ASTM A276 - 10	*Standard Specification for Stainless Steel Bars and Shapes*
	ASTM F844 - 07a	*Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use*
	ASTM F467-06ae1	*Standard Specification for Nonferrous Nuts for General Use*
	ASTM A563 - 07a	*Standard Specification for Carbons and Alloy Steel Nuts*
	ASSTM F594 - 09e1	*Standard Specification for Stainless Steel Nuts*
	ASTM A194M - 10a	*Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*
	ASTM B 316M - 02	*Standard Specification for Aluminum and Aluminum-Alloy Rivet and Cold-Heading Wire and Rods,*
	ASTM B179 - 11	*Standard Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes*
	ASTM B221 - 08	*Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*
	ASTM A36M - A36M -2008	*Standard Specification for Carbon Structural Steel*

AASHTO Designation	ASTM Designation	Title
	ASTM A666 - 10	*Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar*
AASHTO M 232M		*Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
AASHTO M164		*Standard Specification for High-Strength Bolts for Structural Steel Joints*
AASHTO M 253		*Standard Specification for Structural Bolts, Alloy Steel, Heat-Treated, 150 ksi Minimum Tensile Strength*
	ASTM F606 - 11	*Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets*
AASHTO M 291		*Standard Specification for Carbon and Alloy Steel Nuts*
AASHTO M 292M		*Standard Specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both*
AASHTO M 293		*Standard Specification for Hardened Steel Washers*
	ASTM F959 - 09	*Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners*
AASHTO M 298		*Standard Specification for Coatings of Zinc Mechanically Deposited on Iron And Steel*
	ASTM A500M - 10a	*Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes*
	ASTM A53M - 10	*Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*
	ASTM A992M - 11	*Standard Specification for Structural Steel Shapes*
	ASTM A588M - 10	*Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance*
	ASTM A572M - 07	*Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*
	ASTM A582M - 05	*Standard Specification for Free-Machining Stainless Steel Bars*
	ASTM A653M - 10	*Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*
	ASTM A325 - 10	*Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*
	ASTM A123M - 09	*Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*
	ASTM B766 - 86(2008)	*Standard Specification for Electrodeposited Coatings of Cadmium*

AASHTO Designation	ASTM Designation	Title
	ASTM B633 - 07	*Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel*
AASHTO M 32M		*Standard Specification for Steel Wire, Plain, for Concrete Reinforcement*
	ASTM F1554 - 07a	*Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength*
	ASTM F436 - 11	*Standard Specification for Hardened Steel Washers West Conshohockan, PA : ASTM International, 2011*
AASHTO T 180		*Standard Method of Test for Moisture-Density Relations of Soils Using a 4 54-kg (10-lb) Rammer and a 457-mm (18-in) Drop*
	ASTM D4505 - 05	*Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life*
AASHTO M85-12	ASTM C150 / C150M - 12	*Standard Specification for Portland Cement*
AASHTO M 232M/M 232-10	ASTM A153 / A153M - 09	*Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

Table 8-2: Designations and titles for BS, BS EN, and DIN standards that apply to concrete structures works

BS Designation	BS EN Designation	Title
	BS EN 1871:2000	*Road marking materials. Physical properties*
	BS EN 1426:2007	*Bitumen and bituminous binders. Determination of needle penetration*

8.2 Permanent Pavement Marking

8.2.1 Description

This section covers the preparation of the roadway and the furnishing, installation and removal of pavement markings, as indicated on the Contract plans or as approved by the Engineer.

8.2.2 Materials

All pavement marking material shall be UV stable and shall be selected as per the intent of usage from the following types as shown on the Contract plans or as approved by the Engineer:

1. Thermoplastic
2. Cold Plastic Methyl Methacrylate (MMA)
3. Acrylic-Alkyd Paint
4. Epoxy
5. Polyester
6. Preformed plastic (tape and symbols)

Longitudinal lines, including lane lines and edge lines, unless otherwise shown on the Contract plans or approved by the Engineer shall be one of the following material types:

1. Thermoplastic
2. MMA
3. Alkyd Paint
4. Epoxy
5. Polyester.

Symbols, legends, and transverse lines, including stop bars and crosswalks, unless otherwise shown on the Contract plans or directed by the Engineer shall be one of the following material types:

1. MMA
2. Polyester
3. Preformed plastic

Kerb painting shall use one of the following material types:

1. Alkyd Paint
2. Acrylic paint

All pavement markings on precast concrete pavers shall use one of the following types:

1. MMA
2. Epoxy

8.2.2.1 Packaging and Marking

Materials shall be delivered at the site in sealed containers bearing the following information, as applicable:

1. Manufacturer's name and address
2. Contact person and phone number
3. Name of product
4. Lot or batch numbers
5. Colour
6. Net mass and volume of contents
7. Date of manufacture, month and year
8. Date of expiration, month and year
9. Statement of contents
10. Mixing proportions and instructions and
11. Safety information

Material safety data sheets and technical bulletins for all materials shall be furnished to the Engineer with each shipment.

8.2.2.2 Acceptance

Materials shall be delivered, stored and handled so as to assure the preservation of their quality and fitness for the works. Even though approved before storage or handling, materials may again be inspected and tested prior to use in the Works.

Materials that do not comply with the requirements of these Specifications will be rejected by the Engineer and removed immediately from the site of the Works. No rejected materials shall be used in the works.

If any material which does not comply with the requirements is used in the works, or if any work of an unacceptable quality is carried out, such material or work shall be removed, replaced or repaired as required by the Engineer at the Contractor's own cost.

Rejected road markings and paint which has been splashed or dripped onto the pavement, kerbs, structures or surfaces, shall be removed so the paint is not visible by the Contractor at the Contractor’s own cost in an approved manner per Article 8.2.3.7.

8.2.2.3 Submittals

At least seven (7) days before applying pavement markings, the Contractor shall furnish to the Engineer a written copy of the manufacturer's recommendations for use of each material as well as the manufacturer's written documentation of the sampling and test methods used. Contractor’s submittal shall include a detailed method statement, including methods and equipment to be used in the locating, positioning and placing of all pavement markings.

The Contractor shall perform field demonstrations if required by the Engineer to verify the adequacy of recommendations and method statements.

Prior to use of each material, the Contractor shall submit to the Engineer the following:

- Materials safety data sheets (MSDS) for each material
- Product data sheets listing the material constituents and their proportions
- Samples for testing as necessary to comply with these specifications.

8.2.2.4 Marking Colours

Marking colours shall be as shown on the Contract plans or otherwise specified. Colour of the pavement marking material shall be evaluated per ASTM D1729 or EN 1871 or any international standard approved by the Engineer or the Owner This test method covers the spectral, photometric, and geometric characteristics of light source, illuminating and viewing conditions, sizes of specimens, and general procedures to be used in the visual evaluation of color differences of opaque materials relative to their standards.

Colors shall match Federal Standard 595a as follows:

1. White: #37925
2. Yellow: #33538
3. Red: #31136
4. Black: #37031

Alternatively, colour may be evaluated with instrumental measurements per ASTM D2244 or BS EN 1871 or any international standard approved by the Engineer or the Owner and pavement marking materials shall meet the requirements stated in the following tables. Coordinates shown (x and y) are the corner points defining the recommended color boxes in the 1931 CIE Chromaticity Diagram. Lines drawn between these corner points specify the limits of the chromaticity allowed in the diagram. Pavement marking materials shall maintain the required colors and luminance factors throughout service. Colour coordinates of samples that lie within these lines are acceptable.

Table 8-3: Daytime colour specification limits for retro reflective pavement marking material with CIE 2^{o} standard observer and 45/0 (0/45) geometry and CIE standard illuminant D65.

Color	Chromaticity Coordinates							
	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375
Yellow	0.560	0.440	0.490	0.510	0.420	0.440	0.460	0.400
Red	0.480	0.300	0.690	0.315	0.620	0.380	0.480	0.360
Blue	0.105	0.100	0.220	0.180	0.200	0.260	0.060	0.220

Table 8-4: Daytime luminance factors (%) for retro reflective pavement marking material with CIE 2º standard observer and 45/0 (0/45) geometry and CIE standard illuminant D65.

Colour	Luminance Factor (Y%)	
	Minimum	Maximum
White	35	
Yellow	25	
Red	6	15
Blue	5	14
Grey0		

Table 8-5:Nightime colour specification limits for retro reflective pavement marking material with CIE 2º standard observer, observation angle of 1.05º, entrance angle of +88.76º and CIE standard illuminant A.

Color	Chromaticity Coordinates							
	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.480	0.410	0.430	0.380	0.405	0.405	0.455	0.435
Yellow	0.575	0.425	0.508	0.415	0.473	0.453	0.510	0.490

Luminance factors for retroreflective pavement marking materials are for materials as they are intended to be used. For paint products, that means inclusion of glass beads and/or other retroreflective components.

8.2.2.5 Thermoplastic Markings with Type 1 Glass Beads

Types of thermoplastic marking materials are defined by application procedure in Article 8.2.3.3. Types of glass beads are defined in Article 8.2.2.11.

Thermoplastic markings shall consist of thermoplastic material and surface-applied glass beads installed to produce an adherent reflectoried marking capable of resisting deformation. Molten thermoplastic material shall provide complete and even coverage of specified areas to the required thicknesses by way of the required application method and rate. Thermoplastic striping material shall comply with AASHTO M 249 or BS EN 1871 or any other equivalent standard.

Colour shall be as shown on the Contract plans as required by the Owner.

Thermoplastic material shall melt uniformly with no evidence of skins or unmelted particles. Material shall not exude fumes that are toxic, obnoxious, or injurious to persons or property when it is heated during applications.

Material shall remain stable when held for four hours at 211 ±7º C, or when subjected to four reheatings, after cooling to ambient temperature. There shall be no obvious change in colour or viscosity of the thermoplastic material as a result of reheating, and the colour of the material shall not vary from batch to batch. The application temperature has to be defined by the manufacturer depending upon the actual road surface temperature of the location.

The manufacturer shall be ISO 9001 certified or equivalent as approved by the Owner and provide proof of current certification.

a. Packaging and Marking

Thermoplastic material shall be packaged in suitable containers to which it will not adhere during shipment and storage.

In granular form, it shall be in white or yellow plastic bags of approximately 23 kg and shall be made of a material that when introduced into the mix hopper of the application equipment will become a part of the mix without any adverse effect to the performance of the thermoplastic material.

In block form, blocks of cast thermoplastic material shall be approximately 300 by 915 by 51 mm and shall have a mass of approximately 20-25 kg.

Label shall specify the recommended application temperature in compliance to the applicable specification.

b. Storage of Materials

There are three important aspects of thermoplastic materials and glass beads.

1. The storage time for the powdered form of thermoplastic material & glass beads must not exceed the time limit recommended by the manufacturer.
2. The powdered form of thermoplastic material and glass beads are to be kept in dry places. Excessive absorbance of moisture from air by the thermoplastic powder will render the formation of solid lumps and cause difficulty for thorough melting and mixing of the material, even under sufficiently high temperature.
3. The wetted glass beads will lead to poor bonding with the thermoplastic materials.

c. Composition & Usage

Thermoplastic composition shall conform to AASHTO M 249 or BS EN 1871 or any other equivalent standard approved by the Owner and the following requirements:

The marking materials shall be composed of either hydro carbon resin or alkyd resin in conjunction with the aggregates, pigments, binders and glass beads which have been factory produced as a finished material.

Thermoplastic material shall not exceed 0.5 % by weight of retained water when tested in accordance with the requirements of ASTM D570.

Hydrocarbon binder shall consist mainly of synthetic petroleum hydrocarbon resins with appropriate fillers and pigments.

As Hydrocarbon tends to break down under oil drippings and other automobile contaminants, hydrocarbon is recommended for edge lines and long lines where cars are not stationary and not recommended for lines such as stop lines, cross walks, turn arrows etc. where cars are stationary.

Alkyd binder shall consist of a mixture of synthetic resins, at least one of which is solid at room temperature, and of high-boiling-point plasticizers. At least one third of the binder composition and no less than eight percent by weight of the entire material formulation shall be solid maleic-modified glycerol ester resin. The alkyd binder shall not contain any petroleum-based hydrocarbon resins.

Alkyd is recommended for inner city markings and other high traffic areas where petroleum drippings are common. Alkyd thermoplastic exhibits higher retro-reflective values, greater resistance to cracking, oil imperviousness and more durability.

The material composition shall conform to the road marking performance for road users as per BS EN 1426 or any other equivalent standard approved by the Owner.

d. Retro-reflectance

As it is not realistic to obtain the maximum coefficient of illuminance (CIL) in hot countries, the following minimum retro-reflectivity (CIL) values are adequate. Retro-reflectance shall be measured using a handheld retro-reflectometer meeting the requirements of ASTM E1710 with a 30-m geometry, entrance angle of 88.76° and an observation angle of 1.05° or as per EN 1436 (road marking performance for road users) or any equivalent standard approved by the Engineer or the Owner, with the following reflectivity levels:

1. White – 150 millicandelas/metre^2/lux
2. Yellow –100 millicandelas/metre^2/lux

Visibility of the road markings is reduced in wet conditions.

e. Drying Time

Thermoplastic material shall set to bear traffic in not more than 10 minutes when the air temperature is 32 ± 2º C and when the application temperature is within the range of the melting temperature of the road marking compound and up to +5^0 C. The manufacturer’s recommendations shall be applied as approved by the Engineer. when the application temperature is within the range

Setting / hardening time is 10 minutes at a surface temperature of 20^0 C and a light breeze.

f. Material Sampling and Testing for Acceptance

Sampling and testing shall be performed per AASHTO T 250 or EN 1871 or any other equivalent standard approved by the Engineer or the Owner. Minimum size batch of thermoplastic traffic striping material sampled and tested shall not be less than 1080 kg unless the total order is less than this amount. Acceptance shall be evaluated per the criteria established in AASHTO M 249 or any equivalent standard for:

1. Binder content
2. Glass bead content
3. Glass bead content, grading & roundness
4. Reflectance & yellowness index
5. Colour & luminance
6. Titanium dioxide
7. Lead chromate
8. Flowability (percent residue)
9. Low temperature stress resistance
10. Bond strength
11. Impact resistance
12. Softening point
13. Specific gravity
14. Heat Stability
15. Ultraviolet light and condensate exposure
16. Hardness
17. Flash point

8.2.2.6 Cold Applied Plastics

Cold plastic is a double component road marking material. Unlike thermoplastic material, no application heat is required (it is a catalytic reaction process). The material is excellent for countries with low temperatures. Due to the hot climate in this vicinity, the use of this material may not be cost effective. However, the cost factor has to be appropriately decided based on the intent of the usage and approved by the Engineer/ Owner.

a. Methyl Methacrylate Markings with Type 1 Glass Beads

Types of methyl methacrylate (MMA) are defined by the application in Sub-article g of Article 8.2.3.3. Types of glass beads are defined in Article 8.2.2.11. Material shall conform to the following or any other international standards, considered equal or better:

Table 8-6: Methyl methacrylate material requirements

Standard	Criteria
Chemical Resistance	Material shall show no effect after seven day immersion in anti-freeze, motor oil, diesel fuel, gasoline, calcium chloride, sodium chloride or transmission fluid.
Composition	
Type M1	3.8 litres MMA and 90 millilitres of benzoyl peroxide powder
Type M2, M3, M4, M5	Four parts MMA and one part liquid benzoyl peroxide.
Elongation - ASTM D638	20 % minimum
Hardness – ASTM D2240 (Shore Durometer Type D)	55 minimum after 24 hours
No Track Time – ASTM D711, modified as follows:	15 minutes at 40 mils.
Reflectance – ASTM D6359	Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m^2/lux for white and 175 mcd/m^2/lux for yellow in accordance with ASTM D6359 when measured with a 30-metre retroreflectometer. Compliance shall be measured with a Delta LTL-X retroreflectometer.
Skid Resistance – ASTM E303	45 BPN units minimum
Tensile Strength – ASTM D638	0.088 kg/mm^2 minimum at break
Viscosity – ASTM D2196 Method B, LV Model at 50 rpm.	
Type M1	11,000 to 15,000 cps, spindle #7
Type M2	26,000 to 28,000 cps, spindle #7
Type M3	17,000 to 21,000 cps, spindle #7
Type M4	8,000 to 10,000 cps, spindle # 4
Type M5 White	5,000 to 8,000 cps, spindle #4
Type M5 Yellow	7,000 to 11,000 cps, spindle #4
Ultraviolet Light	No effect

8.2.2.7 Alkyd Resin Paint Markings

This material specification covers alkyd resin type, ready-mixed white, yellow, red, and black traffic paints for use on bituminous and Portland cement concrete pavements. Alkyd resin paint shall comply with the requirements of AASHTO M 248-91, which classifies alkyd resin paint into three types:

1. Type S Traffic Paint—Slow drying paint for use in areas where drying is acceptable for 1 hour or more. Medium oil soya modified alkyd resin. Primary solvent is VM and P Naphtha.
2. Type N Traffic Paint—Paint with immediate drying properties for use in areas where drying is acceptable for 15 to 30 minutes. Medium oil soya-modified pentaerythritol alkyd resin; chlorinated rubber, 4 to 1. Primary solvent is toluene.
3. Type F Traffic Paint—Paint for use where faster drying time is required, typically 3 to 6 minutes if heated to 51.5 ±2.5ºC in the applicator. Medium oil soya/linseed alkyd resin; chlorinated rubber; chlorinated paraffin; 1.03 to 1.30 to 1.00. Primary solvent is MEK.

Road-marking paint shall be Type F. Types N and S may be used to paint kerbs. Alkyd resin paint for road markings shall not be thinned. For kerb marking, thinning with manufacturer recommended product shall be allowed up to 3 % or the manufacturer’s recommended minimum, whichever is lesser.

Alkyd resin paints may be reflectorized for night visibility by adding glass beads immediately after application of the alkyd resin material.

Red and black alkyd resin paint shall be non-reflectorized road marking paint based on alkyd resin and chlorinated rubber blended with rich pigments and low VOC contents.

a. Composition of Alkyd Resin Paint Markings

Composition of alkyd resin markings (paint) shall be as stated in AASHTO M 248.

Inert or filler pigments shall be first quality paint grade products.

Paint drawdowns shall be performed per ASTM D823. Alkyd resin paint shall be low VOC solvent based paint that meets the following requirements for white (W), yellow (Y), red (R), or black (B) paint as applicable:

Table 8-7: Alkyd resin paint characteristics

Standard	Criteria	W/Y	R/B
Bleeding over asphalt ASTM D969, modified as follows:	Reflectance measurement of the alkyd resin paint over asphalt paper shall be at least 90 % of the reflectance measurement of the material over a taped (non-bleeding) surface.	●	
Chromium content ASTM D3718	< 50 ppm	●	
Directional reflectance ASTM E1347	White paint shall have a minimum reflectance of 80 %.	●	
Density ASTM D1475, at 21^{o} C	1.5 kg/litre minimum	●	●
Flexibility ASTM D522	Alkyd resin shall be applied at a wet film thickness of 0.15 mm to a 75x125 mm panel that has been solvent cleaned and lightly buffed with steel wool. With the panel kept in a horizontal position, the paint shall be allowed to dry for 18 hours at 24 ± 2.8^{o} C then baked for 3 hours at 60 ± 2.2^{o} C. Panel shall be cooled to 24 ± 2.8^{o} C for at least 30 minutes, bent over a 0.25-inch mandrel and then examined without magnification.	●	●

	Alkyd resin shall show no cracking, flaking or loss of adhesion.		
No track time (dry to no-pick-up time for pavement marking)	When applied in a line at a rate of 0.38 mm wet film thickness with 0.84 kg of glass beads per litre of paint added to the paint, surface shall "dry to no-pick-up" in 90 seconds maximum. Test line shall be applied over a 30 day old (approximate), non-beaded state standard paint line. Test line shall be applied using a striper capable of maintaining the 0.38 mm wet film thickness specified. Glass beads shall be blown onto the line during material application. Test shall be conducted on dry pavement when the pavement temperature is between 10 and 38^{o} C and the relative humidity is less than 85%. "Dry to no-pick-up" tests shall be performed by having a standard size sedan or equivalent test vehicle coast across the paint line with no turning or accelerating at a speed of approximately 65 kph no more than 90 seconds after the test line is applied to the pavement. A successful test shall be considered one in which at least three out of four line crossings show no visible paint from the line tracked onto the adjacent pavement when viewed standing 15 m from the point where the test vehicle crossed the line.	●	●
Lead content ASTM D3335	0.06 % maximum	●	●
Nonvolatile content ASTM D2369	65 % minimum	●	●
Package stability ASTM D1849	6 rating minimum for all criteria	●	●
Pigment content ASTM D2371	53 % maximum	●	●
Retroreflectance ASTM D6359	Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m^2/lux for white and 175 mcd/m^2/lux for yellow in accordance with ASTM D 6359 when measured with a 30-metre retroreflectometer. Measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.	●	
Skinning	Alkyd resin shall not skin within 48 hours in a ¾ filled tightly closed container.	●	●
Settling properties during storage ASTM D1309	Sample shall show no more than 12.7 mm of clear material over the opaque portion of the paint and there shall be no settling below a rating of seven.	●	●
Titanium dioxide (rutile type II) ASTM D476	White – 0.12 kg/litre minimum. (ASTM D4563) Yellow – 0.02 kg/litre maximum. (ASTM D4563)	●	
Viscosity ASTM D562	105 Krebs units maximum at 10^{o} C 75-85 Krebs units at 21^{o} C 65 Krebs units minimum at 49^{o} C	●	●
Volatile Organic Compound Content	0.15 kg/litre maximum	●	●

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8.2.2.8 *Epoxy Pavement Markings*

Contractor shall furnish a 2-component, 100 % solids type system for hot spray application conforming to Table 8-8.

White and Yellow marking materials may be reflectorized by adding glass beads. Red and black epoxy marking material shall be non-reflectorized.

Table 8-8: Epoxy marking material characteristics

Pigments. Component A. Percent by mass.		
White	Titanium dioxide (TiO_2), ASTM D 476, types II and III	18 % min.
	Epoxy resin	75 to 82 %
Yellow	Chrome yellow ($PbCrO_4$), ASTM D126, type III	23 % min
	Epoxy resin	70 to 77 %
Non-lead yellow	Titanium dioxide (TiO_2), ASTM D476, types II and III	14 % min
	Organic yellow	7 to 8 %
	Epoxy resin	75 to 79 %
Epoxy content. Component A.		
	Mass per epoxy equivalent, ASTM D1652	Manufacturer's target value ±50
Amine value. Component B.		
	ASTM D2074	Manufacturer's target value ±50
Toxicity	Toxic or injurious fumes at application temperature	none
Directional reflectance (without glass beads)		
White	ASTM E1347	84 % relative to magnesium oxide standard
Yellow	ASTM E1347	55 % relative to magnesium oxide standard
Drying time. 0.38-millimetre film thickness with beads.		
Laboratory at 22 º C	ASTM D711 to no-pick-up condition	30 minutes maximum
Field at 25 º C	Viewed from 15 m to no-tracking condition	10 minutes maximum
Abrasion resistance:	Wear index with a CS-17 wheel under a 1000 g load for 1000 cycles, ASTM D4060	82 max
Hardness	Shore D hardness with 72- to 96-hour cure at 22 º C, ASTM D2240	75 to 100
Storage	Individual epoxy components shall not require mixing before use.	When stored for up to 12 months

8.2.2.9 Polyester Markings

Contractor shall furnish a 2-component system conforming to the following:

Table 8-9: Polyester marking material characteristics

Directional reflectance (without glass beads)		
White	ASTM E1347	80 % relative to magnesium oxide standard
Yellow	ASTM E1347	55 % relative to magnesium oxide standard
Viscosity	Uncatalyzed polyester at -4º C, ASTM D562	70 to 90 Krebs units
Bleeding	ASTM D969	6 minimum
Field drying time	Viewed from 15 m to no-tracking condition	45 minutes maximum

Colour shall be white or yellow or as shown on the Contract plans.

8.2.2.10 Preformed Plastic (Tape and Symbols) Types 1 and 2

Preformed plastic tape and symbols shall be a high durability retro-reflective pliant polymer film for preformed striping and markings to be used for permanent pavement markings.

Colour shall be white or yellow or as shown on the Contract plans or as directed by the Engineer.

It should be a durable retro-reflective marking material suitable for roadway, intersection, commercial or private pavement delineation and markings. The markings shall be resilient thermoplastic product with uniformly distributed glass beads throughout the entire cross section area.

The markings shall be resistant to detrimental effects of motor fuels etc. The lines, legends, symbols are to be capable of affixing to bituminous or cement concrete pavements.

The manufacturer shall be ISO 9001 certified or equivalent as approved by the Owner and provide proof of current certification.

Preformed plastic tape and symbols material is identified by the following designations:

a. Type 1: On bituminous surfaces, Type 1 preformed pavement marking tape and symbols shall be capable of being installed onto wearing surfaces during the final roller operation. Application on concrete surfaces shall be in accordance with the manufacturer’s application recommendations. After application, the tape shall be immediately ready to receive traffic.

   Tape and symbols shall consist of a mixture of polymeric material, pigments and glass beads distributed throughout the cross-sectional area, with a reflective layer of glass beads embedded in the top surface. Material shall be sufficiently flexible to conform to the roadway without cracking or breaking. A patterned surface will be allowable; however the tape and symbols, without adhesive, shall have a minimum thickness of 1.5 mm over at least 50 % of the tape’s surface. The edges of the tape/symbols shall not be tapered.

   Tape/symbols shall be supplied with a pre-coated factory-applied adhesive for immediate application to bituminous pavement without the use of heat, solvent or other adhesive operations. Tape/symbols and adhesive shall be of a type that water used on the compaction roller will not be detrimental to successful application. On concrete surfaces, application shall be in accordance with the manufacturer’s recommendations.

b. Type 2: Type 2 preformed pavement marking tape/symbols shall consist of a mixture of polymeric material and pigments with beads distributed throughout the cross-sectional area and with a reflective layer of ceramic beads embedded in the embossed, patterned surface.

Patterned surface shall have 50 % ±15 % of the surface area raised and presenting a near vertical face (angle of 0o to 60o from vertical) to traffic from any direction. Channels between the raised areas shall be substantially free of exposed beads or particles.

Marking shall be capable of adhering to bituminous or concrete surfaces by a flexible conforming backing. A primer may be required to precondition the pavement surface. Tape/symbols (prior to adhesive backing applied) shall have a patterned surface with a minimum thickness of 1.6 mm in the raised (thickest) area of the cross section and a minimum thickness of 0.5 mm in the depressed (thinnest) areas of the cross section. Tape/symbols shall be supplied with a pre-coated factory-applied pressure sensitive adhesive.

The material shall be composed of alkyd resin to resist the degradation by motor fuels, lubricants etc.

Retro reflectance shall be measured using a handheld retro-reflect meter meeting the requirementsof ASTM E1710 with a 30 m geometry, entrance angle of 88.76° and an observation angle of 1.05°, with the following reflectivity levels:

1. White – 250 mill candelas/metre^2/lux
2. Yellow – 175 mill candelas/metre^2/lux

a. Composition

Preformed plastic pavement marking material shall consist of the following components:

Table 8-10: Composition of preformed plastic materials types 1 and 2

Material	Minimum percent by weight/quantity
Resins and plasticizers	20
Pigments (as per EN 1790)-white and Yellow	30
Reflective glass beads (premix)	30
Other fillers	30 (maximum)
Surface beads (factory applied)	300g/m^2

The material shall be supplied at thickness of 2.8 (-0.3+0.4) mm. The material shall be resistant to deterioration due to exposure to sunlight, water, salt or any adverse weather conditions and resistant to oil and gasoline.

b. Packing

The preformed thermoplastic material shall be placed in protective cardboard boxes and shall contain no plastic in between the sheets/layers. Liner materials shall be cut into a maximum of 100cm long pieces. Legends and symbols also supplied in flat pieces. The cartons size shall not exceed 110x70cm and the weight of the individual carton must not exceed 20 kg.

c. Material Sampling and Testing for Acceptance

Preformed plastic marking materials Type 1 and 2 shall meet the requirements of Table **8-11**.

Table 8-11 Preformed plastic tape testing and acceptance criteria

Test	Procedure	Criteria for Acceptance
Bend test	Temperature: 25° C to 28° C Specimen: 75 mm by 150 mm unmounted piece of material (without adhesive and paper backing) Bend specimen over a 25 mm mandrel until the end faces are parallel and 25 mm apart.	No visible fracture lines in the uppermost surface.

Test	Procedure	Criteria for Acceptance
Tensile strength Test	Temperature: 21° C to 27° C Specimen: 25 mm by 150 mm unmounted piece of material (without adhesive and paper backing) Test specimen in accordance with ASTM D638. Rate of pull shall be 6 mm per minute.	Minimum tensile strength 275 kPa. Elongation no greater than 75 %.
Abrasion resistance test	Abrade the plastic film according to Federal Test Method Standard No. 141, Method 6192, using H-18 calibrase wheels with a 1000 g load on each wheel.	Maximum loss in weight of 0.25 g in 500 revolutions

8.2.2.11 Acrylic Paint

A quick drying paint based on acrylic or modified acrylic resin especially formulated for application in the harsh UAE environment with high durability and excellent adhesion to concrete. The acrylic paint shall be a non-yellowing, UV-resistant material with excellent gloss and colour retention properties. The minimum requirements for paint are given below:

- Solids by volume: minimum 37%
- Specific gravity: minimum 1.2
- Highly UV resistant against fading and peeling.

8.2.2.12 Glass Beads

This specification covers glass beads to be dropped or sprayed upon pavement markings, or intermixed with pavement marking material, so as to produce a reflectorized pavement marking. Glass beads shall be transparent, clean, colourless glass, smooth and spherically shaped, free from milkiness, pits, or excessive air bubbles. Glass beads shall be dry and free of lumps and clusters. Glass beads that show a tendency toward decomposition, including surface etching, when exposed to atmospheric conditions, moisture, dilute acids or alkalis will be rejected.

Glass beads shall conform to AASHTO M 247 or any equivalent standard approved by the Owner.

Pre-mix glass beads: The thermoplastic material shall contain thirty percent (30%) glass beads by weight. The premix shall conform to the above standard or equivalent as approved by the Owner.

Drop-on glass beads: The drop on glass beads shall be within the range of 400 to 500 g/m^2. It is recommended that adding a minimum of 10% high performance glass beads by weight to the traditional glass beads to produce good performance on the retro-reflectivity. The Coefficient of Retroreflected Luminance (RL) of newly applied road marking should be >250 mcd/m2/lux.

a. Packaging and Marking

Glass beads shall be packaged in moisture-proofed bags guaranteed to furnish dry and undamaged beads.

b. Sampling and Testing

Acceptance shall be evaluated per the test methods and criteria for acceptance identified in AASHTO M247 or any other equivalent standard approved by the Owner for the following parameters:

1. Gradation
2. Roundness
3. Refractive index
4. Coatings: flotation, flow, moisture resistance and adherence

Glass beads shall conform to gradation requirements established in AASHTO M247, or EN 1423 or any other equivalent standard approved by the Owner and shall meet the gradation requirements for type as given in Table 8-12.

Type 1 shall be known as a standard gradation.

Type 2 shall be known as a uniform gradation.

Table 8-12: Gradation of glass beads

Sieve designation	**Mass percent passing**	
Standard, mm	**Type 1**	**Type 2**
0.850	100	---
0.600	75 – 95	100
0.425	---	90 - 100
0.300	15 – 35	50 - 75
0.180	---	0 - 5
0.150	0–5	---

Table 8-13 Gradation of glass beads

Sieve Designation	**Mass % Passing**	
mm	Type 4	Type 5
2.35	-	100
2.00	100	95-100
1.70	95-100	80-95
1.40	80-95	10-40
1.18	10-40	0-5
1.0	0-5	0-2
0.850	0-2	-

8.2.3 Construction Requirements

8.2.3.1 Preparation of Roadway Surfaces

New and existing pavement shall be dry, clean, and free of contaminants such as surface oils or curing agents or any material which will be detrimental to the bond between the marking and the surface. Clean pavement is essential for a good bond to pavement marking material.

Contaminants and existing pavement markings shall be removed from surfaces where the pavement marking is to be applied by approved mechanical means: watering, brooming or compressed air if required. Contractor shall avoid damaging the pavement surface.

Contaminants up to 1.6 mm^2 may remain if they are not removed by the following test, performed just before application of markings:

1. Air-blast the surface to be tested
2. Firmly press a 250 mm, 50 mm wide strip of monofilament tape onto the surface, leaving approximately 50 mm free

3. Grasp the free end and remove the tape with a sharp pull.

Portland cement concrete pavement shall have cured for a minimum of 28 days prior to pavement marking.

Pavement markings shall be applied to bituminous surfaces after sufficient time has elapsed to ensure that damage will not be caused to the painted surface by volatiles evaporating from the surfacing, typically 21 days, as approved by the Engineer.

Pavement markings shall not be applied when wind strength may adversely affect the painting operations in the opinion of the Engineer.

Cost for preparing kerbs and roadway surfaces shall be considered part of the cost for applying pavement markings.

8.2.3.2 Preliminary Spotting

Contractor shall be responsible for preliminary spotting for pavement markings. Approval by the Engineer is required before marking begins. Preliminary spotting to guide the striping machine is required for all longitudinal lines.

Positions and outlines of special markings shall be produced on the finished road in chalk. Approved templates may be used on condition that the positioning of the marking is approved by the Engineer before painting is commenced.

Any additional work necessary to establish satisfactory lines for stripes and all layout work required for pavement markings shall be performed by the Contractor at the Contractor's expense. Material used for spotting shall be the same colour as the permanent marking.

Preliminary spotting for lines shall be established with painted marks, cat tracks or dribble lines, the use of laser guidance devices or by a combination of these techniques. Preliminary spotting shall be provided at a spacing of 60 m maximum on tangents and 15 m maximum on curves.

Cat tracking shall consist of stretching a rope on a straight line between control points on tangent alignment and on a true arc through control points on curved alignment and placing spots of paint along the rope. The spots shall be not more than 50 mm in width and not more than 1.5 m apart on curves nor more than 3 m apart on tangents.

Dribble lines shall consist of marking the pavement with a thin line of paint using a striping machine or other suitable device. Dribble lines shall be on a straight line between control points on tangent alignment and on a true arc through control points on curved alignment.

Laser guidance equipment shall be capable of maintaining the alignment of traffic stripes with an accuracy equivalent to, or better than, that obtainable through use of cat tracking or dribble lines, as determined by the Engineer.

8.2.3.3 Marking Application

Pavement markings shall be installed as shown on the Contract plans and as approved by the Engineer.

Rate of application shall be checked and adjusted until pavement marking dimensions are within tolerances as stated in these Specifications before application on a large scale is commenced.

Double lines shall be applied simultaneously by the same machine.

Centre lines on two-lane highways with broken line patterns shall be applied in the increasing kilometer post or stationing direction to be in cycle with existing broken line patterns at the beginning of the project. Broken line patterns applied to multi-lane or divided roadways shall be applied in cycle in the direction of travel.

When 2 or more spray applications are required to meet thickness requirements, top dressing with glass beads is only allowed on the last application. Successive applications shall be applied squarely on top of the preceding application and in the opposite direction as the first application direction.

Cure period between successive applications shall be in accordance with the manufacturer’s recommendations. Any loose beads, dirt or other debris shall be swept or blown off the line prior to application of each successive application.

Pavement marking material shall be stirred before application in accordance with the manufacturer's instructions. Pavement marking material shall be applied without the addition of thinners. Curves shall not consist of chords but shall follow the correct radius.

After pavement markings are applied, the Contractor shall be responsible for protecting them against damage by traffic or other causes. Contractor shall be responsible for erecting, placing and removing all warning boards, flags, cones, barricades and other protective measures which may be necessary to accomplish this.

During application operations, a large working sign with the marking "TRAFFIC STRIPING" in Arabic and English shall be placed at the beginning of each operation. Engineer may direct that other safety signs be placed at various locations to guide or warn traffic regarding the operation.

Additional pavement marking information, including troubleshooting tips for nonconforming pavement markings, is as follows as per Texas DOT Pavement Marking Handbook.

Table 8-14: Problems and Solutions associated with the application of thermoplastic markings (Texas DOT pavement Marking handbook)

Trips	Tips
Debonding	▪ Unclean road surface ▪ Low temperatures ▪ Moisture in pavement ▪ Defective material ▪ Marking speed too fast
Bubbles in line	▪ Moisture in pavement ▪ Overheated material
Flowing Line (i.e., no defined edge), line with excessive edges	▪ Material too hot
Cracks in line	▪ Temperature stress from overheating ▪ Low temperatures ▪ Material applied too thin
Rough line surface or crumbly edges	▪ Material temperature too low ▪ Material has been scorched ▪ Moisture in pavement
Smooth shiny, glossy line	▪ No or insufficient glass beads or beads too deeply embedded
Smooth line with slight dimples	▪ Glass beads too low ▪ Bead gun too close to application shoe
Cratered line	▪ Glass beads have popped out ▪ Material is too cool or bead gun located too far back
Greenish yellow appearance	▪ Material has been scorched ▪ Material reheated too many times or inadequate cleaning of application pots
Splattering	▪ Material too hot or too cold
Dingy or dull white colour	▪ Material has been scorched ▪ Material reheated too many times or inadequate cleaning of application pots ▪ Yellow thermoplastic not completely removed before white was added to the application pots
Lumps in line	▪ Material is either overheated or under heated

Trips	Tips
	▪ Charred material has been overheated where unblended pigments and fillers have been under heated

a. Equipment

Before any marking machine is used on the permanent works, the satisfactory operation of the machine shall be demonstrated on a suitable site which is not part of the permanent works. Adjustments to the machine shall be followed by further testing. When the machine has been correctly adjusted and its use has been approved by the Engineer after testing, the machine may be used on the permanent work.

Pavement marking machines shall be capable of producing at least two parallel lines simultaneously and producing lines with uniform widths within the tolerances specified without the paint running or splashing. Machine shall be further capable of painting lines of different widths by adjusting the spray jets on the machine or by means of additional equipment attached to the machine and applying the pavement marking material and glass beads to a uniform film thickness at the specified rates of application.

Equipment utilized shall form an extruded line which shall be uniform in shape having clear and sharp dimensions.

Pavement marking traffic control shall be done in accordance with the applicable provisions of the MUTCD for work zone traffic safety management. In addition, pavement marking machines shall have clearly visible amber warning flashing lights which shall always be in operation when the machine is on the road.

b. Marking of Kerbs, Noses, and Kerb Cuts

Kerbs, noses, and kerb cuts shall be painted as indicated on the Contract plans as per the nature of the parking zone as follows:

i. Alternating colours of turquoise and gray shall be used to indicate a Mawaqif pay parking zone.

ii. Alternating colours of turquoise and white shall be used to indicate a premium Mawaqif pay parking zone, typically next to a major building entrance.

iii. Either unpainted kerbs or gray kerbs may be used within zones indicating that parking is allowed.

iv. Solid yellow shall be used to indicate a loading zone.

v. Alternating colours of gray and yellow shall be used to indicate a no parking zone as well as the edges of kerbs and channelization islands. Yellow shall be provided on the nose of any channelization island, including barriers that protect the front of the island and any signal poles or other devices located behind the nose of the island.

vi. Solid red shall be used to indicate the presence of fire hydrants along roads.

Length of each band shall be 1.20 m (or two precast kerb stones) and shall be painted on the exposed kerb surfaces after kerb and pavement are in place or as approved by the Engineer.

Areas adjacent to fire hydrants shall be painted solid with red non-reflectorized paint.

Kerb marking may be accomplished by applying non-reflectorized epoxy or alkyd resin paint with a roller, brush or spray.

c. Application of Glass Beads

Where reflective pavement markings are required, glass beads shall be applied at a uniform rate, in one continuous operation, by a bead dispenser immediately following the pavement marking material application. Rate of application of the beads shall be as indicated in these Specifications for each material or such other rate as may be approved by the Engineer.

Machines which apply glass beads by means of gravity only shall not be used. Glass beads shall be sprayed onto the paint layer by means of a pressure sprayer except that for small areas, such as application of traffic symbols, hand application of glass beads is acceptable and a gravity bead dispenser may be allowed by the Engineer for hand application if it properly gauges and dispenses the correct amount of glass spheres.

d. Inspecting and Testing for Acceptance

Random spot checks of the pavement marking thickness will be made by the Engineer to ensure conformance with the criteria of these Specifications. Random samples will be taken at maximum intervals of 600 m. If three or more successive readings meet the minimum thickness, the Engineer may designate an alternative interval.

To test the thickness of the stripe, a small strip of metal with a known thickness shall be placed immediately ahead of the striping apparatus. Plate shall be removed after the pavement marking material and glass beads have been applied at the normal rate and the sample has cooled sufficiently so that no deformation to the stripe occurs when removing the plate from the roadway. A knife may be used to assist with the removal.

A suitable device, such as a micrometre, shall be used to measure the thickness of the marking. Stripe thickness shall be measured at the centre and at approximately 25 mm intervals to the edge of the stripe. Measurements shall be taken to the top of the pavement marking material, not to the top of the bead. Care shall be taken not to indent the thermoplastic film with the micrometre points. No measurements shall be closer than 6 mm to the edge of the stripe. Additional readings may be taken if necessary. Average of the readings across each sample must be equal to or above the specified minimum thickness. No reading shall be more than 250 μm below the specified minimum thickness.

e. Application of Alkyd Resin

Each layer of alkyd resin shall be continuous over the entire area being marked. Where applied by machine, it shall be applied in one layer. Where applied by hand, it shall be applied in two layers, and the second layer shall not be applied before the first layer has dried. As most road-marking paint reacts with the bitumen surface of the road, the paint shall be applied with one stroke only of the brush or roller.

Time between applications will vary depending on the type of pavement per the following table. The manufacturer’s recommendations shall be applied as approved by the Engineer.

Table 8-15: Alkyd resin time between successive applications

Pavement Type	Time Period
Bituminous surface treatment	40 min. min., 48 hrs. max.
Hot mix asphalt pavement	40 min. min., 30-days max.
Cement concrete pavement	40 min. min., 30-days max.

Alkyd resin paint for road markings shall not be thinned.

For kerb marking, thinning with manufacturer recommended product shall be allowed up to 3 % or the manufacturer’s recommended minimum, whichever is lesser.

1. Preparation of Roadway Surface

The Contractor shall meet the general requirements of Article 8.2.3.1. In addition:

1. Pavement surface temperature shall not exceed 82º C. Requirement may be superseded by manufacturer's written installation instructions.
2. Test for pavement dryness: place a square piece of clear plastic measuring 300 mm along a side on the pavement. Weight the edges. Pavement is dry if no condensation has occurred on the underside of the plastic after 15 minutes.

2. Equipment

The Contractor shall meet the general requirements of Sub-article (a) of Article 8.2.3.3. In addition:

1. Motorized airless striping machine shall be used for road marking applications.
2. For nonlinear applications and kerb marking, material may be brushed or rolled onto concrete surface.

3. Application Thickness

For reflectorized markings, glass beads shall be applied immediately after the pavement marking material has been applied and as per the approved manufacturer's recommendation including the thickness.

Table 8-16: Minimum thickness, application rates for alkyd resin and glass beads

	Minimum Thickness	Application Rate
Alkyd resin – first coat	0.25 mm	4.0 m^2 per liter max.
Alkyd resin – second coat	0.38 mm	2.6 m^2 per liter max.
Type 1 glass beads	0.38 mm	0.85 kg/litre of paint min.

f. Application of Thermoplastic

Thermoplastic material shall be applied by spraying, screed extrusion, or ribbon extrusion, as shown in the Contract plans or as directed by the Engineer, at temperatures of 211 ±7º C from approved equipment to produce a continuous and uniform in shape line having clear and sharp dimensions, particularly when extruded.

Contractor shall utilize the material manufacturer's recommended procedure for the application. A manufacturer's technical representative shall be present at the initial installation of plastic material to supervise the installation procedure, if required by the Engineer.

1. Preparation of Roadway Surface

The contractor shall meet the general requirements of Article 8.2.3.1. In addition:

i. Pavement surface temperature shall not exceed 82º C. Requirement may be superseded by manufacturer's written installation instructions.

ii. Pavement shall be free from existing pavement marking materials. The Contractor shall conform to the requirements of Article 8.2.3.7 for removal methods.

iii. Thermoplastic test for pavement dryness: place a sample of thermoplastic pavement marking material on a piece of tarpaper placed on the pavement. Allow material to cool to ambient temperature. Pavement is dry if there is no condensation on the underside of the tarpaper in contact with the pavement.

2. Equipment

The contractor shall meet the general requirements of Sub-article (a) of Article 8.2.3.3. In addition:

i. Application equipment shall be truck-mounted units, motorized ride-on equipment, or manually pushed equipment, depending on the type of marking required.

ii. Truck-mounted or motorized ride-on units for center lines, lane lines, and edge lines shall consist of a mobile self-contained unit carrying its own material capable of operating at a minimum speed of 8 kph while applying striping. The manufacturer's recommendations shall be applied as approved by the Engineer.

iii. Hand applicator equipment shall be sufficiently maneuverable to install curves and straight lines, both longitudinally and transversely.

iv. Application equipment shall be so constructed as to assure continuous uniformity in the dimensions of the stripe. The applicator shall provide a means for cleanly cutting off square stripe ends and shall provide a method of applying skip lines.

v. Equipment shall be constructed so as to provide varying widths of traffic markings.

vi. Application equipment shall be capable of following straight lines and normal curves in a true arc.

vii. Bead dispenser shall utilize pressure type spray guns which will embed the beads into the stripe surface to at least 1/2 the bead diameter. Bead dispenser shall be equipped with an automatic cut-off synchronized with the cut-off of the thermoplastic material.

viii. Equipment used to install hot applied thermoplastic material shall be provide continuous uniform heating to temperatures exceeding 204° C while mixing and agitating the material. Conveying portion of the equipment, between the main material reservoir and the line dispensing device, shall be configured to prevent accumulation and clogging.

ix. All parts of the equipment which will come in contact with the material shall be constructed for easy accessibility for cleaning and maintenance. Equipment shall operate so that all mixing and conveying parts including the line dispensing device, maintain the material at 211 ±7º C. Use of pans, aprons or similar appliances which the dispenser overruns will not be permitted.

x. A special kettle shall be provided for uniformly melting and heating the thermoplastic material. The kettle must be equipped with an automatic thermostat control device and material thermometer for positive temperature control to prevent overheating or under heating of the material.

xi. If screed or extrusion application or thermoplastic is allowed by the Engineer for short applications, the screed/extrusion application method shall be utilized wherein one side of the shaping die is the pavement and the other three sides are contained by equipment suitable for heating or controlling the flow of material.

3. Application

Primer

Use the thermoplastic manufacturer's recommended primer on:

1. Portland cement concrete pavement
2. Asphalt surfaces that are more than two years old, oxidized and/or have aggregate exposed

Primer shall be applied to all pavement surfaces at manufacturer's recommended application rates. It must set for the specified cure or evaporation time prior to thermoplastic being applied.

Primed pavement surfaces shall be striped within the manufacturer's recommended set time or within the same working day. If the primed surfaces are not striped within these time limits, they shall be re-primed prior to the thermoplastic application at the prescribed rate denoted by the manufacturer.

If an approved epoxy primer is used, proportional mixing shall be checked and thermoplastic application must occur before epoxy has cured.

Improper primer/sealer application will cause bond failure between the thermoplastic and substrate. Improper application may also result in physical degradation of the thermoplastic material by excessive pinholing and blistering of the line. This degradation may occur through extraction of the binder by the solvent system contained in the primer/sealer promoted by improper drying time and application rates.

Temperature

Thermoplastic striping material shall be applied at a material temperature range between 204 ^{0}C to 220 ^{0}C. Material temperature shall be measured at the point of road contact. Material temperature for application on Portland cement concrete shall not be less than 218 ^{0}C.

The top surface of the material shall have regularly spaced heat indicators to ensure that the material has reached the molten state and to the required criteria for application.

Glass Beads

Drop-on glass beads must be immediately mechanically deposited after applying the thermoplastic line. If the glass beads are not adhering to the thermoplastic line, all operations shall immediately be suspended until the problem can be corrected. Drop-on beads anchor and reflect best at 50-60 % embedment and this depth of embedment should generally be achieved (confirmed by visual inspection), unless otherwise approved by the Engineer or the Owner.

Types and Thickness

Thermoplastic marking types are defined by application procedures as shown in Table 8-17 and/or as recommended by the manufacturer's specification and approved by the Owner.

Pavement markings shall be installed at the following base line thicknesses measured above the pavement surface or above the groove bottom for grooved markings:

Table 8-17: Minimum thickness for thermoplastic pavement markings

Type	Use	Method	Minimum base line thickness (mm)	
			On HMA/ PCC (mm)	On BST (mm)
T1 or T2	Flat/transverse & symbols	Extruded	3.2	3.2
T1 or T2	Flat/long line & symbols	Spray	2.3	3.0
T1 or T2	With profiles	Extruded	2.3	3.0
T1 or T2	Embossed	Extruded	4.1	4.1
T1 or T2	Embossed with profiles	Extruded	4.1	4.1

Type	Use	Method	Minimum base line thickness (mm)	
			On HMA/ PCC (mm)	On BST (mm)
T1 or T2	Grooved/flat/long line	Extruded	5.8	5.8
T1 or T2	Retracing on thermoplastic	Spray	1.5	1.5
T3	Preformed thermoplastic markings, flat/transverse symbols and tape	Rolled into hot asphalt, adhesive backed and heat fused (if approved by the Engineer)	1.5 – 1.6	1.5 – 1.6

Pavement marking material yield depending on thickness shall not exceed the following:

Table 8-18: Application rates for Type T1 & Type T2 thermoplastic material

Thickness (mm)	Liquid material yield (maximum)		Solid material yield (maximum)	
	Metres of 100 mm line/litre	M^2/litre	Metres of 100 mm line/23 kg bag	M^2/23 kg bag
1.5 flat	6.67	0.67	46.6	4.7
2.3 flat	4.37	0.44	37.0	3.7
2.3 with profiles	2.44	0.24	20.7	2.1
3.0 flat	3.28	0.33	27.8	2.9
3.0 with profiles	1.35	0.13	17.9	1.8
3.2 flat	3.15	0.31	26.5	2.7
4.1 embossed	2.46	0.25	22.9	2.3
4.1 embossed with profiles	0.53	0.05	4.9	0.5
5.8 grooved	1.71	0.17	14.5	1.4

g. Application of Methyl Methacrylate

Methyl methacrylate (MMA) pavement marking material exists as a solid that is mixed in a static mixer immediately prior to application and shall be sprayed or extruded onto the pavement.

MMA material consists of a two-part mixture of methyl methacrylate and a catalyst that is applied cold to the pavement. Material can be applied at a continuously uniform thickness or it can be applied with profiles (bumps). The material is classified by type designation, depending upon the method of application.

Table 8-19: MMA type designations

Type	Application Method	Intermix Glass Beads	Surface Dress Glass Beads
Type M1	By hand (pour, trowel, extrude)	Prior to MMA application	
Type M2	Spray	Prior to MMA application	
Type M3	Machine extrusion	Prior to MMA application	Immediately after MMA application
Type M4	Machine extrusion	Prior to MMA application	Immediately after MMA application
Type M5	Spray	Prior to MMA application	Immediately after MMA application

Glass beads, intermixed and surface dress, shall conform to the manufacturer's recommendations as necessary to meet the reflectance requirements of Article 8.2.2.6 of these Specifications.

A manufacturer's technical representative shall be present at the initial installation of MMA material to supervise the installation procedure if so requested by the Engineer. Application shall be done in accordance with the manufacturer's recommended procedure.

1. Preparation of Roadway Surface

The Contractor shall meet the general requirements of Article 8.2.3.1. In addition:

i. Pavement surface temperature shall not exceed 82° C. Requirement may be superseded by manufacturer's written installation instructions.

ii. Pavement shall be free from existing pavement marking materials. Refer to Article 8.2.3.7 for methods.

iii. Prior to application, complete pavement cure period of 21 days for bituminous asphalt. Prior to application, complete pavement cure period of 28 days for Portland cement concrete. These cure periods may be reduced if the Contractor performs a successful bond test and the manufacturer approves the reduction of the pavement cure period.

2. Application Thickness

Pavement markings shall be installed at the following base line thicknesses measured above the pavement surface or above the groove bottom for grooved markings:

Table 8-20: Minimum thickness for MMA pavement markings

Type	Use	Method	Minimum base line thickness (mm)	
			On HMA/PCC	On BST
	Flat/transverse & symbols	Spray	3.0	3.0
	Flat/transverse & symbols	Extruded	3.0	3.0
	Flat/long line	Spray	2.3	3.0
	Flat/long line	Extruded	2.3	3.0
	Profiled/long line	Extruded	2.3	3.0
	Grooved/flat/long line	Extruded	5.8	5.8

Pavement marking material yield depending on thickness shall not exceed the following:

Table 8-21: Application rates for MMA material

Thickness (mm)	Liquid material yield (maximum)		Solid material yield (maximum)	
	Metres of 100 mm line/litre	M^2/litre	Metres of 100 mm line/23 kg bag	M^2/23 kg bag
2.3 flat	4.37	0.44	37.0	3.7
2.3 with profiles	2.44	0.24	20.7	2.1
3.0 flat	3.28	0.33	27.8	2.9
3.0 with profiles	1.35	0.13	17.9	1.8
5.8 grooved	1.71	0.17	14.5	1.4

Glass beads shall be applied immediately to the uncured MMA material, as part of the striping process.

h. Application of Epoxy

Heat the components A and B separately at 43 ±17º C and mix. Apply epoxy markings at 43 ±17º C (gun tip temperature). Discard all material heated over 60º C.

A manufacturer's technical representative shall supervise the initial installation of plastic material if so directed by the Engineer. Applications shall be done in accordance with the manufacturer's recommendations.

Types of epoxy markings shall be defined by the following application methods:

1. Type E1: Immediately apply type 1 glass beads on the epoxy
2. Type E2: Immediately apply type 2 glass beads on the epoxy, immediately followed by an application of type 1 glass beads.

If the epoxy does not dry within the manufacturer's recommended drying time, the components likely did not react properly and will not cure. In this case, the markings shall be removed per Article 8.2.3.7 and the road restriped.

1. Preparation of Roadway Surface

The Contractor shall meet the general requirements of Article 8.2.3.1. In addition:

i. Pavement surface temperature shall not exceed 82º C. Requirement may be superseded by manufacturer's written installation instructions.
ii. Pavement shall be free from existing pavement marking materials. Refer to Article 8.2.3.7 for applicable methods.
iii. Epoxies may be applied when pavement surfaces are slightly wet.
iv. Prior to application, complete pavement cure period of 21 days for bituminous asphalt.
v. Prior to application, complete pavement cure period of 28 days for Portland cement concrete.

2. Application Thickness and Application Rates

Minimum dry film thickness of epoxy material shall be 0.38 mm, and maximum rate of application shall be 2.6 m2/litre. Glass beads for reflectorized pavement markings shall be applied as follows:

Table 8-22: Epoxy type designations and glass bead application rates

Type	Minimum application rate (kg per litre of epoxy)	
	Type 1 glass beads	Type 2 glass beads
Type E1	1.8	none
Type E2	1.4	1.4

i. Application of Polyester

A manufacturer's technical representative shall supervise the initial installation of plastic material if so directed by the Engineer. Application shall be done in accordance with the manufacturer's recommended procedure.

Spray at 53 ±4º C (gun tip temperature). Discard all material heated over 66º C. Fast dry polyester markings shall not be used on asphalt pavements less than 1-year-old.

Types of polyester markings shall be defined by the following application methods:

1. Type P1: Immediately apply type 1 glass beads on the polyester
2. Type P2: Immediately apply type 2 glass beads on the polyester, immediately followed by an application of type 1 glass beads.

1. Preparation of Roadway Surface

The contractor shall meet the general requirements of Article 8.2.3.1. In addition:

i. Pavement surface temperature shall not exceed 82º C. Requirement may be superseded by manufacturer's written installation instructions if approved by the Engineer.

ii. Pavement shall be free from existing pavement marking materials. Refer to Article 8.2.3.7 for applicable methods.

2. Application Thickness and Application Rates

Minimum dry film thickness of polyester material shall be 0.38 mm, and maximum rate of application shall be 2.6 m^2/litre. Glass beads for reflectorized pavement markings shall be applied as follows:

Table 8-23: Minimum application rates for glass beads on polyester

Type	Minimum application rate (kg per litre of polyester)	
	Type 1 glass beads	Type 2 glass beads
Type P1	1.8	none
Type P2	1.4	1.4

j. Application of Preformed Plastic Tape and Symbols

Unless otherwise shown on the Contract plans, permanent preformed pavement markings shall only be used for symbols, transverse markings (e.g. cross-walks) and legends.

A manufacturer's technical representative shall be present at the initial installation of plastic material to supervise the installation procedure if so requested by the Engineer. Installation of the plastic material shall be done in accordance with the manufacturer's recommended procedure unless otherwise approved by the Engineer.

Where applied during final compaction of asphalt pavement, apply preformed plastic when the pavement temperature is about 60º C. Roll the marking into the surface with a steel wheel roller. The finished pavement marking may extend approximately 0.25 mm above the final surface.

1. Preparation of Roadway Surface

The contractor shall meet the general requirements of Article 8.2.3.1. In addition:

i. Pavement surface temperature shall not exceed 82º C. Requirement may be superseded by manufacturer's written installation instructions if approved by the Engineer.

ii. Pavement shall be free from existing pavement marking materials. Refer to Article 8.2.3.7 for applicable methods.

2. Application Thickness

Preformed plastic tape and symbols for transverse markings, legends and symbols shall be 2.3 mm thick for application on HMA or PCCP.

k. Marking Colours

Colours used for pavement marking shall be as indicated on the Contract plans. If not indicated on the Contract plans, then the colour shall be white, unless otherwise directed by the Engineer.

l. Patterns

Line patterns for pavement marking shall be as indicated on the Contract plans or as directed by the Engineer.

m. Line and Symbol Surfaces

Line and symbol surfaces shall be as indicated on the Contract plans. Acceptable types are:

1. Flat Line – Consists of a line or symbol with a flat surface.
2. Profiled Marking – Consists of a base line thickness and a profiled thickness which is a portion of the pavement marking line that is applied at a greater thickness than the base line thickness. Profiles shall be applied using the extruded method in the same application as the base line. The profiles may be slightly rounded provided the minimum profile thickness is provided for the length of the profile.
3. Embossed plastic line – Consists of a flat line with transverse grooves. An embossed plastic line may also have profiles.

8.2.3.4 Tolerances

Place markings in accordance with the colour, length width, shape, and configuration shown in the Contract plans. Pavement markings outside the stated tolerances shall be removed per Article 8.2.3.7 and reinstated or corrected at the expense of the Contractor.

Allowable tolerances are as follows:

1. Alignment of the edges of longitudinal lines shall be reasonably straight and shall not deviate from the alignment shown in the Contract plans or as directed by the Engineer by more than 50 mm in 100 m.
2. Longitudinal lines shall be offset at least 100 mm from construction joints unless directed otherwise by the Engineer.
3. Position of lines, letters, figures, arrows, and other markings shall not deviate from the position shown on the Contract plans or directed by the Engineer by more than 100 mm in the longitudinal and 20 mm in the transverse direction.

4. Longitudinal accumulative error within a 12 m length of skip line shall not exceed plus or minus 12 mm.
5. Width of lines and other markings shall not be less than the specified width. Actual width of stripe shall be within the limits specified in the following table, according to the width of stripe called for on the Contract plans:

Table 8-24: Line width tolerances

Plan Width	Actual Width
100 mm	100 to 115 mm
150 mm	150 to 170 mm
200 mm	200 to 225 mm
Over 200 mm	+25 mm

6. Lane width, which is defined as the lateral width from the edge of pavement to the centre of the lane line or between the centres of successive lane lines, shall not vary from the widths shown in the Contract by more than plus or minus 100 mm.
7. Pavement markings shall not be less than the specified thickness. A thickness tolerance not exceeding plus 10 % will be allowed for thickness or yield in paint and plastic material application.
8. Gap tolerance between parallel lines is 12 mm.
9. Length of segments of broken longitudinal lines shall not deviate by more than 150 mm from the specified length.

8.2.3.5 Criteria for Acceptance of New Striping Installations

Striping shall meet the tolerance limits defined in Article 8.2.3.4.

Pavement markings shall exhibit uniform retroreflectance that makes the entire surface of the pavement marking stripe appear to glow, regardless of the observation distance, from immediately in front of the test vehicle to the effective distance of the headlights on high beam. Evaluate during hours of darkness when headlights are necessary for roadway visibility and the road surface is free of moisture. Vehicle shall travel in the proper lane and direction of travel, parallel to the pavement marking stripe to be observed, aligned so that the front fender intersects the driver’s line of sight to the stripe.

Pavement markings that exhibit alternating bright, dim, or dark bars or areas across the stripe; dark or nonreflecting lines or strips parallel to the length of the stripe; or dark and nonreflecting sections, shall be unacceptable. Contractor shall replace rejected markings at the Contractor’s expense.

During daytime, 10 or more skip stripes, or approximately 120 m of stripe, shall be distinctly visible in contrast to the pavement surface when observed in an area relatively free of vertical curvature.

All permanent pavement markings shall perform to the following standards for at least 15 calendar days after installation. Within 30 days of notification the Contractor shall remove and replace pavement markings that fail to meet requirements, at the Contractor’s expense.

1. Markings shall not lift, shift, smear, spread, flow, or tear by traffic action.
2. Markings shall present a neat, uniform appearance that is free of excessive adhesive, ragged edges, and irregular lines or contours.
3. Markings shall have uniform and distinctive reflectance when inspected in accordance with this section of the Specifications.

8.2.3.6 Restripe

Restriping operations shall be performed in conformance with these Specifications for preparation of roadway surfaces, materials, and application of permanent pavement marking material. Specifically, existing pavement markings shall be removed per Article 8.2.3.7 to facilitate good bonding of the restripe material to the pavement.

Restriping shall be carried out in accordance with the Contract plans or as designated by the Engineer and any roadway surface preparation or traffic control necessary for the operation shall be considered part of the restriping work with no additional measurement or payment.

8.2.3.7 Removal of Pavement Markings

Pavement markings to be removed shall be obliterated until blemishes caused by the pavement marking removal conform to the colouration of the adjacent pavement.

If, in the opinion of the Engineer, the pavement is materially damaged by pavement marking removal, such damage shall be repaired by the Contractor at the Contractor's expense. Sand or other material deposited on the pavement as a result of removing lines and markings shall be removed as the Work progresses to avoid hazardous conditions.

Contaminants and existing pavement markings shall be removed from surfaces where the pavement marking is to be applied by approved mechanical means: watering, sand blasting, burning, brooming or compressed air if required. Contractor shall avoid damaging the pavement surface.

Use of black paint or chemical paint remover to obliterate existing markings will not be permitted, except where it is ordered by the Engineer as a temporary measure.

All tracking marks, spilled marking material, markings in unauthorized areas, and defective markings, and all conflicting pavement markings, shall be removed prior to application of new pavement markings.

8.3 Temporary Pavement Marking

8.3.1 Description

This Specification covers furnishing and installing temporary pavement markings. Temporary pavement markings shall be provided where noted in the Contract plans and for all lane shifts and detours resulting from construction activities.

Unless otherwise shown on the Contract plans or required by the Engineer, temporary pavement markings shall be yellow in color.

Temporary pavement markings shall be provided when permanent markings are eliminated because of construction operations. Temporary pavement markings shall be maintained in serviceable condition throughout the project until permanent pavement markings are installed.

Temporary pavement markings that are damaged shall be repaired or replaced immediately. Temporary markings that are, in the opinion of the Engineer, damaged by traffic, shall be replaced. Any temporary line marked with tape shall be repaired immediately when it no longer provides the intended use.

8.3.2 Materials

Materials for temporary markings shall be one of the following as shown on the Contract plans or as directed by the Engineer:

1. Alkyd Paint
2. Preformed plastic tape
3. Temporary flexible reflective tabs

4. Acrylic Waterborne Paint

8.3.2.1 Alkyd Resin

Alkyd resin paint shall conform to the requirements of alkyd resin for permanent markings as described in Article 8.2.2.7.

8.3.2.2 Preformed Plastic Tape and Symbols - Type 3 (Temporary - removable)

Type 3 shall be a removable preformed retro reflective pavement marking capable of performing for the duration of a normal construction season. A reflective layer of glass beads shall be bonded to the top surface. Glass beads shall meet the criteria in Article 8.2.2.11.

Material shall be a nonmetallic mixture of high quality material and shall be capable of being removed intact or in large pieces either manually or with a recommended roll up device without the use of heat, solvents, grinding, or sand blasting.

Markings shall be precoated with a pressure sensitive adhesive capable of adhering to roadway surfaces without the use of heat, solvents or other additional adhesives.

When extruded, pavement marking material without adhesive shall be a minimum of 1.1 mm thick. New material shall be of good appearance, free from cracks, and edges, shall be true, straight, and unbroken.

8.3.2.3 Preformed Plastic Tape and Symbols - Type 4 (Temporary - nonremovable)

Type 4 shall be nonremovable preformed retroreflective film on a conformable metallic backing capable of performing for the duration of a normal construction season.

A reflective layer of glass beads shall be bonded to the top surface. Glass beads shall meet the criteria in Article 8.2.2.11.

Markings shall be precoated with a pressure sensitive adhesive capable of adhering to roadway surfaces without the use of heat, solvents or other additional adhesives.

8.3.2.4 Temporary Flexible Reflective Tabs

Temporary flexible reflective tab pavement markers shall consist of an L-shaped marker body with retroreflective tape on both faces of the vertical section, capable of retroreflecting light from opposite directions, with an adhesive on the base. Temporary flexible reflective tabs shall be one of the following types:

1. Type Y—yellow marker with amber reflective area on both sides
2. Type W—white marker with white or silver reflective area on both sides

Marker body shall be fabricated from 1.5 mm minimum thickness polyurethane, polyester elastomer, or other approved material. Vertical leg shall measure 51 to 76 mm high by 100 ±3 mm wide. Base leg shall measure 25 to 64 mm wide. A pressure sensitive adhesive with minimum dimensions of 3 mm thick by 19 mm wide by 100 mm long shall be factory applied to the marker base and protected with release paper.

Reflective material shall not exceed 25 mm in width and be the approximate length of the vertical wall. Reflective material must be protected with an easily removable cover of heat resistant material capable of withstanding and protecting the reflective material from the application of 204° C asphalt. Stapling or clipping devices used to retain the protective cover must not protrude through the reflective material.

Variations in design and dimensions to meet manufacturer's standards shall be permitted with the approval of the Engineer.

Vertical wall of the tabs must be sufficiently flexible to bend under normal traffic and sufficiently resistant to permanent deformation to pass the road test listed below.

Table 8-25 Temporary flexible reflective tab pavement marker road test

Step	Requirement
1	Affix the tab to the pavement before the road test by positioning by hand, stepping on it with one foot, and placing all the body weight on the one foot. The individual placing the marker will weigh a minimum of 61 kg. Road test procedure:
2	Affix five tabs at 610 mm intervals on an asphaltic pavement in a straight line.
3	Using a medium size sedan, run over the tabs with front and rear wheels at a speed of 56 to 64 kph, four times in each direction.
4	Remove the reflective surface protective cover and run over the tabs again at 56 to 64 kph four times in each direction.
Acceptance criteria	Tabs will be considered sufficiently flexible and resistant to deformation if after the road test all tabs are intact, the reflective material is still adhered to the vertical wall and exhibits no apparent visual damage, and the top of the vertical wall is within 30° of the vertical line through the base of the vertical wall. Tabs must adhere to the pavement such that no tab dislodges.

Minimum coefficient of retroreflection shall be 1.2 mcd/lux/m^2 at 0.1^o observation angle and -4^o entrance angle.

Package tabs such that the vertical wall will not take a permanent set in excess of 15° from true vertical with respect to the base plane.

8.3.2.5 Acrylic Resin

Acrylic resin paint shall be ready-mixed, one-component, 100% acrylic waterborne paint conforming to the requirements of US Federal Specifications TT-P-1952F or other similar international standard.

8.3.3 Construction Requirements

8.3.3.1 Preliminary Layout

All preliminary layout and marking in preparation for application shall be the responsibility of the Contractor. Preliminary layout shall be done in accordance with Article 8.2.3.2.

8.3.3.2 Marking Application

Temporary flexible raised pavement markers are required for bituminous surface treatment operations.

Markings shall be installed so they are visible from a distance of at least 100 m in daylight conditions and from a distance of at least 50 m in nighttime conditions, illuminated by automobile low-beam headlight. Determine visibility distances using an automobile traveling on the roadway under dry conditions.

Temporary pavement markings consisting of paint or tape may be paved over, but temporary raised pavement markers or removable tape shall be removed prior to paving.

Any temporary pavement markings that are required on the wearing course prior to construction of permanent pavement markings and are not a part of the permanent markings shall be completely removed concurrent with or immediately subsequent to the construction of the permanent pavement markings.

Temporary flexible raised pavement markers on bituminous surface treatment pavements shall be cut off flush with the surface if their location conflicts with the alignment of the permanent pavement markings.

All damage to the permanent Work caused by removing temporary pavement markings shall be repaired by the Contractor at the Contractor's expense.

a. Temporary Pavement Marking Paint

Paint for temporary striping, arrows, symbols and legends shall be applied per the requirements for permanent striping paint as set forth in Sub-article e of Article 8.2.3.3 and as approved by the Engineer.

Paint for temporary symbols and legends shall be white or yellow as shown on the Contract plans or approved by the Engineer.

Alkyd resin or acrylic waterborne resin shall be applied in one application at a thickness of 0.38 mm

b. Preformed Plastic Tape Types 3 and 4

Type 3 shall be used on finished pavement surfaces where traffic control or channelization through the construction zone is temporary requiring removal prior to final pavement markings.

Type 4 shall be used in construction zones where removal is unnecessary due to placement of future paving courses or where pavement will be removed, obliterated or abandoned at the completion of the project.

Newly applied markings shall be capable of being immediately exposed to traffic without pickup or distortion by vehicles. Markings shall be weather resistant and through normal traffic wear shall show no appreciable fading, lifting, shrinkage, tearing, roll back, or other signs of poor adhesion throughout the useful life of the marking.

Damaged or missing temporary pavement markings shall be replaced immediately at the Contractor's expense.

c. Temporary Flexible Reflective Tabs

Newly applied markings shall be capable of being immediately exposed to traffic without pickup or distortion by vehicles.

Damaged or missing temporary pavement markings shall be replaced immediately at the Contractor's expense.

8.4 Raised Pavement Markers

8.4.1 Description

Raised pavement markers (RPMs) shall comply with the dimensions and shapes indicated on the Contract plans and shall be installed at the locations shown on the Contract plans or where designated by the Engineer.

Longitudinal markings shall be supplemented with RPMs as indicated on the Contract plans.

8.4.2 Materials

8.4.2.1 Packaging and Marking

Shipments shall be packaged in such a manner as to ensure delivery in perfect condition. Damaged shipments shall be replaced by the Contractor at the Contractor's expense. Each package shall be clearly marked as to the name of the manufacturer, type of marker, colour, quantity enclosed, lot number, and date of manufacture. All markers on any one project shall be supplied by the same manufacturer.

8.4.2.2 Submittals

A minimum of 10 days prior to installation in the permanent works, Contractor shall provide sufficient samples of the RPMs and adhesive to complete the testing required by these specifications.

Contractor shall furnish manufacturer's data sheets and application recommendations.

8.4.2.3 Non-reflective Raised Pavement Markers (Type NR)

Non-reflective (Type NR) raised pavement markers (RPMs) shall consist of a heat-fired, vitreous, ceramic base measuring 102 mm in diameter with a heat-fired, opaque, smooth matte surface.

Base of the RPM shall be free from glaze and substances which may reduce its bond to the adhesive. Base shall be flat, and its deviation from a flat surface shall not exceed 1.3 mm. Type NR RPMs shall be precast in the form of a single base, convex, spheroid terminating in a rounded or squared shoulder where the spherical top meets the base. Top radius of curvature shall be between 90 mm and 150 mm, except that the radius of the 13 mm nearest the edge may be less.

Type NR RPMs shall be produced from any suitable combination of intimately mixed clays, shales, talcs, flints, feldspars, or other inorganic material which will meet the properties herein required. Type NR RPMs shall be of uniform composition, thoroughly and evenly matured. They shall be free of defects that affect appearance, application or durability, including surface irregularities, cracks, checks, chipping, peeling, spalling, crazing, or other physical damage. Type NR RPMs shall meet the following requirements:

Table 8-26: Properties of Type NR RPMs

Property	Value
Weight	125 g minimum
Height	16.5-19.8 mm
Diameter	97.8-102.9 mm
Shoulder height	2-3.6 mm
Planeness of base: Concavity Convexity	 1.27 mm maximum 1.27 mm maximum
Color	White, unless otherwise indicated on the Contract plans or directed by the Engineer
Glaze thickness	127 mm minimum
Moh's hardness	6 minimum
Directional reflectance (white): Glazed surface Body of marker	 75 70 minimum
Yellowness index (white): Glazed surface Body of marker	 0.07 maximum 0.12 maximum
Strength	310.14 kg/cm^2 minimum
Water absorption	2.0 % by weight maximum
Bond strength	49.21 kg/cm^2 minimum

8.4.2.4 Reflective Raised Pavement Markers (Type CR, Type YR, Type YY)

Reflective raised pavement markers (RPMs) shall consist of an ASTM B85, alloy No. 380 aluminum alloy shell containing two prismatic reflective faces, oriented 180° to each other, and a base with an integral stud in the center that is designed to secure the casting to the road. Reflective RPMs are identified by type as follows:

Table 8-27: Reflective RPM types

Item	Reflective color	Opposite face reflective color	Body color	Intent
Type CR	White (clear)	Red	White or silver-white	Channelizing traffic- or edge lines, 2-way
Type YR, CR	Yellow or white (clear)	Red	Yellow or white or silver white	Edge lines, 2-way
Type YY	Yellow	Yellow	Yellow	Centre lines, 2-way
Type C/-; Y/-	White (clear) /yellow	Nil	White or silver white or yellow	Lane lines/edge lines 1-way

Note that colours used per location shall be as shown on the Contract plans or directed by the Engineer

Reflective RPMs shall be in the shape of a shallow frustum of a pyramid with dimensions as shown in Figure 8-1. Alternatively, RPMs shall have dimensions of 115mm x 115mm. Corners and edges exposed to traffic shall be rounded. Standard stud length allows installation of the RPM on bridge decks with 50 mm asphaltic concrete overlays. Longer studs may be used with the Engineer's written approval. Slope of the reflective faces shall be 30^{o} from the horizontal. Each reflective surface shall have a minimum area of 1440 mm^2.

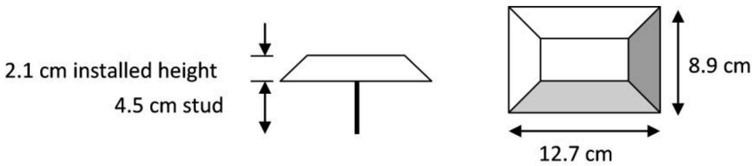

Figure 8-1: Reflective raised pavement marker dimensions

Base of the RPM shall be free of scale, dirt, rust, oil, grease or any other contaminant which may reduce its bond to the epoxy adhesive. Base shall be flat, and its deviation from a flat surface shall not exceed 1.3 mm.

Surfaces other than the base shall be smooth except for the manufacturer's unique imprint. Reflective faces shall be molded of methyl methacrylate (MMA) or acrylonitrile butadiene styrene (ABS) in the colours specified on the Contract plans, with a thin untempered glass bonded to the prismatic reflective face.

RPM studs (stems) shall consist of an anti-twist type to help resist displacement where used on high-speed roadways having traffic speeds of 80 kph or more, as approved by the Engineer

Body core material other than the reflective faces shall be as approved by the Engineer, typically a mixture of an inert thermosetting compound and filler material.

a. Optical Performance

A sample of five markers shall be tested in accordance with ASTM E1347 except that the test area shall be 50 mm in diameter and no more than 3 mm of the curved surface shall protrude into the measuring apparatus.

For any one marker, the glazed surface shall have a daylight directional reflectance of not less than 75 %.

b. Test for Strength

Strength by compressive loading shall be at least 9.0 kN. Strength shall be evaluated in the following manner:

An RPM shall be centered over the open end of a vertically positioned hollow metal cylinder that measures 25.4 mm high with an internal diameter of 76.2 mm and wall thickness of 6.35 mm. Load shall be slowly applied to the top of the RPM through a 25.4 mm diameter by 25.4 mm high metal plug centered on the top of the RPM.

Failure shall constitute either a breakage or significant deformation of the marker at any load of less than 9.0 kN.

8.4.2.5 LED Raised Pavement Markers

a. Description

This Item will govern for the furnishing and installation of raised pavement markers that contain LED lights, powered either by external power source and permanent wiring or by internal rechargeable battery or capacitor with electronics inside the markers that monitor ambient light levels and activate the LED’s when the light drops below pre-set levels.

b. Materials

Contractor shall provide LED raised pavement markers that meet the requirements of Article 8.4.2.4, with the following additional requirements for solar powered LEDs:

1. Furnish markers that maintain an adequate charge for a full duty cycle. The markers will recharge by sunlight, lower level light, and from other light sources such as vehicle headlights.
2. Provide markers that are backed by a one year warranty (18 months on capacitor powered) and have a service life up to 7 years.
3. Furnish markers that use photovoltaic LED technology.
4. Furnish markers with a PVC coated aluminium housing material.
5. Provide markers with reflectors that are corner cube, Polycarbonate lens with a colour as shown on the Contract plans or as directed by the Engineer.
6. Furnish markers that are unidirectional with 2 white or coloured LED’s built into the marker. LED type will be 5000 mcd/LED with an output frequency of steady. Colour shall be as shown on the Contract plans or as directed by the Engineer.
7. Provide markers with visibility of 1,000 m. With activation that is photo sensor.
8. Furnish markers that use NiMH (nickel-metal hydride) batteries or capacitor for electrical storage. Output on full charge shall be 96 hours.
9. Provide markers that have a manufacturer’s warranty of 1 year (battery) and a 1.5 year (capacitor).
10. Furnish markers that are tested ASTM D4280.

Prior to RPM delivery to site and installation, Contractor shall also provide the following for approval by the Engineer:

1. Written details of the adhesive proposed for fixing the markers to the pavement surface together with the method of handling, mixing, application and other relevant procedures.
2. Written confirmation from the adhesive manufacturer that it is suitable for long term fixing of markers to road pavements.

Should an adhesive prove clearly unacceptable for long term fixing of markers to a pavement surface the Engineer may withdraw the approval and require the Contractor to obtain approval for an alternative adhesive with a proven record of use. Adhesive and method of use shall not be changed without the approval of the Engineer.

8.4.2.6 Epoxy Adhesive for Raised Pavement Markers

Epoxy adhesive for securing raised pavement markers (RPMs) to the road shall be furnished in two separate components for combining in equal volumes immediately prior to use.

Adhesive for RPMs shall conform to AASHTO M 237 for Types I, II or III as follows:

1. Type I—Rapid setting, high viscosity, epoxy adhesive. This type of adhesive provides rapid adherence of traffic markers to the surface of the pavement.
2. Type II—Standard setting, high viscosity, epoxy adhesive. This type of adhesive is recommended for adherence of traffic markers to pavement surfaces when rapid set is not required. This type shall be used, unless directed otherwise by the Engineer.
3. Type III—Rapid setting, low viscosity, water resistant, epoxy adhesive. This type of rapid setting adhesive, due to its low viscosity, is appropriate only for use with embedded traffic markers. It is more water-resistant than Type I or Type II.

Adhesive for RPM application shall comply with the material requirements of AASHTO M 237, which details the following for each type:

1. Chemical composition of component A and component B by mass
2. Physical requirements of the individual components
3. Physical requirements for the mixed epoxy (component A mixed with component B)
4. Certificate of compliance requirements
5. Test methods
6. Recommended practice

In lieu of the square base test specimen molds for the slant shear strength test specified in AASHTO M 237, cylindrical molds in accordance with ASTM C882M may be used.

Acceptance of each lot will be based on a manufacturer’s certificate of compliance. Entire lot of both components may be rejected if samples submitted for test fail to meet any requirements of this Specification.

a. Packaging and Marking

Components of epoxy adhesive for RPMs shall be supplied in separate containers that are non-reactive with the materials contained. Contents of each container shall be such that when the container contents are combined, a properly proportioned final mixture results.

Containers shall be identified as “Component A” (contains the epoxy resin) and “Component B” (contains the curing agent) and shall show the mixing directions. Each container shall be marked with the name of the manufacturer, the lot or batch number, the date of packaging, and the weight or volume of the quantity contained.

Every shipment shall include a statement of the proper type of dispensing equipment to be used, weather conditions during application that are detrimental to material performance, and materials safety data sheets.

8.4.2.7 Flexible Bituminous Adhesive for Raised Pavement Markers

Flexible bituminous adhesive shall be used only with imbedded stem type markers and shall be a hot melt thermoplastic bituminous material used for bonding items to pavement. Material shall conform to the following requirements:

Table 8-28: Properties of flexible bituminous adhesive

Property	Test Method	Requirement
Penetration, 25^o C, 100 g, 5 sec, mm	AASHTO T 49	30 max
Softening Point, C	AASHTO T 53	93.3 min
Rotational thermoset viscosity, mPa·s, #27 spindle, 20 RPM, 204^o C	AASHTO T 316	5000 max
Ductility, 25^o C, 5 cm/minute, cm	AASHTO T 51	15 min
Ductility, 4^o C, 1 cm/minute, cm	AASHTO D51	5 min
Flexibility, 2.5 cm, -6.7^o C, 90^o bend, 10 seconds, 0.32 cm × 2.5 cm × 15 cm specimen	ASTM D3111 *	Pass
*Flexibility test is modified by bending specimen through an arc of 90^o at a uniform rate in 10 seconds over a 2.5 cm diameter mandrel.		

Flexible bituminous adhesive shall develop bond pull-off strength greater than 345 kPa when tested in accordance with the following procedures:

Materials and apparatus required to perform the test shall be:

1. Commercially available Portland cement mortar block measuring 20 cm x 45 cm x 5 cm with a compressive strength of 20 to 35 mPa, conditioned for 24 hours at standard laboratory conditions prior to test.
2. Gyratory compacted asphalt concrete puck measuring 15 cm in diameter conditioned for 24 hours at standard laboratory conditions prior to test.
3. Type NR RPM, drilled in the center to accept a threaded steel rod. RPMs shall be from at least two different manufacturers with different patterns on the bottom of the markers.
4. Laboratory melter as described in ASTM D5167
5. Drill press with bit sized for the threaded rods described below.
6. Threaded steel eye bolt for attaching to the RPM.
7. Tensile testing apparatus as described in AASHTO T 237 Section 13, fitted with a threaded steel rod with a 5 cm hook.

Procedure shall be completed as follows:

1. Pull-off tests shall be run in triplicate.
2. Adhesive shall be heated in the laboratory melter to the manufacturer's recommended application temperature.
3. A quantity of adhesive sufficient to squeeze out a small bead around the entire periphery of a 100 mm RPM shall be poured onto a Portland cement mortar block or asphalt concrete puck. A predrilled RPM shall be seated on the adhesive and allowed to cure for at least 4 hours.
4. A threaded steel eye bolt shall be inserted into the predrilled hole in the RPM.
5. Block, or puck, and RPM shall be placed in the tensile testing apparatus and the threaded hook shall be inserted in the eye bolt.
6. Load shall be applied slowly until failure and the maximum load shall be recorded.

Pull-off strength shall be calculated as follows:

$$S = L/A$$

S = Pull-off Strength, kpa

L = Maximum Load, kN

A = Surface Area of RPM (m2)

Equation 8-1 Pull-off strength

Pull-off strength reported shall be the average of the three determinations on a Portland cement mortar block unless otherwise specified. Results are applicable for Portland cement concrete pavement as well as bituminous asphalt concrete pavement.

8.4.3 Construction Requirements

RPM installation shall be done in accordance with the manufacturer's recommendations and as per the Contractor's approved method statement.

Mark locations for each RPM as shown on the Contract plans or as directed by the Engineer. Lateral location of RPMs shall be established with guide marks that conform to Article 8.2.3.2. Guide marks shall not be permanent marks on the roadway. Any RPMs placed out of alignment or sequence shall be removed and replaced in the proper alignment at the Contractor's expense.

After installation, RPMs shall be firmly bonded to the pavement. Lines formed by the RPMs shall be true and the entire installation shall present a neat appearance.

8.4.3.1 Surface Preparation

Pavement surface shall be prepared in accordance with Article 8.2.3.1 and as specified below:

a. All sand, dirt and loose extraneous material shall be swept or blown away from the RPM location and the cleaned surface prepared by one of the following procedures:
    1. Pavement surface shall be heated by intense radiant heat (not direct flame) for a sufficient length of time to char extraneous, organic surface contaminants but not to exceed 1½ minutes.
    2. Pavement surface shall be sandblasted for a sufficient length of time to remove all surface contaminants and unsound particles but not so long as to expose buried aggregate. A hot air blast shall be used to remove loose sand and dirt from the blasted areas and ensure that the surface is completely dry.
b. When RPMs are placed on new cement concrete pavement, any curing compound shall be removed
c. Newly placed asphaltic concrete pavement need not be sandblasted unless, in the opinion of the Engineer, the surface is contaminated with materials that would adversely affect the bond of the adhesive.
d. RPMs shall be placed on new asphaltic concrete only after the new surface has aged at least 14 days, unless a longer period is required by the adhesive manufacturer.
e. RPMs shall be installed on dry pavement. RPMs shall not be installed when the relative humidity is 80 % or higher, or when the pavement is not surface dry.

8.4.3.2 RPM Preparation

RPMs shall be free of rust, scale, dirt, oil, grease, moisture, and contaminants that might adversely affect the adhesive bond.

Resin-rich, waxy or greasy surface that characterizes RPMs, is not satisfactory as a bonding surface. A satisfactory bonding surface may be secured by sanding off the bottom of the marker, or by structurally bonding a layer of glass beads or sand into the bottom surface during manufacture.

When it is necessary for the adhesive to achieve the minimum bonding strength within 15 minutes, RPMs shall be preheated as described in Article 8.4.3.4.

8.4.3.3 Epoxy Adhesive Preparation

Heat epoxy components A and B separately with indirect heat, mix, and apply at 21º ±6º C. Discard all material heated over 49º C or stiffened by polymerization.

Epoxy adhesive shall be maintained at a temperature of 15° to 29° C before use and during application.

Catalyst shall be added to the base just before the use and mixed to a smooth, uniform blend. Unused mixed adhesive shall be discarded when catalytic action has caused stiffening and reduction of workability or a small ball of jelled resin has formed in the center of the container.

Any voids in the base of the marker shall be filled with adhesive before placing the marker on the road surface unless approval has been obtained from the Engineer to an amended procedure. Generally, the Engineer will require a written recommendation from the marker manufacturer to justify the amended procedure.

Excess adhesive shall be placed on the marker or the road surface such that after placing the marker on the road surface the following requirements are met:

- There are no voids in the adhesive beneath the marker;
- A small bead of adhesive has exuded from the full perimeter of the marker base; should the bead of adhesive rise above the base of the marker on any edge beneath reflective elements the excess adhesive shall be removed;
- Any adhesive on the body or lens of the marker shall be removed without damaging the marker;

Where stem type markers are installed the hole to accommodate the stem shall be filled with the same adhesive used to fix the marker to the pavement.

a. **Application Procedure with Epoxy Adhesives**

RPMs shall be of the type indicated on the Contract plans and shall be fixed in the positions approved by the engineer.

Contractor shall protect RPMs against impact until the adhesive has hardened. A displacement of not more than one centimeter, left or right of the established guide line will be permitted. Contractor shall remove and replace at the Contractor's own expense all improperly placed markers.

Reflective RPMs shall be installed in such a manner that the reflective face of the marker is perpendicular to a line parallel to the roadway center line. No pavement markers shall be installed over longitudinal or transverse joints of the pavement surface.

Adhesive shall be machine-mixed and applied in accordance with the manufacturer's recommendations.

1. Standard Adhesive Set: On roadway sections that are not open to public traffic, it shall not be necessary to preheat the markers provided the adhesive develops the required bond strength of 124 gm/ cm^2 in less than 3 hours.
2. Rapid Adhesive Set: On roadway sections that are open to public traffic, the Contractor shall preheat the roadway surface and the markers so as to insure the bonding of the marker in not more than 15 minutes. Bonding will be considered satisfactory by the Engineer when adhesive develops a minimum bond strength in tension of not less than 124 gm/cm^2 within 15 minutes.

RPMs whose surfaces have been prepared by sanding or structural bonding beads may be preheated in either the fluid heating bath or a dry oven controlled between 135° C and 150° C for not less than 10 minutes before setting.

Adhesive shall be applied to the prepared pavement area to be covered by the RPM and the RPM immediately pressed into place so as to squeeze out a small bead of adhesive around the entire periphery of the marker, ensuring that the full base of each RPM is seated on a continuous layer of adhesive. Required amount of adhesive per marker will typically be in the range of 20 to 40 g.

Sequence of operations shall be as rapid as possible to ensure proper bonding. Adhesive shall be in place and the RPM seated in not more than 30 seconds after the removal of the pavement preheat or warm air blast. RPM itself shall not have cooled more than one minute before seating. Length of the pavement preheat or warming shall be adjusted so as to ensure bonding of the marker in not more than 15 minutes.

No adhesives or other materials that impair the functional retro-reflectivity of the reflective RPMs shall be used. Any excess adhesive on the pavement or the exposed surfaces of the RPMs shall be immediately removed. Thinners or solvents which may be detrimental to either the RPMs or the bond provided by the adhesive shall not be used in removing excess adhesive.

b. Application Procedure with Hot Bitumen Adhesive

Hot bituminous adhesive shall be used only for stem type markers. Bituminous adhesive shall be applied at temperatures recommended by the manufacturer.

Apply hot melt bituminous adhesive where marker is to be placed. Markers shall be placed immediately after application of the adhesive. Place marker on the spot desired and apply pressure for five (5) seconds.

Traffic must not be allowed to run over markers until adhesive has cooled.

8.4.3.4 Recessed Raised Pavement Marker

Recessed raised pavement markers, when specified, shall be installed at the locations shown on the Contract plans. All recessed RPMs shall have an abrasion resistant coating. Contractor shall prepare the surface in and install RPMs in the recess in accordance with Article 8.4.3.1.

Contractor shall construct recesses for RPMs by grinding the pavement at a 40:1 slope in accordance with the dimensions shown in Figure **8-2**. Taper lengths will be approximately 95 to 110 mm in length at a 40:1 slope.

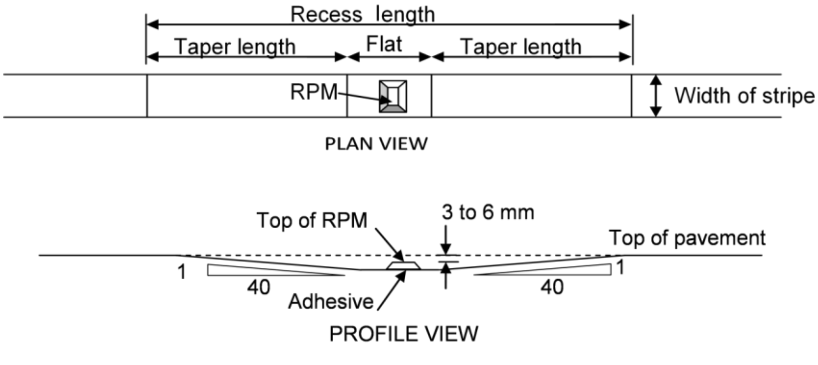

Figure 8-2 Recessed RPM configuration

8.4.4 Flexible Guide Posts

8.4.4.1 Description

This Work shall consist of furnishing and placing flexible guide posts of the type in accordance with these Specifications and the Contract plans, at the locations shown on the Contract plans or where designated by the Engineer.

8.4.4.2 Materials

Flexible guide posts shall be made of a flexible, nonwarping, nonmetallic, durable plastic material; shall be resistant to damage due to impact, ultraviolet light, ozone, hydrocarbons, and other effects of atmospheric weathering; shall resist stiffening with age; and shall exhibit good workmanship and be free of burns, discolouration, contamination and other objectionable marks or defects that affect appearance or serviceability.

Portion of ground mounted guide post installed below ground may be the same material as the portion above ground or other durable material suitable for firmly anchoring the post in the ground. When iron or steel are used for the in ground portion, they shall be galvanized in accordance with AASHTO M 111.

Top of tubular posts shall be closed to prevent moisture or debris from entering. Surface mounted guide posts shall be mounted on a base made of a rigid high impact resistant material and be resistant to ultraviolet light, ozone, and hydrocarbons. Post shall mount directly into or onto the base in a tamper proof manner and shall allow for easy replacement. Guardrail mounted guide posts shall be the same as ground mounted guide posts except the length shall be adjusted to meet the mounting height requirements in the Contract plans. Appropriate holes shall be provided for fastening the guide post to the guard rail post.

Material composition of flexible guide posts subsequently furnished shall not vary from that of the samples upon which approval is based. If analysis reveals there is a change in material composition, such change shall constitute grounds for rejection.

Post system shall be designed for permanent installation to resist overturning, twisting, and displacement from wind and impact forces. Each flexible guide post shall be permanently identified with the manufacturer’s name, and the month and year of fabrication. Ground mounted guide posts shall have a permanent a mark indicating the recommended burial depth. Letters shall be solvent resistant, a minimum of 6 mm in height, and permanently affixed to the post.

Unless otherwise specified on the Contract plans, the colour of the guide post shall be white.

a. Dimensions

Guide posts shall have the following dimensions:

1. Flat type – Minimum post width shall be 75 mm of continuous flat surface with no curvature for the entire length of the post. This will allow for ridges on the outer edges and back of post intended for structural support.
2. Tubular type – Post is tubular or round/circular in shape. This allows for a tubular post with a minimum diameter of 75 mm or a tubular post with a minimum diameter of 50 mm with a flat or flattened oval surface at least 75 mm wide and 305 mm long measured from the top for mounting reflective sheeting.
3. Non-flat and non-tubular type – Posts that do not fit into the two types indicated above, including convex, w-shape, oval, and other designs. Post shall be wide enough to accept 75 mm wide reflective sheeting. Any curvature or rounding shall not significantly reduce the brightness value of the reflective sheeting.
4. Surface mount guide post base – Base for surface mount guide posts shall be approximately 200 mm in diameter with a maximum height of 50 mm.

Guide posts shall be of such length to provide the required mounting height above the pavement surface in accordance with Contract plans.

b. Reflective Sheeting

Reflective sheeting for guide posts shall be Type III or IV conforming to Sub-article (b)of Article 8.5.3.4.

Reflective panel on a flat or elliptical guidepost shall have a minimum width of 7.5 cm facing traffic. Reflective sheeting shall have a minimum area of 155 cm^2. Reflective panel on a round guidepost shall have a 200 mm minimum band of reflective sheeting visible for 360°. Reflective sheeting shall be mounted on the guide post as detailed in the Contract plans.

Sheeting shall remain in place during the life of the post.

c. Adhesive

Adhesives for surface mounted guide posts shall meet the requirements for flexible bituminous adhesive or epoxy adhesive as defined in Articles 8.4.2.5 and 8.4.2.7.

d. Acceptance of Flexible Guide Posts

Flexible guide posts and reflective sheeting shall be approved by the Engineer prior to use on the works. No rejected material shall be incorporated into the works.

Contractor shall submit manufacturer's certified test report, including test data developed by an approved testing laboratory, which demonstrates that the flexible guide post complies with the requirements of these specifications. At the request of the Engineer, the Contractor shall perform tests to verify compliance with these specifications. Results of the testing shall be reported in sufficient detail to enable the Engineer to evaluate compliance with these specifications.

1. Test Procedures (Laboratory Tests)

Sample size: 2 posts. Procedures shall be performed as follows:

i. Test for tensile strength and elongation per ASTM D638;

ii. Expose to 1,000 hours QUV weatherometer exposure (ASTM G154);

iii. Test again after exposure for tensile strength and elongation per ASTM D638;

iv. Prepare 6 bow tie specimens from the delineator post samples submitted for the purpose of ultraviolet (UV) exposure;

v. Cycle specimens at 1,000 hours in a weatherometer in accordance with ASTM G154 (3 hr. 60C UV, 3 hr. 50C CON);

vi. Reserve 3 specimens as controls;

vii. Subject remaining 3 specimens to 1000 hours of UV exposure in the QUV weatherometer.

Laboratory test data shall include the following:

i. Tensile strength and elongation of each specimen;

ii. Average tensile strength and elongation for control specimens;

iii. Average tensile strength and elongation weathered specimens.

iv. Percent change in tensile strength (based on average values);

v. Percent change in elongation (based on average values).

Acceptable specimens shall show no signs of delamination, distress, or discolouration. Physical properties of tensile strength and rigidity shall be maintained within 80 % of the unconditioned values.

2. Field Impact Test Procedure

This testing shall be conducted by the manufacturer, and included in the manufacturer's certificate of conformance documentation that is provided by the Contractor to the Engineer for approval. This testing may be witnessed at the manufacturer's location by the Engineer/Owner, or conducted by the Contractor on site, if so requested by the Engineer.

Sample size: 8 posts

Test vehicle: a standard sedan with a bumper height of approximately 45 cm traveling at a speed of 88 kph ±3 kph.

Test for field impacts shall be performed per the following procedure once for flexible ground mounted posts and separately for flexible surface mounted posts:

i. At least 8 hours prior to testing, install 4 posts manually and 4 posts mechanically

ii. Using the same test samples for all 10 hits, hit 4 delineators at an angle perpendicular to the front of the post

   a) 5 impacts at an ambient temperature of 0^o C ±3^o C (not required for project site impact testing)

   b) 5 impacts at an ambient temperature of 29^o C ±3^o C

iii. Using the same test samples for all 10 hits, hit 4 delineators at an angle of 25^o clockwise from the angle perpendicular to the front of the posts (hit on the bumper near the vehicle headlight):

   a) 5 impacts at an ambient temperature of 0^o C ±3^o C (not require for project site impact testing)

   b) 5 impacts at an ambient temperature of 29^o C ±3^o C

Each post shall be inspected after each impact and the following documented:

i. Any splits, cracks, breaks or other forms of deformation or distress;

ii. The percent list to vertical two minutes after each impact;

iii. The approximate percentage of the reflective area that is damaged after each impact to an extent it no longer performs as intended;

iv. Any problems or comments associated with the installation and removal of the posts and bases. Testing agent shall document any special equipment or techniques required for installing or removing the posts and bases.

v. Any problems or comments associated with the performance of each ground mounted flexible delineator post that would be of interest;

vi. Type of soil and impact surface.

A minimum of 50 % of the reflective sheeting shall be retained undamaged. An area of damage greater than 50 % is considered a failure. If the guide post leans more than 10o from vertical it is considered a failure. Any cracking, other than surface cracking evident on only one face of the post, is considered a failure. Pullout in excess of 75 mm is considered a failure. At least six of the guide posts must pass each criterion in the series of impacts to be acceptable.

8.4.4.3 Construction Requirements

Flexible guide posts shall be installed according to the manufacturer's recommendations. At least ten days prior to installation, the Contractor shall provide the Engineer with the manufacturer's recommended installation procedures, as part of the Contractor's method statement for installation, for prior approval by the Engineer.

Flexible guide posts shall be installed as shown in the Contract plans or as directed by the Engineer. Posts shall be installed plumb, ±1.5º.

Guide posts shall be of such length as to provide a height as shown on the Contract plans, ±70 mm, above the nearest edge of traveled pavement surface. Final guide posts lengths will be approved by the Engineer.

Surface mounted guide posts shall be bonded to the pavement surface.

Only one type of ground mount or guardrail mount flexible guide post shall be used on each project.

If the ground adjacent to the posts is disturbed in any manner, it shall be backfilled to the level of the existing surface and thoroughly compacted. Ground surface adjacent to guide posts shall be replaced with like materials, including bituminous treatment if previously existent.

8.4.5 Shoulder Rumble Strips

8.4.5.1 Description

This work consists of constructing shoulder rumble strips by grinding hot mix asphalt. Rumble strip grooves shall be cylindrical in configuration in the direction of the traffic flow and shall be placed as shown on the Contract plans.

Work shall include cleanup and disposal of cuttings and other resultant debris. Patterns and construction details for the centerline rumble strip and the shoulder rumble strips shall be as shown on the Contract plans or as approved by the Engineer.

In cases where rumble strips are required to be applied in traveled lanes they shall be produced by application of MMA road marking material to a nominal thickness of 5mm.

8.4.5.2 Equipment

Rumble strips shall be constructed with equipment specifically designed to remove asphalt concrete material by means of grinding to a controlled line and grade without scarring the adjacent pavement.

Equipment shall be capable of removing the existing asphalt concrete to the dimensions and tolerances specified in the Contract plans.

Equipment shall have a rotary type cutting head or series of cutting heads capable of grinding 1 or more recesses as detailed in the Contract plans.

Equipment shall also be equipped with an approved guide that is clearly visible to the operator so that proper alignment of the grooves will be obtained.

8.4.5.3 Construction Requirements

Rumble strips shall not be constructed in new asphalt concrete pavements for a minimum of three days after placement, or 10 days after placement of new asphalt concrete pavements with –polymer modified bitumen.

Location and alignment shall be per the requirements shown on the Contract plans. Contractor shall place a continuous control line to guide installation. Lateral deviation of the rumble strips shall not exceed 25 mm in any 30 m interval. Difference between high and low surfaces shall not exceed 3 mm. Gaps in continuous rumble strips not shown on the Contract plans will be designated by the Engineer. Accumulative error in the longitudinal spacing of the rumble strips and the gaps, when required, shall not exceed ±5 %.

Rumble strips shall not be constructed on bridge decks, bridge approach slabs, or cement concrete surfaces. In areas where monuments, drainage structures, induction loop lead-ins, pavement markings or other features will not allow the rumble strips to be constructed as detailed, the rumble strips shall be eliminated or relocated as approved by the Engineer.

Traveled lanes shall be kept free of cuttings and other construction debris at all times. Immediately upon completion of rumble strip grinding, all cuttings, grinding debris, dust, and other loose materials shall be removed from the area. All cuttings and other debris shall become the property of the Contractor and be disposed of as approved by the Engineer.

8.5 Permanent Signing

8.5.1 Description

Signs shall be as indicated on the Contract plans, as specified herein and as directed by the Engineer, unless otherwise indicated in the particular specifications. This work shall consist of furnishing and installing reflectorized sign panels, sign supports, sign support foundations, sign removal, sign relocation, and refacing existing signs.

Where required on the Contract plans or in the Particular Specifications, illumination for overhead signs and other signs shall conform to the requirements of Section 10.8.6 of Chapter 10, Lighting and Electrical Distribution Works, and shall be as indicated on the Contract plans.

8.5.2 Definition of Terms

Brightness: A measurement of the ratio of the quantity of incident light per unit area returned to an observer from a reflector. This measurement is expressed in units of candlepower per unit area per lumens (mcd/m^2/lux).

Divergence angle: Angle at the reflector between the observer's line of sight and the axis of the incident light beam.

Entrance angle: Angle at the reflector between the axis of the incident light beam and the normal to the reflective surface.

Intensity: A measurement of the ratio of the quantity of incident light per total area returned to an observer from a reflector. This measurement is expressed in units of lumens/m^2.

Legend: Characters, letters, numbers, and symbols including the border appearing on the background on the sign face.

Sign face: That part of a sign panel facing toward oncoming traffic.

Sign panel: Structural part of a sign made of assembled units or sheet metal, plywood or fibreglass, including reflectorized material applied to the face and bearing a legend, but excluding the supporting posts or structure.

Sign supports: Posts, beams and structural tubes necessary to support the sign panels shall be as indicated on the Contract plans.

8.5.3 Materials

Materials for the construction of permanent signing shall comply with the following sections:

a. Sign panels – Article 8.5.3.4
    1. Reflective sheeting – Sub-article b of Article 8.5.3.4
    2. Aluminium sign panels – Sub-article 8.1.1.1e of Article 8.5.3.4
    3. Plywood sign panels – Paragraph 4 of Sub-article e of Article 8.5.3.4
    4. Fiberglass signs – Sub-article f of Article 8.5.3.4

b. Sign mounting – Article 8.5.3.5

c. Sign posts – Article 8.5.3.6

d. Sign foundations – Article 8.5.3.7

8.5.3.1 Submittals

Contractor shall submit shop drawings, and samples of all required materials for approval of the Engineer prior to fabrication of the signs and delivery to the site

Submittals shall conform to the requirements of Article 8.2.2.3. Certificate of compliance shall verify that all materials, including the reflective sheeting and fabrication meet all the requirements of this specification

8.5.3.2 Acceptance

Acceptance of materials shall be per Article 8.2.2.2. It is expressly understood that the furnishing of certificates of compliance will not relieve the Contractor from the obligation to replace materials found defective after delivery to the project, nor will they prevent the Engineer from sampling material when it arrives on the project and subjecting it to such laboratory tests as they may deem appropriate or significant.

Signs shall be inspected by the Contractor at the fabricator's plant before shipment to the project, and shall provide the Engineer a certificate of compliance that the fabricated signs meet all requirements of the specifications. Engineer may also conduct inspections at the fabricators plant and the Contractor shall provide the necessary provisions for these inspections.

Inspections shall not be made until all materials have been tested and approved.

A "FABRICATION APPROVED" decal shall be applied to back of all fabricated signs at the fabricators plant, for signs that have been inspected and approved by the Contractor and/or Engineer. Signs without this decal will not be installed on the project with the exception of double-faced signs which do not receive decals or fabricator's stickers.

8.5.3.3 Packaging and Marking

Materials shall be packaged and marked in accordance with Article 8.2.2.1.

Both ends of each box of reflective sheeting shall be clearly labeled with the sheeting type, color, adhesive type, manufacturer's lot number, date of manufacture, and supplier's name. Material safety data sheets and technical bulletins for all materials shall be furnished to the Engineer with each shipment.

All signs shall show the manufacturer's name and date of manufacture on the back. In addition, the width and height dimension, in cm, and the number of the sign as it appears in the Contract plans shall be placed using 76 mm series C (see the MUTCD TR-511 for standard letters) black letters on the back of destination, distance and large special signs.

Hand painted numbers is not permitted.

8.5.3.4 Sign Panels

a. Corner Radius

All regulatory and warning signs shall have rounded corners with the exception of stop signs. Information and guide signs may have square cut corners. Borders for signs having square cut corners shall have a corner radius approximately 1/8th of the lesser side dimension of the sign, up to a maximum radius of 300 mm. For signs with rounded corners, the borders shall be concentric with the rounded corners.

b. Reflective Sheeting

Reflective sheeting specified herein is intended for highway applications to assure optimum visibility by day and at night when exposed to a light source and whether dry or totally wet by rain.

Contractor shall supply for the Engineer's approval, the manufacturer's certificate of compliance for the reflective sheeting. Contractor shall submit a guarantee for replacement of any defective reflective sheeting (and sign panels) within a 7 year period for high intensity grade and 10 year period for cube corner grade, after installation of the signs.

Type of reflective sheeting appropriate for anticipated use and durability, type of adhesive backing, and all other materials for signs shall be as shown on the Contract plans and as specified herein.

All materials shall be new and shall be handled and installed in compliance with these Specifications, the Contract plans, and the approval of the Engineer. Construction material shall not be stored on the pavement or shoulder. Signs stored on or near the job site shall be under a roof or otherwise covered for protection against weather and dirt. Materials shall be stored off the ground and such that they do not come in contact with surface runoff water.

Reflective sheeting shall be one of the following types, conforming to the requirements of ASTM D 4956 which defines the reflective sheeting and classes of adhesive backing:

1. Type III : retroreflective sheeting referred to as “high-intensity” that is typically manufactured as an encapsulated glass-bead retroreflective material or as an unmetalized microprismatic retroreflective element material.
2. Type IV : retroreflective sheeting referred to as “high-intensity” that is typically an unmetalized microprismatic retroreflective element material.
3. Type IX : retroreflective sheeting typically manufactured as an unmetalized cube corner microprismatic retrorereflective element material.
4. Type XI : retroreflective sheeting typically manufactured as an unmetalized cube corner microprismatic retrorereflective element material.

Adhesive backing classes shall be as follows:

1. Class 1: Adhesive backing shall be pressure-sensitive and require no heat, solvent, or other preparation for adhesion to smooth, clean surfaces.
2. Class 2: Adhesive backing shall have an adhesive that shall be activated by applying heat and pressure to the material. Temperature necessary to form a durable permanent bond shall be a minimum of 66° C. Reflective sheeting materials with Class 2 adhesive shall be repositionable under normal shop conditions and at substrate temperatures up to 38° C without damage to the sheeting.

   Reflective sheeting materials with Class 2 adhesive may be perforated to facilitate removal of air in heat-vacuum laminators, but the perforations must be of a size and frequency such that they do not cause objectionable blemishes in the finished sign as determined by the Engineer.
3. Class 3: This adhesive backing shall be a positionable low-tack pressure-sensitive adhesive that requires no heat, solvent, or other preparation for adhesion to smooth, clean surfaces. Reflective sheeting materials with Class 3 adhesive shall be repositionable up to a temperature of 38° C without damage to the sheeting.
4. Class 4: Adhesive backing shall be a low-temperature pressure-sensitive adhesive that permits sheeting applications down to –7° C without the aid of heat, solvent, or other preparation for adhesion to smooth, dry, and clean surfaces.

Chemical activators shall not be used to activate Class 2 adhesive.

Reflective sheeting shall meet the requirements of these specifications and of ASTM D 4956 as defined for:

1. Adhesive
2. Liner removal
3. Daytime colour
4. Nighttime colour

5. Colour
6. Coefficient of retro reflection
7. Accelerated laboratory weathering
8. Accelerated outdoor weathering
9. Shrinkage
10. Workability
11. Positionability
12. Thickness
13. Processing
14. Identification

All sheeting shall be weather resistant and have a protected pre-coated adhesive backing.

c. Sampling and Testing

For the purpose of testing and qualification, sample size for reflective sheeting shall be a full width by 1 m long sample selected at random to represent the entire sheet, roll, or lot. Package marking shall include the ASTM sheeting type and ASTM backing class designations.

d. Wet Performance

Wet performance measurements on unweathered sheeting shall be conducted in accordance with one of the following methods:

- Standard rainfall test specified in Federal Specification LS 300C and the brightness of the reflective sheeting totally wet by rain shall not be less than 90 % of the dry values.
- Samples shall be submerged in a tank of clean water (22° C) for 5 min. Reflex-reflective performance of the sheeting shall be viewed in a darkened room by reflected light through the surface of the water or through a transparent plane surface of the tank parallel to the sample surface. Light source shall be such as a hand flashlight held close to the eye. Wet sheeting shall show no loss of reflective performance as compared to dry material.

1. Specular Gloss

Reflective sheeting for road signs shall have an 85ºspecular gloss of not less than 50 for when tested in accordance with ASTM D523.

2. Flexibility

Reflective sheeting for signs, with the liner removed and conditioned for 24 hr at 22o C and 50 % relative humidity, shall be sufficiently flexible to show no cracking when slowly bent, in one second's time, around a 3.20 mm mandrel with adhesive contacting the mandrel. Note: For ease of testing, spread talcum powder on adhesive to prevent sticking to the mandrel.

3. Impact Resistance

Reflective sheeting materials, applied according to the manufacturer's recommendations to a cleaned, etched aluminium panel of alloy 6061-T6 (ASTM B308M), 1.0 mm by 76 mm by 127 mm and conditioned for 24 hr at 23° C and 50 % relative humidity, shall show no cracking when the face of the panel is subjected to an impact of a 0.9 kg weight with a 16 mm rounded tip dropped from a 1.13 Nm setting on a Gardner Variable Impact Tester, 1G-1120 (ASTM D2794).

4. Surface

Reflective sheeting surface shall show no loss of the colour coat with normal handling, cutting, and application.

Reflective sheeting shall be heat resistant and permit force curing without staining of unapplied sheeting or applied sheeting at temperatures recommended by the manufacturer not to exceed 66o C for unapplied sheeting or 93o C for applied sheeting.

Sheeting surface shall be solvent resistant to permit cleaning by wiping with a clean soft cloth dampened with naphtha or mineral spirits.

5. Tensile Strength

Tensile strength of reflective sheeting shall be 34 to 138 kPa when conditioned for 48 hr in accordance to ASTM D685 and tested in accordance with ASTM D828.

6. Letters, Numerals, Arrows, Symbols and Borders

Letters, numerals, arrows, symbols, borders and other features of the sign message shall be of the type, size, and series indicated on the Contract plans or as required by the Engineer.

Colours shall be as specified herein or as indicated on the Contract plans. Completed letters, numerals, and other units shall be formed to provide continuous stroke width with smooth edges and shall present a flat surface free of warp, blisters, wrinkles, burrs, and splinters. Units of the sign message of the type indicated on the Contract plans such as the letters, numerals, symbols, borders and other features of the sign message shall be cut from reflective sheeting of the colour and type specified on the Contract plans and applied to the reflective sheeting of the sign field in accordance with the instructions of the manufacturer of the reflective sheeting.

7. Process Colours

Transparent and opaque process colours used in silk screening sign messages shall be as recommended by the manufacturer. When properly applied, process colours shall perform satisfactorily for the expected life of the sheeting.

Applied colours shall present a smooth surface, free from foreign material, and all messages and borders shall be clear and sharp. Sheeting shall conform to the retroreflective minimum values and colour limits established for its type and colour without regard to whether the colour is integral to the sheeting or achieved by applying transparent colours to silver/white sheeting.

There shall be no variations in colour, and overlapping of colours will not be permitted.

Properly applied and cured process colours shall exhibit no blistering, bubbling, or loss of colour or transparency when cleaned with a mild non-abrasive detergent solution. Minor loss of colour may be detected when solvents such as kerosene, mineral spirits, heptane, or naphtha are used to clean severely contaminated signs; e.g., paint vandalism. However, the colours shall not blister, bubble, peel, or be easily removed.

e. Aluminum Sign Panels

Extruded aluminum channels shall be used for all guide signs and shall be as indicated on the Contract plans.

Basis for acceptance of aluminum sign blanks and panels shall be a mill test certificate from the aluminum manufacturer attesting to the correct alloy and temper of the metal supplied. At the option of the Engineer, laboratory tests may also be performed to confirm metallurgical data. If the panel consists of more than one part, all panel parts shall be of the same material, sheeting, paint, etc.

Traffic sign panel blanks for "warning and regulatory signs" shall be of sheet aluminum with reflective sheeting all as specified herein and as indicated on the Contract plans. Sheet aluminum sign blanks

0.58 m^2 or less in area shall not be less than 2 mm thick; sign blanks 0.58 to less than 2.25 m^2 in area shall not be not less than 3 mm thick. Sign panels 2.25 m^2 and larger shall be extruded aluminum as specified herein and as indicated on the Contract plans.

Surface area shall be determined by calculating the area of the smallest rectangle that will circumscribe an individual sign, except in the case of a triangular sign. The area of a triangular sign shall be the net triangular area.

Aluminum sign blanks shall be free from laminations, blisters, slivers, open seams, pits from heavy rolled-in scale, ragged edges, holes, turned down corners, or other defects which may affect appearance or use for the intended purpose. All blanks shall be as nearly uniform in thickness as is practicable and shall be commercially flat. All shearing, cutting and punching shall be done prior to preparing the sign blanks for the application of reflective material.

Sheared edges of all sign blanks shall be straight and free from tears and raggedness and distortion of the metal. All punched or drilled holes shall be round, free from tears and raggedness.

Sheet aluminum signs shall be constructed of material conforming to ASTM B209 alloy 6061-T6 or alloy 5052-H36 or H38. Alloy 5005-H34 may be used for sign overlays.

After the sheeting has been fabricated, the sheeting for all multiple panel signs shall be degreased, etched by immersion for a minimum of 5 min in a caustic etch solution at 49^{o} C, followed, in order, by a water rinse, de-oxidation, water rinse, hot water rinse, and drying. Etching process shall produce a dull aluminum finish on both sides of the panel which will last the life of the sign.

Treated panel surface shall be compatible with the opaque and reflective sheeting to be applied in accordance with the specifications. Contractor may use an Alodine 1200 application for single panel signs in lieu of the above treatment.

Aluminum signs shall be constructed as shown on the Contract plans or as required in the Particular Specifications. If not otherwise defined, signs shall be constructed as per the following guidelines:

1. Aluminum signs over 3.7 m wide by 1.5 m high shall be comprised of vertical panels in increments of 0.5, 1.0, or 1.5 m wide.
2. No more than one 0.5 m and/or 1.0 m panel may be used per sign. Contractor shall use the widest panels possible.
3. All parts necessary for assembly shall be constructed of aluminum, galvanized, or stainless steel or as shown on the Contract plans.
4. Minimum sheet thickness shall be as follows:

Table 8-29: Minimum thickness for maximum horizontal dimension sheet aluminum

Horizontal dimension	Minimum sheet aluminum thickness
Overlay panels	1.27 mm
Up to 50 cm	1.60 mm
50 cm to 91 cm, inclusive	2.03 mm
Over 91 cm (Permanent Signs)	3.18 mm

Side dimension for a diamond shaped warning sign is considered to be the maximum horizontal dimension.

Before placing aluminum in contact with untreated steel, the steel surfaces shall be protected by proper cleaning and painting with one coat of zinc primer A-9-73 (Mil-P-21035) and two coats of aluminum paint with the following formula:

1. Aluminum paste (ASTM D962, Type 2 Class B): 0.91 kg.

2. Spar Varnish (Federal TT-V-119): 3.79 litres
3. Aluminum paint shall be mixed on the job site, and only enough for one day shall be mixed at a time. Weighed amount of paste shall be placed in a suitable mixing container and the measured volume of varnish then poured over it. Paste shall be incorporated by vigorous stirring with a paddle.

Metal shall be handled by device or clean canvas gloves between all cleaning and etching operations and the application of reflective sheeting.

1. Preparation for Application of Reflective Sheeting

Aluminum sign base material, before the application of reflective sheeting, shall be prepared as follows:

i. Blank panel shall be given a preliminary cleaning by being completely submerged in a 3 % solution of an inhibited alkaline cleanser at 70° C to 80° C for 3 min, followed by a thorough rinse with clean, cold running water. As an alternative, a grease solvent such as naptha, or trichloroethylene may be used, provided the application is in strict accordance with the directions of the manufacturer of the cleaner.

ii. Preliminary cleaning shall be followed by etching. This shall consist of immersion for at least 3 min in a 6 to 8 % solution of phosphoric acid at 40° C. Blank panels shall then be rinsed in a spray of cold water, followed by immersion for one minute in circulating hot water at 80°C. They shall then be dried by forced warm air or infrared lamps.

iii. If total immersion is impossible because of the length of the panels, 6 to 8 % phosphoric acid at 40° C may be applied to the surface by swabbing, brushing, or spraying, allowed to remain for 5 min, and then removed by a cold water rinse, followed by drying with warm or forced air.

iv. Metal shall not be handled except by a device or clean canvas gloves between all cleaning and etching operations and the application of reflective sheeting. There shall be no opportunity for the metal to come in contact with greases, oils, or other contamination prior to the application of reflective sheeting.

v. If a chemical conversion coating is used, the coating shall be light, tight, and free from all powdery residue.

When the reflective sheeting is applied to individual extruded aluminium channels, the channels shall be assembled after the background sheeting has aged for 48 hr at 24° C.

Channels shall be bolted together using the panel bolt assembly indicated on the Contract plans which shall be on 600 mm maximum centers. Nuts on panel bolts shall be drawn tight.

Side-trim molding shall be installed on both vertical edges of the extruded aluminium panels after the clear finish has dried. Any damage to the clear film shall be repaired and the contact between the molding and the reflective sheeting shall be edge sealed as recommended by the sheeting manufacturer.

2. Application of Background Sheeting

Reflective sheeting shall be applied in the manner specified by the sheeting manufacturer. Applied sign face shall not have bubbles, wrinkles, or foreign material beneath the reflective sheeting.

Reflective sheeting shall be applied to all sign faces by an approved vacuum or continuous roll applicator. The background reflective sheeting shall adhere over and around the sides of all panels to a minimum distance of 2 mm beyond the edges. All edges and splices of reflective sheeting signs shall be coated with an edge sealer when recommended by the manufacturer of the reflectorized sheeting. Side-trim molding shall be installed on both vertical edges of the extruded aluminum panels after the clear finish has dried. Any damage to the clear film shall be repaired and the contact between the molding and the reflective sheeting shall be edge sealed as recommended by the sheeting manufacturer.

i. Reflective sheeting with Class 1 pressure sensitive adhesive**:** Pressure sensitive sheeting shall be applied to the individual extruded channels, to assembled panels of extruded channels, and to those sheet panels that are too large for the approved vacuum applicator. Reflective sheeting shall be applied by a continuous roll applicator. Process shall be in strict compliance with the recommendations of the reflective sheeting manufacturer and shall be approved by the Engineer.

ii. Reflective sheeting with Class 2 heat activated adhesive**:** Heat activated adhesive shall be applied to sheet panels capable of being inserted in the approved vacuum applicator. Legend for signs which will have the legend screened onto a reflective sheeting with heat activated adhesive shall be added to the background before the sheeting is applied to the panel.

When vacuum applied, the pre-coated adhesive on the back of the reflective sheeting shall be activated by a minimum temperature of 85° C and with a minimum vacuum pressure of 635 mm of mercury. This operation shall be in effect for a minimum of 5 min. After aging for 48 hr at 24° C the adhesive shall form a bond equal to or greater than the strength of the reflective sheeting.

Splicing of reflective sheeting shall be minimized as much as possible, and generally shall not be permitted on signs or panels with dimensions up to and including 1.2 m in height or width. Widest size of material available shall be used. When sheeting joints are required, they shall be lap-jointed with the top sheet overlapping the bottom sheet by no less than 5 mm.

Fabricator shall endeavor to use the least number of seams possible with the horizontal lap preferable. Roller applied or reverse screened sheeting may be butt-jointed with joint gap not to exceed 1.0 mm. No splice shall fall within 50 mm of the edge of the panel. No borders shall be spliced other than the splice of the tangent border to the corner radius

Sign faces comprising two or more pieces of reflective sheeting must be carefully matched for colour at the time of sign fabrication to provide uniform appearance and brilliance, both day and night. Noncompliance may result in non-uniform shading and an undesirable contrast between adjacent width of applied sheeting, which will not be acceptable.

Damaged reflective sheeting due to poor workmanship or defective material shall be rejected, and shall be replaced by the Contractor at the Contractor's 'expense.

When reflective sheeting is applied to individual extruded aluminum channels, the channels shall be assembled after the background sheeting has aged for 48 hr at 24° C.

Channels shall be bolted together using the panel bolt assembly indicated on the Contract plans which shall be on 600 mm maximum centers. Nuts on panel bolts shall be drawn tight.

3. Finishing

Legend, borders, and sheeting cuts at intersecting panel edges shall be finished with a clear coating approved by the sheeting manufacturer. After message or border application, the complete sign including edges shall be finished with a clear coating approved by the sheeting manufacturer.

4. Plywood Sign Panels

Plywood sign panels shall only be used for temporary construction or construction management type scenarios unless otherwise shown on the Contract plans. Plywood for highway signs shall be smooth, weather-resistant, of one-piece construction, and free of either scarf or finger joints. Plywood will bear legible grade markings of APA, The Engineered Wood Association or the Canadian Council of Forest Industries (COFI). Colour shall be natural or as approved by the Engineer. Plywood shall meet the following criteria:

i. Group 1 species classification

ii. Exterior exposure durability classification (type of glue)

iii. Grade B or better for the face and back veneers

Note: Defects in veneer will be in accordance with the latest revision of U.S. Product Standard PS-1 or Canadian Standard CSA 0121.

iv. Grade B jointed or Grade C plugged jointed inner plies

v. Inner ply gaps shall not exceed 9.5 mm for any gaps between adjacent pieces of jointed inner ply and shall not exceed 4.8 mm for average of all gaps in a panel. Inner ply gaps shall not exceed four core gaps and edge splits per 2.4 m of cross-band layer.

Unless otherwise specified, overlay sheets on both sides of the plywood panel shall be used of high-density material that meets or exceeds the requirements of the latest revision of U.S. Product Standard PS-1 or Canadian Standard CSA 0121.

Hard, smooth, unbroken finished surfaces that do not require further finishing by paint or varnish shall be provided for the overlay sheet.

For the complete panel, plywood for sign panels that do not deviate from a plane surface by more than 50 mm at any point shall be provided. Panels shall be free of dents, bruises, scratches, veneer or overlay delaminations, paint stains, or other damage that would interfere with use of the panel in sign construction.

f. Fiberglass Reinforced Plastic Signs

Fiberglass reinforced plastic signs and overlay panels shall be constructed of a fiberglass reinforced thermosetting polyester laminate. Sign panel shall be acrylic modified and UV stabilized for outdoor weathering ability. Sign panel shall be stabilized to prevent the release of migrating constituents (such as solvents, monomers, etc.) over the expected life of the sign. Sign panel shall contain no residue release agents on the surface of the laminate so neither migrating constituents or release agents will be present in amounts which will interfere with any subsequent bonding operations.

Sign panel shall not contain visible cracks, pinholes, foreign inclusions, or surface wrinkles that would affect implied performance, alter the specific dimensions of the panel, or otherwise affect its serviceability. Sign panel surface shall be wiped clean with a slightly water dampened cloth before applying reflective sheeting.

1. Mechanical Properties

All mechanical properties are stated as minimum requirements. Mechanical properties are measured in both the line direction of the panel and at 90o to the line as noted in the appropriate ASTM test referenced.

Table 8-30: Mechanical properties of fibreglass reinforced plastic signs

Mechanical property	Ave. min. requirement	ASTM test
Tensile Strength	0.703 kg/cm^2 × 103	ASTM D638
Tensile Modulus	0.084 kg/cm^2 × 106	ASTM D638
Flexural Strength	1.406 kg/cm^2 × 103	ASTM D790
Flexural Modulus	0.084 kg/cm^2 × 106	ASTM D790
Compression Strength	2.25 kg/cm^2 × 103	ASTM D695
Compression Modulus	0.098 kg/cm^2 × 106	ASTM D695
Punch Shear	0.914 kg/cm^2 × 103	ASTM D732

2. Physical Properties

Sign panels are to be 3.43 mm thick. Overlay panels are to be 1.91 mm thick. Panel thickness tolerance shall be plus or minus 0.127 mm. Panel tolerance on nominal length and width shall be plus or minus 3.18 mm for dimensions of 3.66 m or less and shall be within 3.18 mm of square per 3.66 m length when measured in accordance with ASTM D3841.

Panels shall be manufactured with smooth surfaces on both top and bottom of the panel. Panel flatness of a 750 mm x 750 mm panel shall be measured by hanging the panel diagonally in suspension. Maximum deflection measured diagonally, parallel and perpendicular to the panel by lines drawn through the center of the panel, shall not exceed 12.7 mm. Panel shall then be hung diagonally in suspension in an oven for 48 hr at 82o C. Maximum deflection shall again be measured as previously noted and shall not exceed 12.7 mm. All measurements shall be made when panels are at ambient temperature.

Panels shall be pigmented to a visually uniform gray color within the Munsell range of N.7.5/G to N.8.5/G.

Panels shall be classified as to a minimum Grade II (weather resistant) panel as specified in ASTM D3841 following 3,000 plus or minus 100 hr weatherometer test.

Panels shall contain additives designed to be less responsive to fire ignition and flame propagation. As such, the extent of burning shall not exceed 25 mm when tested in accordance with ASTM D635.

Panels shall resist the impact energy of 27.12 J applied with a hemispherical tipped object 25 mm in diameter.

Panels’ thermal stability for strength and impact resistance qualities shall not be appreciably affected over a temperature range of -54º C to 100° C.

8.5.3.5 Sign Mounting Materials

a. Structural High Strength Steel

Structural high strength steel shall be high yield strength, quenched and tempered structural steel conforming to AASHTO M 270, Grades 70W, 100, or 100W as specified in the Contract plans and Chapter 23, Steel Structures, of these standard specifications. All structural steel shall be assembled, formed and fabricated per the requirements of Chapter 23, Steel Structures.

b. Aluminum Structures

Welding of aluminum shall be in accordance with ANSI/AWS D1.2.

Aluminum materials shall conform to ASTM B209. Grades shall meet the following:

1. Filler alloy shall be 4043, 5365, or 5556 for welding base metals 6061, 6062, 6063or A356.
2. Filler alloy for welding base metal 5086 shall be 5356 or 5556.

c. Hardware

Bolts, nuts, locknuts, and washers shall be of the same material for each attachment.

Bolts, nuts, locknuts, and washers for signs mounted on overhead sign structures (i.e. sign bridges, cantilevered sign structures, and bridge mounted sign brackets) shall be stainless steel only.

All bolts, nuts, washers, cap screws, and coupling bolts shall conform to Table 8-31. Hardware for structural steel sign supports shall comply with Paragraph 1 of Sub-article c of Article 8.5.3.5.

Table 8-31: Hardware for sign installations

Hardware	Specification
Bolts	ASTM F468 2024-T4 Aluminum ASTM A307 Steel ASTM F593 Group 1, Condition A Stainless Steel, or ASTM A193, Grade B8, Class 1 Stainless Steel
U-bolts	ASTM A276 Type 304 Stainless Steel
Washers	ASTM B209 2024-T4 Aluminum ASTM F844 Steel ANSI B.18.22.1 Stainless Steel Alloy 304
Nuts	ASTM F467 2024-T4 Aluminum ASTM A563 Grade A Steel ASTM F594 Group 1 Stainless Steel, or ASTM A194 Grade 8 or 8A Stainless Steel
Locknuts (with nylon insert unless otherwise in the Contract plans)	ASTM F467 2024-T4 Aluminum ASTM A563 Grade A Steel ASTM F594 Group 1 Stainless Steel, or noted ASTM A194 Grade 8 or 8A Stainless Steel
Rivets	ASTM B316 5052 Aluminum Alloy ASTM B316 5056 Aluminum Alloy
Post Clips	ASTM B179 356-T6 Aluminum
Wind beams	ASTM B221 6061-T6 Aluminum
Angle and “Z” Bar	ASTM B221 6061-T6 Aluminum ASTM A36 or ASTM A 992 Steel
Strap and Mounting Bracket	ASTM A666, Type 201 Stainless Steel

All steel parts shall be galvanized per AASHTO M 111. Steel bolts and related connecting hardware shall be galvanized per AASHTO M 232.

Contractor shall provide mill test reports from the producing mill for all structural components—frames, wind beams, stiffeners, exit number panel supports, splice bars, and high strength fasteners. Mill test reports must reflect the chemical analysis of the base metal and the physical test results (i.e., yield and tensile strength and elongation) obtained on the finished product.

1. High Strength Bolts

High strength bolts for structural steel joints shall conform to the requirements of AASHTO M 164 or M 253 Type 1, 2, or 3.

Bolts conforming to AASHTO M 164, having an ultimate tensile strength above 1000 MPa and are galvanized in accordance with AASHTO M 232, shall be tested for embrittlement. Embrittlement testing shall be conducted after galvanization in accordance with ASTM F606, Section 7. Manufacturer's certificate of compliance for the lot provided shall show the ultimate tensile strength test results.

Bolts conforming to AASHTO M 253 shall not be galvanized. AASHTO M 253 Type 1 and 2 bolts shall be painted with two coats of zinc rich paint, formula A-9-73, consisting of a minimum dry film thickness of 0.051 mm per coat.

Unpainted and nongalvanized bolts shall conform to AASHTO M 164 and M 253 Type 3.

Nuts for high strength bolts shall meet the following requirements:

Table 8-32: Nuts for high strength bolts

AASHTO M 164 Bolts Black or galvanized Type 1	AASHTO M 291 Grade C, C3, DH, and DH3
AASHTO M 253 Bolts Black Type 1 and 2 Black weathering Type 3	 AASHTO M 291 Grade DH, DH3 AASHTO M 292 Grade 2H AASHTO M 291 Grade DH3

Nuts that are to be galvanized shall be tapped oversized the minimum required for proper assembly. Amount of overtap shall be such that the nut will assemble freely on the bolt in the coated condition and shall meet the mechanical requirements of AASHTO M 291 and the rotational capacity test specified in AASHTO M 164.

Galvanized nuts shall be lubricated in accordance with AASHTO M 291 including supplementary requirement S2. Documentation shall include the name, method of application, and dilution of the lubricant applied to the nuts.

Washers for AASHTO M 164 Type 1 and 3 bolts; and AASHTO M 253 Type 1, 2, and 3 bolts shall meet the requirements of AASHTO M 293. Surface condition and weathering characteristics of the washers shall be the same as for the bolts being specified.

Direct Tension Indicators (DTIs) shall conform to the requirements of ASTM F 959 and may be used with either AASHTO M 164 or M 253 bolts. DTIs shall be galvanized by mechanical deposition in accordance with AASHTO M 298 class 55. Hot dip galvanizing shall not be allowed.

All bolts, nuts, and DTIs shall be marked and identified as required in the pertinent Specifications.

Lock-pin and collar fasteners which meet the materials, manufacturing, and chemical composition requirements of AASHTO M 164 or AASHTO M 253, and which meet the mechanical property requirements of the same Specification in full size tests, and which have a body diameter and bearing areas under lock-pin head and collar not less than those provided by a bolt and nut of the same nominal size may be used. Contractor shall submit a detailed installation procedure to the Engineer for approval. Approval to use a lock-pin and collar fasteners shall be given by the Engineer prior to use on these types of fasteners.

Contractor shall provide manufacturer's certificate of compliance for all bolts, nuts, washers, and load indicators. Manufacturer's certificate of compliance shall include certified mill test reports and test reports performed on the finished bolt confirming that all of the materials provided meet the requirements of the applicable AASHTO or ASTM specifications. Documentation shall also include the name and address of the test laboratory, the date of testing, the lot identification of the bolts and nuts, and coating thickness for galvanized bolts and nuts. Shipping containers (not lids) shall be marked with the lot identification of the item contained therein.

Bolts will be sampled prior to incorporating into a structure. For the purposes of selecting samples, a lot of bolts shall be the quantity of bolts of the same nominal diameter and same nominal length in a consignment shipped to the project site. Minimum number of samples from each lot will be as follows:

Table 8-33: Sample size for bolt lots

Lot Size	Sample Size [a,b]
0 to 50	*
51 to 150	4
151 to 1,200	6
1,201 to 10,000	10
10,001 to 35,000	16
35,001 and over	24
*Manufacturer's certificate of compliance — samples not required.	
[a] If bolts are galvanized, increase the sample size by 1.5 times the table value for the number of bolts being sampled.	
[b] Nuts, washers, and load indicator devices shall be sampled at the same frequency as the bolts.	

All testing of bolts, nuts, washers, and load indicating devices will be performed on specimens as they are to be installed. All samples shall include a manufacturer's certificate of compliance for each lot of bolts provided.

8.5.3.6 Sign Posts

All sign support structures shall be constructed as shown in the Contract plans.

a. Steel Posts

Posts for single post sign structures shall meet the requirements of ASTM A500 Grade B or ASTM A53M - 10 Grade B, Type E or S.

Posts for multiple post sign structures shall conform to either ASTM A36M - A36M -2008 or ASTM A992. Posts conforming to either ASTM A588 or ASTM A572 Grade 50 may be used as an acceptable alternate to the ASTM A36 and ASTM A992 posts. All steel not otherwise specified shall conform to either ASTM A36 or ASTM A992.

Triangular base stiffeners for one-directional multi-post sign posts shall conform to ASTM A588 or ASTM A572, Grade 50.

All steel, including posts, base plates, and base stiffeners, shall be galvanized after fabrication in accordance with AASHTO M 111.

Truss chords, struts, and diagonals, end posts, and end post struts and diagonals for sign bridge structures and cantilever sign structures shall conform to either ASTM A36 or ASTM A53M - 10 Grade B Type E or S. Nominal pipe diameter and the pipe wall thickness shall be as shown in the Contract plans. All other structural steel for sign bridge structures and cantilever sign structures shall conform to either ASTM A36 or ASTM A992. Truss member connection hardware shall conform to Paragraph 1, Sub-article c, of Article 8.5.3.5 of these Specifications.

Pipe members for bridge mounted sign brackets shall conform to ASTM A53M – 10 Grade B Type E or S, and shall be Schedule 40 unless otherwise specified. All other structural steel for bridge mounted sign brackets shall conform to either ASTM A36 or ASTM A992. U bolts, and associated nuts and washers for bridge mounted sign brackets shall be stainless steel conforming to Sub-article cc of Article 8.5.3.5.

Steel sign structures and posts shall be galvanized after fabrication in accordance with AASHTO M 111, unless noted otherwise in the Contract plans. Unless otherwise specified in the Contract plans or Particular Specifications, metal surfaces shall not be painted.

b. Breakaway Sign Posts

Base connectors for multiple directional steel breakaway posts shall conform to the following:

Table 8-34 Base connector requirements for breakaway sign posts

Brackets	Aluminum alloy 6061 T-6
Bosses for Type 2B Brackets	ASTM A582
Anchor ferrules	Type 304 stainless steel for threaded portion. AISI 1038 steel rod and AISI 1008 coil for cage portion.

Anchor couplings for multiple directional steel breakaway posts shall conform to AMS 6378D with a tensile breaking strength range as follows:

1. Type 2A - 17,000 to 21,000 lb.
2. Type 2B - 47,000 to 57,000 lb.

For multi-directional breakaway base connectors, shims shall conform to ASTM A653, SS Grade 33, coating designation G 165. For one-directional breakaway base connectors, single post or multi-post, shims shall be fabricated conforming to ASTM B36.

Posts shall be fabricated from structural steel conforming to the requirements of ASTM A572, Grade 50 or ASTM A588 at the option of the Contractor. Base plates for the breakaway connections and friction fuse plates and back plates for the post hinge assembly shall be fabricated from the same type structural steel selected for the sign posts.

All plate holes shall be drilled and all plate notches shall be saw cut, except that flame cutting will be permitted provided all edges are ground. Flange holes shall be drilled or sub-punched and reamed. Posts shall be saw-cut for the hinge and bolted as detailed on the plans.

Bolts, nuts and washers shall conform to the requirements of ASTM A325.

Posts and plates shall be galvanized after fabrication in accordance with the requirements of ASTM A123. Bolts, nuts and washers shall be cadmium plated in accordance with the requirements of ASTM B766, or zinc plated in accordance with the requirements of ASTM B633.

c. Parallel Flanged Channel Sign Posts

Parallel flanged channel posts shall be fabricated from rerolled rail steel or hot-rolled carbon steel bars.

Yield point of the steel shall be 551.5 mPa minimum. Cast heat analysis of the steel shall conform to the following requirements:

Table 8-35: Composition of steel for U-channel sign posts

Element	Composition (Percent)
Carbon	0.67 - 0.82
Manganese	0.70 - 1.10
Phosphorus	Max. 0.04
Sulfur	Max. 0.05
Silicon	0.10 - 0.25

Posts shall be a uniform, modified, flanged channel-section as shown in the Contract plans. Weight of the posts shall be 4.47 kg per lineal meter, ±5 %. Post shall be punched with continuous 9.5 mm diameter holes on 25 mm centers. First hole shall be 25 mm from top and bottom of post.

Posts shall be machine straightened to have a smooth uniform finish, free from defects affecting their strength, durability, or appearance. All holes and rough edges shall be free from burrs. Permissible tolerance for straightness shall be within 1.6 mm over 1.0 m.

Posts shall be galvanized after fabrication in accordance with the requirements of ASTM A123. Bolts, nuts, washers and spacers shall be cadmium plated in accordance with the requirements of ASTM B766 or zinc plated in accordance with the requirements of ASTM B633.

For shipment, posts shall be nested and fastened in such a manner that they will not slip. Care shall be taken during shipping to minimize the rubbing of posts together resulting in damage to the galvanized finished surface. Excessive damage to the finish of the posts during shipping or handling will result in rejection of the damaged posts.

Posts shall be bundled in groups of no more than 100.

d. Perforated Sign Posts (Ornamental)

Single and telescoping perforated posts shall be square tube fabricated from galvanized sheet steel. Sheet steel shall have a thickness of 2.67 mm or 3.43 mm as required by the project specifications. Sheet steel shall conform to the requirements of ASTM A653 for either SQ Grade 40 or SQ Grade 50 Class 1, and be galvanized in accordance with the requirements of Coating Designation G-90. Posts shall have a wall thickness, including coating, of 2.46 mm to 2.95 mm for 12 gauge and 3.23 mm to 3.71 mm for 10 gauge.

Posts shall be welded directly in the corner by high frequency resistance welding or equal. Outside edges of the posts shall be scarfed as necessary to produce a standard corner radii of 3.97 ±0.79 mm. External welded surfaces and scarfed areas shall be re-galvanized after fabrication.

Holes 11.11 ±0.40 mm in diameter shall be provided on 25 mm centers along all four sides over the entire length of the post. Holes shall be laterally centered on the longitudinal centerline of each face. Hole positioning and spacing shall be the same on all four faces, such that the hole centerlines for each group of four holes shall pass through a common point on the longitudinal centerline of the tube. For telescoping posts, holes shall be in proper alignment to allow 9.53 mm diameter bolts to pass through the entire post.

Finished posts shall be straight and have a smooth, uniform finish. All consecutive sizes of posts shall be freely telescoping for not less than 3 m of their length without the necessity of matching any particular face to any other face.

8.5.3.7 Foundations

Concrete foundation materials shall meet the requirements of Section 4.3 of Chapter 4, Concrete Works.

Concrete for sign posts shall be C30 or stronger, concrete for sign bridge and cantilever sign structure foundations shall be C40 or stronger, except as otherwise Specified or shown on the Contract plans.

Where water is present in the shaft excavations for foundations for sign bridges and cantilever sign structures, the shaft concrete shall be C40 or stronger unless otherwise Specified or shown on the Contract plans.

Spiral steel reinforcing bars for sign posts shall conform to AASHTO M 32. All other steel reinforcing bars for sign structure foundations shall conform to the applicable requirements of Chapter 5, Reinforcing Steel.

a. Anchor Bolts

Anchor bolts shall meet the requirements of ASTM F1554 and, unless otherwise specified, shall be Grade 105 and shall conform to supplemental requirements S2, S3, and S4 and the following requirements.

1. Nuts for ASTM F1554 Grade 105 black anchor bolts shall conform to AASHTO M 291, Grade D or DH.
2. Nuts for ASTM F1554 Grade 105 galvanized bolts shall conform to AASHTO M 291, Grade DH and shall conform to the lubrication requirements in Paragraph 1, Sub-article c of Article 8.5.3.5.
3. Nuts for ASTM F1554 Grade 36 or 55 black or galvanized anchor bolts shall conform to AASHTO M 291, Grade A. Washers shall conform to ASTM F436.

Bolts shall be tested by the manufacturer in accordance with the requirements of the applicable specification. Contractor shall submit to the Engineer for approval a manufacturer’s certificate of compliance for the anchor bolts, nuts, and washers. If the Engineer deems it appropriate, the Contractor shall provide a sample of the anchor bolt, nut, and washer for testing.

All bolts, nuts, and washers shall be marked and identified as required in the applicable specification.

8.5.4 Construction Requirements

8.5.4.1 Location of Signs

Signs shall be located as shown in the Contract plans or as directed by the Engineer. Post lengths specified in the Contract plans are estimated for bid purposes only. Final lengths of sign posts will be determined or verified by the Engineer prior to fabrication.

It shall be the responsibility of the Contractor to determine the location of any underground utilities or drainage structures in the vicinity before beginning work. Contractor shall conduct the work so as to avoid damage to these installations. Contractor shall refer to his approved shop drawings and record drawings in locating underground utilities, structures, and facilities that have been installed during construction.

Contractor shall repair any damage caused by the Contractor's operation to the satisfaction of the Engineer, at the Contractor’s own expense.

8.5.4.2 Placement of Signs

Contractor shall install signs at the station, elevation, offset, and orientation as shown on the Contract plans and as approved by the Engineer. Face of the sign shall be vertical.

Rreflectorized signs located less than 10 m from the edge of the lane should be turned out approximately 3 degrees, or as directed by the Engineer, from the pavement edge of oncoming traffic lanes, and those located 10 m or more from the edge of the lane should be turned in approximately 3 degrees from the pavement edge of oncoming traffic lanes. All sign posts shall be plumb and signs level.

Ground mounted signs on ramps or curves shall be oriented as shown on the Contract plans or as directed by the Engineer, to provide the most effective display for both day and night.

Sign faces will be examined by the Engineer during conditions of daylight and darkness. If specular glare occurs from failure to install the sign at the prescribed angle, the Contractor shall reinstall the signs at his own cost.

Post holes shall be of sufficient dimensions to allow placement and thorough compaction of selected backfill material or concrete completely around the post as shown on the Contract plans or as approved by the Engineer. Selected backfill material shall consist of fine sandy gravel free from organic matter with no individual particles exceeding 38 mm in diameter.

Where the paint has been damaged during erection, the Contractor shall repair the paint at the Contractor's expense.

8.5.4.3 Sign Covering

When directed by the Engineer, the Contractor shall cover or uncover certain signs. Covering shall consist of burlap dyed with a waterproof dye of colour that generally matches the sign background colour, and shall extend over the edges of the sign and be fastened on the back. Contractor shall not use any type of adhesive tape on the face of the signs. Other methods of covering may be considered if approved by the Engineer.

8.5.4.4 Sign Removal

Where shown in the Contract plans or directed by the Engineer, existing signs and, if so indicated, sign structures shall be removed by the Contractor. Where indicated, the Contractor shall remove concrete pedestals to a minimum of 600 mm below subgrade or finished ground elevation, whichever is lower, and backfill the hole to the satisfaction of the Engineer.

Where an existing sign post is removed from within a sidewalk area, the Contractor shall finish the area so as to make the sidewalk continuous. Aluminium signs, wood signs, wood sign posts, wood structures, metal sign posts, windbeams, and other metal structural members shall be inspected by the Engineer, and if suitable shall be cleaned, crated for long-term storage and delivered to the Owners storeyards by the Contractor. If not suitable the removed materials shall become the property of the Contractor and removed from the project.

8.5.4.5 Sign Relocation

Where shown in the Contract plans, existing signs and sign structures shall be relocated by the Contractor to the location noted. Where the existing sign structure is mounted on concrete pedestals, the Contractor shall remove the pedestal to a minimum of 600 mm below subgrade or finished ground elevation, whichever is lower, and backfill the hole with material similar to that surrounding the hole to the satisfaction of the Engineer.

Where an existing structure is to be relocated, the Contractor shall provide necessary materials, labor, and hardware, and if so indicated, electrical conduit, conductors, electrical services, and connections so as to erect and provide an operable unit to the satisfaction of the Engineer.

All materials damaged by the Contractor shall be replaced at no extra cost.

Unless otherwise allowed, relocation of each existing sign and structure shall be accomplished during the day in which it was removed.

Where shown on the Contract plans or ordered by the Engineer, the Contractor shall dismantle existing road signs, store them, and re-erect them at new positions indicated.

Where required by the Engineer, the signs shall be repainted or repaired and new materials shall be used for part or all of the supporting structure.

8.5.4.6 Sign Re-facing

Where shown in the Contract plans or in the Particular Specifications, the Contractor shall reface existing signs with sheet aluminium overlay panels. Unless otherwise indicated in the Contract plans or allowed by the Engineer, all work shall be accomplished while the existing sign is in place. Modifications to each sign shall be completed during the same day in which the work is commenced.

Prior to the installation of overlay panels, the existing legend (message and border) shall be removed. Aluminium overlay panels shall be butt jointed. Aluminium or stainless steel screws shall be used to attach overlay panels to existing plywood signs. In addition to the screws, two 6.35 mm diameter aluminium or stainless steel bolts shall be installed through the top of each panel and the existing plywood sign. Aluminium blind rivets shall be used to attach overlay panels to existing aluminium signs. Screws or rivets shall be installed at 600 mm centers.

After installation of overlay panels, the existing legend shall be reinstalled or, where shown in the Contract plans, new legend or portions thereof shall be furnished and installed by the Contractor. New legend components shall be of the same type and size as the existing materials, and it shall be the Contractor’s responsibility to verify material type and size.

Direct applied legend shall be applied to the new face prior to resurfacing. Layout and letter spacing shall be in accordance with the Contract plans unless otherwise directed by the Engineer.

Materials damaged by the Contractor shall be replaced at no extra payment.

8.5.4.7 Sign Message Revision

Where shown on the Contract plans or required in the Particular Specifications, the Contractor shall revise existing sign messages or layouts. Contractor shall remove and reinstall portions of or the entirety of the existing message or furnish and install new message components as necessary to provide the revised message as indicated.

Prior to installing the revised message, the Contractor shall thoroughly clean the sign face and plug all existing rivet holes with aluminium blind rivets painted the same colour as the sign background. Plugging screw holes in plywood signs will not be required. Modifications to the sign shall be completed during the same day in which work is commenced and while the sign is in place.

All new materials necessary to accomplish this work shall be the same type and size as the existing components, and it shall be the Contractor’s responsibility to verify such component type and size. Materials damaged by the Contractor shall be replaced at no extra payment. Existing materials not reinstalled shall become the property of the Contractor and shall be removed from the project.

8.5.4.8 Sign Cleaning

Signs shall be cleaned after relocation or installation to the satisfaction of the Engineer. Contractor shall not use cleaning solvents that harm the sign finish.

8.5.4.9 Sign Structures

Sign support structures shall be assembled and installed as per the details shown on the Contract plans, as specified herein and as approved by the Engineer.

If sign support structures have been designated in the Particular Specifications, in the Contract plans or as included in the Bills of Quantities to be installed per a Contractor submitted structural design, then it shall be the Contractors responsibility to provide a detailed set of sign support structure shop drawings to the Engineer for review. Sign support structure assembly shall not begin until written approval is received from the Engineer. Sign support shop drawing submittals shall include as a minimum, the following items:

- Detailed structural design calculations for both the upper support structure and the foundations, prepared by and signed by a Chartered or Professional Structural Engineer or other structural design engineer with a minimum of 10 years of relevant design experience as approved by the Engineer. Structural design calculations shall meet the loading and structural design requirements of the Road Structures Design Manual, Manual TR-516.

- Location, foundation and detail drawings which show relationship with other utilities and road works that may be in close proximity or direct conflict.
- Detailed structural construction/assembly drawings with welding diagrams.
- Sign layout with mounting to support structure details.
- Lighting assemblies and the associated mounting and structure electrical cable routing details. All lighting shall meet the applicable requirements of Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications. Electrical work shall meet the applicable requirements of Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications.
- Electrical supply and associated electrical connection details and cabling/conduit network, as necessary. Electrical connections and arrangement for connection to the supply feeders shall be the Contractor's responsibility to coordinate with the appropriate electrical authority and as approved by the Engineer. Electrical work for power supply shall meet the applicable requirements of Section 10.11.13, Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications.

a. Fabrication of Steel Structures

All welded connections of sign bridge and cantilever sign structure posts, arms, and beams, including base and connection plates, shall be cleaned prior to welding to remove all mill scale from within 50 mm of the weld. Contractor may perform the cleaning using either a blast cleaning process or with power hand tools as approved by the Engineer.

Fabrication shall be in accordance with applicable requirements of Chapter 23, Steel Structures, of these Standard Specifications.

Where shown on the Contract plans or included in the particular specifications, fabricated steel structure coatings and painting shall meet the requirements of Chapter 24, Painting, of these Standard Specifications.

b. Bridge Mounted Sign Brackets

Contractor shall fabricate and install sign supports for mounting signs on bridge structures at the locations and as shown in the Contract plans, including inserts and anchor bolts. Fabrication, painting and installation shall be in accordance with applicable requirements of Chapter 23, Steel Structures, and Chapter 24, Painting, of these Standard Specifications.

8.5.4.10 Foundations

a. Ground-mounted Signs

Holes for all foundations shall be excavated to the size and dimensions required for construction of the foundations. All excavating and backfilling shall comply with the requirements of Sections 2.4 and 2.5 of Chapter 2, Earthworks. All unsuitable excavated materials shall be disposed of by the Contractor and shall not be used as backfill. All backfill shall be approved material compacted, in layers not to exceed 150 mm, to at least 95 % maximum density in accordance with AASHTO T 180.

All concrete for ground-mounted sign foundations shall be cast-in-place using C25/20 or stronger. All concrete work and reinforcement steel shall comply with all applicable requirements of Chapter 4, Concrete Works, and Chapter 5, Reinforcing Steel, of these standard specifications. Forms shall include templates to hold the section of the stub post to be cast into the concrete securely in place during the casting of concrete. Foundations shall be allowed to cure a minimum of 7 days before erecting signs on the foundations.

Where rock is encountered, the rock shall be cored, drilled or removed to a minimum diameter sufficient to place Portland cement concrete 50 mm below the bottom of the base post and fill the hole to within 25 mm of the top.

Solid rock coring or drilling is not required to continue beyond 610 mm in depth regardless of the depth at which the rock is encountered. Base post may be cut at the bottom prior to being set in Portland cement concrete where rock does not permit use of full length base post.

b. Sign Structures

Sign structures (overhead, cantilever and sign bridge structures) shall not be erected on concrete foundations until foundations have attained a compressive strength of 16.5 mPa. Foundations shall be constructed as shown in the Contract plans and as approved by the Engineer.

Excavation and backfill shall be in conformance with the applicable requirements of Sections 2.4 and 2.5 of Chapter 2, Earthworks, of these standard specifications.

Foundation concrete shall conform to the requirements for the specified class, be cast-in-place concrete and be constructed in accordance with Chapter 4.

The bottom of concrete foundations shall rest on firm ground. If the portion of the foundation beneath the existing ground line is formed or cased instead of being cast against the existing soil forming the sides of the excavation, then all gaps between the existing soil and the completed foundation shall be backfilled and compacted in accordance with the applicable requirements of Chapter 2.

Foundations shall be cast in one operation where practicable. Exposed portions shall be formed to present a neat appearance.

Forms shall be true to line and grade. Tops of foundations for roadside sign structures shall be finished to ground line, unless otherwise shown in the Contract plans or directed by the Engineer. Tops of foundations for sign structures shall be finished to the elevation shown on the Contract plans.

Forms shall be rigid and securely braced in place. Conduit ends and anchor bolts shall be plumbed and rigidly placed in proper position and to proper height prior to placing concrete and shall be held in place by means of a template until the forms are removed.

All bolts and anchor bolts shall be installed so that 2 full threads extend beyond the top of the top heavy-hex nut. Anchor bolts shall be installed plumb, $\pm 1^{o}$.

Plumbing of sign bridges and cantilever sign structures shall be accomplished by adjusting leveling nuts. Shims or other similar devices for plumbing or raking will not be permitted.

All bolted connections shall be tightened using the turn-of-the-nut method defined in Table 8-36 and Table 8-37.

Table 8-36 Bolt tightening requirements by turn-of-the-nut method

Bolt Length (Diameters)	Turns Past Snug (rotations)
Length≤4	1/3
4<Length≤8	1/2
8<Length≤12	2/3

Turns past snug for various bolt length on two horizontal surfaces for the turn-of-the-nut method.

Table 8-37 Turn-of-the-nut bolt tightening procedure

Step	Procedure
1	Tighten the bolt and nut as tight as possible using a spud wrench.
2	Chalk mark or paint is then made on the bolt and nut.
3	Tighten bolt further by either hammering on the spud wrench or using a pneumatic impact wrench until the rotating part has rotated the required amount shown in Table 8-36. The paint or chalk mark shows how far the part has rotated and the rotation is always measured relative to the rotation of the bolt.

Both forms and ground which will be in contact with the concrete shall be thoroughly moistened before placing concrete; however, excess water in the foundation excavation will not be permitted. Forms shall not be removed until the concrete has set at least 3-days. All forms shall be removed, except when the Contract plans or particular specifications specifically allow or require the forms or casing to remain.

Class 1 surface finish shall be applied to exposed surfaces of concrete in accordance with the requirements of Section 4.4.3 of Chapter 4, Concrete Works.

Where obstructions prevent construction of planned foundations, the Contractor shall construct an effective foundation as approved by the Engineer.

8.5.4.11 Identification Plates

When shown on the Contract plans or required by the Particular Specifications, the Contractor shall attach sign identification plates to all signs and sign structures. Identification plates will be supplied by the Contractor per pre-approved design. When signs or sign structures are removed, the Contractor shall remove any identification plates and give them to the Engineer.

8.5.4.12 Sign Attachment

All multiple post and multiple panel signs shall be constructed and installed with horizontal extruded windbeams and “Z” bar, when required, as shown in the Contract plans. All bolt and rivet heads visible on the sign face shall be anodized or painted to match the sign area immediately surrounding the bolt or rivet head.

Aluminum sign blanks shall not come in contact with the steel posts. Contractor shall provide a 1.6 mm thick neoprene pad between aluminum sign blanks and steel posts complying with the manufacturer’s recommendations.

a. **Multiple Panel Signs**

After installation of multiple panel signs, the Contractor shall furnish and install an approved reinforced aluminized tape on the reverse side of the sign to prevent visible light through the seam. Tape shall be pressure sensitive and a minimum of 50 mm wide and 0.051 mm thick. In lieu of tape, the Contractor may use 25 mm wide aluminium sheeting riveted to the sign back. Aluminium shall be a minimum of 0.81 mm thick. Rivet heads shall match the sign face colour.

b. **Steel Sign Post**

Steel sign posts shall be connected to concrete bases using the following procedure:

1. Remove all galvanized runs and beads from washer area.
2. Assemble sign post to stub post with bolts, using 1 flat washer on each bolt between plates.
3. Shim as required to plumb sign posts.
4. Tighten bolts in a systematic order to tightening requirements specified in Table 8-37.

After Engineer inspection of installation, burr threads with center punch to prevent loosening.

8.6 Overhead Tubular Sign Supports

8.6.1 Description

Overhead tubular signs shall be as indicated on the Contract plans, as specified herein and as directed by the Engineer. The Contractor shall include all materials, labor, tools, equipment and appurtenances required to complete the furnishing and installing of the overhead tubular signs.

All electrical work at overhead signs, as indicated on the Contract plans shall be as specified and included in Chapter 10, Lighting and Electrical Distribution Works, of these Standard Specifications.

8.6.2 Foundation for Overhead Tubular Sign Supports

8.6.2.1 General

The Contractor shall furnish and install all materials required for the construction of reinforced concrete foundations for overhead tubular sign supports. Foundations shall be in accordance with dimensions as indicated on the Contract plans and in accordance with these Standard Specifications.

The foundations for overhead tubular sign supports shall be as indicated on the Contract plans. The number of anchor bolts, bolt locations, and anchor bolt dimensions shall be as indicated on the Contract plans. The projecting portion of the anchor bolts and the nut and washer shall be treated by hot dip-galvanizing.

The raceway or conduit for overhead tubular signs shall consist of a galvanized steel raceway as indicated on the Contract plans and shall have a bending radius of 600mm.

All overhead tubular sign support foundations shall be drilled or bored in the manner, at the locations and to the penetration or depth indicated on the Contract plans, as specified herein and as approved by the Engineer.

Prior to proceeding with any foundation work for overhead tubular sign supports, the Contractor shall submit to the Engineer for approval, shop drawings, complete details, calculations for temporary metal casings, equipment data, proposed construction procedure and related particulars concerning the completion of the proposed concrete overhead tubular sign support foundations. The shop drawings shall also indicate the proposed method of conduit installation in the foundation. The method of installation shall be subject to approval of the Engineer.

The length or lengths as indicated on the Contract plans are the estimated minimum required length or lengths for the overhead tubular sign support foundations. The final length or lengths of foundations shall be based on soil properties from the advance boreholes made by the Contractor and shall be as approved by the Engineer based on actual conditions encountered in drilling or boring. The Contractor shall make his own analysis of the subsoil conditions and work that will be required to provide the drilled or bored concrete foundation as specified.

8.6.2.2 Materials

All overhead tubular sign support foundations shall be cast-in-place Class C25/20 concrete. All concrete work shall comply with all requirements of Chapter 4, Concrete Works, of these Standard Specifications. The foundations shall be allowed to cure a minimum of seven (7) days before erecting overhead tubular sign supports on the foundations.

All reinforcement steel in overhead tubular sign support foundations shall be in compliance with the requirements of Chapter 5, Reinforcing Steel, of these Standard Specifications.

All foundations for overhead tubular sign supports shall be furnished with an earth electrode as indicated on the Contract plans and complying with Section 10.14.10 of Chapter 10, Lighting and

Electrical Distribution Works, of these Standard Specifications. The size or dimensions of the earth electrode shall comply with Section 10.14.10 unless otherwise indicated on the Contract plans.

8.6.2.3 Construction

Construction of all foundations for overhead tubular sign supports shall comply with the following requirements:

1. All excavations for these foundations shall be made by drilling, boring or sinking a casing.
2. The Contractor shall be responsible for testing all soil at the bearing levels indicated on the Contract plans, and shall submit written reports to the Engineer as to the bearing capacity at the depth indicated on the Contract plans and the coefficient of lateral subgrade reaction over the proposed length of pile, and the acceptability of such soil to support the proposed foundation and appurtenances. The Contractor shall make boreholes to depths, locations and frequencies as directed by the Engineer. The frequency and depth of the boreholes shall depend upon the soil conditions encountered and shall be at the discretion of the Engineer. The total number of boreholes may or may not be equal to the total number of Overhead Tubular Sign Support Foundations. The report on each borehole made shall include all information as directed by the Engineer and specified in Chapter 17, Drilled Piles, of these Standard Specifications.

   In the event unsuitable soil is encountered throughout the length indicated on the Contract plans for the overhead tubular sign support foundation, the Contractor shall advise the Engineer as to the unsuitability of such soil materials. The Contractor shall be responsible for designing the extension of the depth of such overhead tubular sign support foundations to acceptable bearing. The design of such foundations shall be in accordance with the applicable requirements of Abu Dhabi Road Structures Design Manual (TR-516) and AASHTO LRFD Bridge Design Specifications.

   The Contractor shall employ an independent specialty engineer as approved by the Owner or the Engineer to design the increased depth of any such foundations. The Contractor shall submit design calculations and other data required by the Engineer for review before proceeding with extending the depth of such foundations.

   The need for additional foundation depth shall be at the sole discretion of the Engineer.

   The Contractor shall not proceed with further construction of such foundations until receiving written directions from the Engineer.

3. All drilled foundations shall be installed in the presence of the Engineer. The Engineer shall be notified in writing a minimum of 48 hours in advance that the Contractor is commencing operations to install drilled foundations so that the Engineer can be present during the foundation work on a daily basis throughout the installation of the foundations. All foundations shall be located to the lines and spacing indicated on the Contract plans and shall be drilled vertically with a tolerance of one in fifty.

   In cases where the intended bottom of foundation is in soil, bailing will not be permitted by the Engineer. The Contractor shall take measures to ensure that the ground beneath the base of the drilled or bored excavation is not disturbed by upward seepage pressure. In such cases the Contractor shall ensure the stability of the excavation base by maintaining a net positive hydraulic head within the casing. Concrete shall be placed by tremie all subject to the approval of the Engineer.

4. The foundations shall be drilled with a casing being installed such that the bottom of the casing is maintained below the bottom of the excavation at all times. If approved by the Engineer, the casing may be withdrawn as the concrete is placed provided the bottom of the casing is maintained below the top of the concrete while the concrete is being placed and if the reinforcement, anchor bolts, and conduit can be maintained in their correct position during the casing withdrawal. Otherwise, the casing must be left permanently in place unless alternative construction methods are approved by the Engineer.

5. In the event that conditions, during drilling of holes for the foundations, indicate that a drilled foundation is encountering an obstruction before reaching proper bearing stratum, the Contractor shall bore or drill through the obstruction (after confirming that it is not an underground utility) or shall use whatever means are necessary to remove or circumvent the obstruction, without additional cost to the Owner.
6. In the event the Contractor excavates to an elevation below that indicated on the Contract plans or approved by the Engineer, the Contractor shall furnish and place Class C15/20 concrete up to the bottom of the foundation as indicated on the Contract plans or as directed or approved by the Engineer at no additional cost to the Owner.
7. The reinforcement steel cage shall be placed and secured symmetrically about the axis of the foundation and shall be securely blocked to clear the sides of the casing.
8. Unless tremie methods for concrete placement are approved by the Engineer, the casing shall be clean and free of water before the reinforcement steel and concrete are placed.
9. The drilling of holes for foundations, installation of reinforcement, placement of concrete and all appurtenant work shall be carried out in a continuous, uninterrupted operation. Once a foundation hole has been started, work shall be continuous so that concrete placement shall be completed on the foundation without interruption of the Contractor's operation and so that at no time shall work on a foundation be stopped or the drilled hole left open for any reason unless specifically approved in writing by the Engineer.
10. The method of storing and handling of casings shall be such as to avoid injury to the casings.
11. All exposed parts of the concrete foundations extending above the natural or finished ground line shall be finished smooth with a steel trowel or given a rubbed surface finished in accordance with Section 4.4.3 of Chapter 4, Concrete Works, of these Standard Specifications. The foundations for overhead tubular sign supports shall not extend more than 100mm above the finished grade unless otherwise indicated on the Contract plans. The top of the foundations shall be constructed level to provide a proper horizontal surface for erecting all traffic signs.
12. PVC electrical raceway or conduit, of the size indicated on the Contract plans with a bend radius of 600mm, shall be installed in the support foundations as indicated on the Contract plans and as directed by the Engineer.
13. Anchor bolts and PVC raceway or conduit shall be located securely in position during the placing of foundation concrete.

8.6.3 Overhead Tubular Sign Supports

a. The overhead tubular sign supports which are to be installed to support sign panels over the motorway (independent of other motorway structures) shall be as indicated on the Contract plans.

   1. The span of overhead tubular sign supports shall be as indicated on the Contract plans. The span shall carry the sign panels and also support a maintenance walkway.
   2. The tubular overhead sign supports shall be fabricated of galvanized steel pipe complying with ASTM A53M - 10, Type S, Grade B, as specified in Section 30.10.6 of Chapter 30, Miscellaneous Metals, of these Standard Specifications, unless otherwise indicated on the Contract plans or specified in the Particular Specifications. All other steel shapes and members of overhead tubular sign supports shall be fabricated of ASTM A36M - A36M - 2008 steel, all galvanized and all in compliance with Section 23.4.10 of Chapter 23, Steel Structures, of these Standard Specifications.

      All pipe railings shall be as indicated on the Contract plans and shall comply with the requirements of Section 27.3.2.1 of chapter 27, Railings, of these Standard Specifications. All pipe railing shall be galvanized and painted.

      All grating shall be galvanized steel grating, press-locked, rectangular design, with main bars and cross bars as indicated on the Contract plans. Spacing of all bars shall be as indicated. Main bars and cross bars shall be slotted at their intersections so as not to remove excessive material from the sustaining members. Main members shall be dovetail slotted and have their slots solidly filled by the cross bars. All fasteners, clips and similar appurtenances shall be galvanized steel or approved non-corrosive material. All materials and galvanizing including grating, shall comply with the requirements of Section 23.4.10 of Chapter 23, Steel Structures, of these Standard Specifications.

The Contractor shall prepare and submit shop fabrication drawings, in accordance with Section 1.15 of Chapter 1, General Requirements, and Section 23.3 of Chapter 23, Steel Structures, for the overhead tubular sign supports, including connections and walkways, to the Engineer for approval prior to fabrication.

3. Anchor bolts for the overhead tubular sign supports shall conform to the requirements of ASTM A307 –10 with minimum yield strength of 420 MPa. The anchor bolts shall be of the sizes and dimensions as indicated on the Contract plans. Fabrication details of anchor bolts are as noted on the Contract plans. Threaded ends of anchor bolts, to a minimum of 50mm into the concrete, and nuts are to be hot-dipped galvanized in accordance with ASTM A153 / A153M – 09 unless otherwise indicated on the Contract plans. Each bolt in the anchor bolt assembly shall have a threaded section and the bolts shall be double hex nutted for leveling purposes and complete with hardened washers.
4. Fabrication and inspection of overhead tubular sign supports, including connections and walkways, shall be governed by the applicable requirements of Chapter 23, Steel Structures, of these Standard Specifications.
5. All metal surfaces of overhead tubular sign supports shall be prepared and painted in accordance with all applicable requirements of Chapter 24, painting, of these Standard Specifications.

b. Any structural members having welds deemed to be unsatisfactory shall be removed by mechanical means, reannealed, rewelded and reheat treated, or they shall be replaced by new structural members having satisfactory welds. Flame cutting will not be permitted.

c. When the overhead tubular sign supports are placed on the concrete foundation, the nuts supporting the tubular post base plates shall be adjusted to bring the bottom of the base plate level with the top of the cap foundation and to bring the post to a true vertical plane. The nuts on top of the base plate shall then be tightened securely. Springing or racking of overhead tubular sign supports will not be permitted by the Engineer.

After the base plates of the overhead tubular sign supports are at their respective elevation and the end tubular posts are in a true vertical or sloping plane as indicated on the Contract plans, a grout mixture consisting of one part Portland cement and one part of clean fine sand mixed with sufficient water to produce a workable grout mix shall be forced under the base plate after the tubular post is in place so that, after curing, it shall be in contact with the bottom of the base plate at all points. No additional load shall be placed on the end frame until the grout has set at least 72 hours.

Where overhead tubular sign supports are to be anchored on concrete median barriers, the attachment shall be made as indicated on the Contract plans. No part of the tubular post, base, or concrete support shall extend beyond the inside face of barrier. The Contractor shall notify the Engineer in writing at least two weeks prior to the date the Contractor wishes to erect the overhead tubular sign supports.

The maintenance walkway and the lantern support channels shall be supported by "L" shaped hanger arms. The hanger arms shall be fabricated of structural steel shapes as indicated on the Contract plans and shall be attached to the overhead tubular sign supports with steel and associated hardware. The horizontal portions of these "L" shaped hangers are to support the sign lighting fixtures, the lantern support channels, and the maintenance walkways made of steel gratings with folding handrails made of steel bars and fittings, all as indicated on the

Contract plans. The maintenance walkways on overhead tubular sign supports shall extend as indicated on the Contract plans.

All electrical work for the sign lighting shall be as specified in Chapter 10, Lighting and Electrical Distribution Works, of these Standard Specifications. Lanterns for sign lighting shall be located only between hanger arms.

The vertical clearance is measured from the bottom of the horizontal portion of the hanger arm to the highest point of the roadway cross section. The minimum vertical clearance under the lowest point of sign panels, overhead tubular sign supports, walkways or other related construction for signs over the roadway or interchange shall be 6.0 meters.

8.6.4 Mounting of Overhead Sign Panels

a. Sign panels shall be erected so that the bottom of the sign panels is as indicated on the Contract plans, or as directed by the Engineer.

b. Extruded panels shall be horizontal, unless specified otherwise, and the panel faces shall be flush within commercial extrusion tolerances after erection of the sign panels is complete.

c. The shank of the post clip bolts shall fit tightly against the post flange after nuts are torqued tight. Use post clips on both sides of each post at the top and bottom of the sign. Intermediate clips shall be placed on 300mm maximum centers on each post and shall alternate left to right on each post for sign panels less than 7 meters in width. For signs having a width of 7 meters or greater, the intermediate clips shall be placed on both sides of each post on 300mm maximum centers.

d. Sign panels of equal height shall be centered vertically on the horizontal member of the overhead tubular sign support. When signs of different heights are to be mounted on the same side of the horizontal member of the overhead tubular sign support, the sign of smaller height shall be centered on the horizontal member of the overhead tubular sign support and the sign of greater height shall be mounted so that the bottom of such sign is in line with and level with the sign of smaller height.

e. All overhead sign panels shall be erected so that the panel or panels are centered over the lane or lanes for which the message is intended. The sign shall be mounted on the overhead tubular sign support in the manner indicated on the Contract plans.

8.7 Special Designation Signs

Special Designation Signs shall be erected in locations as directed by the Engineer. The purpose of these signs is to identify places of significant interest to the public such as public gardens, clinics, public agencies and other similar landmarks. Appropriate sign messages for each landmark shall be approved by the Engineer.

The size and shape of the sign panels for Special Designations Signs shall vary in accordance with the sign message given in both Arabic and English. Arabic lettering height shall be 100mm (nominal) and English lettering height shall be 70mm. Sign messages shall be white lettering on a blue background with a 30mm wide white border. All reflective sheeting shall be high intensity grade.

Signs wider than one meter shall be mounted on two posts.

All requirements of Section 8.5, shall apply to the Special Designation signs.

INDEX

STANDARD CONSTRUCTION SPECIFICATIONS

PART 1

ROADS

CHAPTER 9 - TRAFFIC CONTROL SYSTEM

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

Chapter 9: Traffic Control System

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9 TRAFFIC CONTROL SYSTEM

In addition to the requirements specified herein, the ITS and traffic control system equipment shall comply with the requirements of the ADQCC (TR-529) Traffic Signals and Electronic Warning and Information Systems Manual.

This specification describes the requirements for the traffic signal system and the Intelligent Transportation System (ITS) subsystems, infrastructure and equipment. The traffic signal system includes the installation of the ITS at the traffic signals. The ITS specification provides for other ITS that may be required within the project. The ITS specification shall be read in conjunction with the requirements of the latest version of the Department of Transport ITS Design Manual and the Department of Transport ITS Requirements.

All traffic signal poles, signal heads, detector loops and amplifiers, traffic controllers, cables, mounting poles, cabinets, enclosures, ITS devices, cables and appurtenant work for the complete traffic system and ITS shall be provided and installed under this contract by an Owner preapproved Subcontractor. Civil works, including the earthworks, foundations, pullboxes, conduits, other poles and pylons as otherwise specified herein, and electric service extending from the power sources to the traffic signal controllers, field equipment cabinet, ITS devices, and poles shall be provided and installed by the main Contractor.

Although the traffic violation recording (TVR) enforcement system is not under the jurisdiction of the Owner, the Contractor shall furnish and install the necessary civil infrastructure (foundation, duct, pullboxes) in accordance with the requirements of the relevant Authority as may be included in the Contract plans, Particular Specifications, Bills of Quantities and as approved by the Engineer.

In the case that the Traffic signal systems or ITS contractor is the main Contractor, the responsibilities assigned to the applicable subcontractor, shall be the responsibility of the main Contractor.

9.1 Reference Standards and Codes

Standards and codes shall be as specified in these specifications, in the Contract documents, if any, and the following, in their latest edition:

AAMA	Architectural Aluminium Manufacturers Association;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Factor Design, Bridge Construction Specifications;
AASHTO LRFD	American Association of State Highway and Transportation Officials - Load and Resistance Fact or Design, Bridge Design Specifications;
AASHTO	Standard Specifications for Transportation Materials and Methods of Sampling and Testing;
AASHTO LTS-5-12	Standard Specifications for Structural Supports of Highway Signs, Luminaires, and Traffic Signals;
ADQCC (TR-529)	Traffic Signals and Electronic Warning and Information Systems Manual;
ASTM	American Society for Testing and Materials;
AWS	American Welding Society;
BS	British Standards;
BS EN	European Standards;
EN AW	European Aluminum Standards - Key to Metals;

IEC 337-1	Internation Electrotechnical Commission - Low-voltage switchgear and controlgear. Part 5: Control circuit devices and switching elements - Section One: Electromechanical control circuit devices, 1990;
IPCEA-NEMA	Insulated Power Cable Engineers Association, Library of Congress TK3307 I5;
IMSA. IMSA 51-3	International Municipal Signal Association - Cross linked polyethylene insulated loop detector wire;
IMSA-	International Municipal Signal Association, 2013.
IMSA 50-2	International Municipal Signal Association - Polyethylene insulated, polyethylene jacketed, loop detector lead-in cable;
ISO 9227:2012	International Organization for Standardization - Corrosion tests in artificial atmospheres -- Salt spray tests;
ITE	Institute of Transportation Engineers.

Table 9-1 and Table 9-2 presents American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing and Materials (ASTM), British (BS), and European (BS EN) Standards that are related to materials for traffic control system works. It also includes designations and titles.

Table 9-1: Designations and titles for AASHTO and ASTM standards that apply to traffic control system works

AASHTO Designation	ASTM Designation	Title
	ASTM A307 - 12	Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.
	ASTM A153 / A153M - 09	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
	ASTM A36 / A36M - 12	Standard Specification for Carbon Structural Steel.
	ASTM B221 - 12a	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes.
	ASTM B209 - 10	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.
	ASTM A193 / A193M - 12b	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
	ASTM A194 / A194M - 12a	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
	ASTM A240 / A240M - 12a	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
	ASTM B3 - 12	Standard Specification for Soft or Annealed Copper Wire.

AASHTO Designation	ASTM Designation	Title
	ASTM B189 - 05(2010)	Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes.
	ASTM B8 - 11	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
	ASTM B33 - 10	Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes.
	ASTM D1248 - 12	Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable.
	ASTM D1047 - 11	Standard Specification for Poly(Vinyl Chloride) Jacket for Wire and Cable.
	ASTM D372-00(2006)	Standard Specification for Flexible Treated Sleeving Used for Electrical Insulation (Withdrawn 2012).
	ASTM A27 / A27M - 10	Standard Specification for Steel Castings, Carbon, for General Application.
	ASTM A606 / A606M - 09a	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance.
AASHTO M 111M/M 111		Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
	ASTM B85 / B85M - 10	Standard Specification for Aluminum-Alloy Die Castings.
	ASTM B108 / B108M - 12e1	Standard Specification for Aluminum-Alloy Permanent Mold Castings.
	ASTM B209 - 10	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.

Table 9-2: Designations and titles for BS and BS EN standards that apply to traffic control system works

BS Designation	BS EN Designation	Title
	BS EN 12368-2006	Traffic Control Equipment. Signal Heads.
	BS EN 12966-1:2005+A1:2009	Road vertical signs. Variable message traffic signs. Product standard

BS Designation	BS EN Designation	Title
	BS EN 12899-1:2007	Fixed, vertical road traffic signs. Fixed signs.

9.2 Foundations, Pullboxes and Conduits

Main Contractor shall complete all civil works, including earthworks, grading, foundations, pullboxes and conduits for the traffic. Civil work shall include installing conduits to the power source and the handhole or pullbox outside the power source as part of this work specified in this section.

9.2.1 Description

Foundations and conduits for the traffic control system and Intelligent transportation system (ITS) shall be as shown on the Contract plans, as specified herein and included in the Bills of Quantities. Work shall include, but not by way of limitation, furnishing and installing cast-in-place concrete foundations for:

- traffic signal and ITS poles;
- ITS gantries;
- traffic signal controllers and artery master controllers;
- field equipment cabinets;
- changeover switch (automatic transfer switch);
- uninterruptible power supply (UPS);
- communications cabinets;
- video surveillance system (VSS) camera poles;
- pullboxes; and
- concrete-encased and non concrete encased conduits

as indicated on the Contract plans. The installation shall also include all required anchor bolts, conduit, ground rods, pullboxes, manholes and interconnecting concrete-encased conduits to the foundations and to the detector loops and power source.

9.2.2 Materials

Materials to be furnished and installed for the traffic control system foundations, pullboxes and conduit shall be as indicated on the Contract plans, as specified herein and as approved by the Engineer

9.2.2.1 Approval of Materials

Within 90 days after award of the Contract and before work is performed, the Contractor shall submit samples of all materials that will be used in this work for approval of the Engineer.

9.2.2.2 Conduit

PVC conduit used for conduit and ducts shall meet the requirements for PVC electrical conduit specified in Section 10.4.3, Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications.

Galvanized metal conduit at pullboxes shall comply with the applicable clauses in Section 10.4.2, Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications.

9.2.2.3 Concrete

All concrete for foundations, pullboxes and concrete-encased conduct and ducts shall comply with the applicable requirements of Section 4.3 of Chapter 4, Concrete works, of these standard specifications.

9.2.2.4 Covers and Frames

Contractor shall furnish and install watertight ductile iron covers and frames as indicated on the Contract plans and as specified herein.

Covers and frames shall be ductile iron meeting the requirements for ductile iron covers and frames specified in Article 12.3.2.3 of Chapter 12, Stormwater Drainage, of these standard specifications. Rubber gasket seals shall be provided for watertightness and the covers shall be bolted to the frames with countersunk stainless steel hex head cap screws.

Most covers and frames will be installed in non-traffic green or sidewalk areas and these shall be medium duty. Covers and frames installed in paved traffic areas shall be heavy duty.

All covers or frames shall be identified with the words "T.C.S Traffic Control System" in both Arabic and English cast into the surface of the ductile iron as approved by the Engineer.

All covers and frames shall be coated on all exposed surfaces with coat tar epoxy meeting the requirements of Section 24.5 of Chapter 24, Painting.

Covers shall be equipped with cast-in lifting eyes, holes or other handling facilities and shall be made in sections as required for larger sizes (1.2 m and larger in one direction) to facilitate removal and lifting unless otherwise shown on the Contract plans or approved by the Engineer.

Contractor shall supply one prying and lifting bar of approved design for each 30 covers (minimum of one tool for every type cover). Prying and lifting bars shall be of approved appropriate design to match the different cover configurations.

Covers shall have two keyed locking devices, one on each end, meeting the requirements of Article 12.3.2.3 of Chapter 12, Stormwater Drainage, of these standard specifications, as directed by the Engineer.

9.2.3 Construction Requirements

Construction and installation of the traffic control system foundations, pullboxes and conduits (includes ducts) shall be as indicated on the Contract plans, as specified herein and as directed by the Engineer.

9.2.3.1 General

Contractor shall furnish and install all traffic signal system and the VSS control system foundations, pullboxes and conduits (also referred to as the traffic control system civil works), which consists of concrete-encased conduit, manholes, pullboxes, junction boxes, concrete foundations for traffic signal poles, controllers and VSS Camera poles and provisions for VSS camera mountings under bridge structures or other structures e.g. retaining wall structures in concrete canyons, where indicated on the Contract plans and as included in the Bills of Quantities. Work shall include, but not by way of limitation, all labour, materials, tools, equipment and appurtenances.

The Design Consultant shall perform a horizontal and vertical clash analysis during the development of the design to determine and resolve conflicts between the ITS infrastructure and the utilities. The Contractor is responsible for identifying onsite conflicts between the ITS infrastructure and the utilities. The Design Consultant and Contractor are responsible for resolving any conflicts between the ITS infrastructure and the utilities, particularly if an ITS corridor has not been allocated within the service reservation corridor.

Traffic signal system and the ITS layouts as shown on the Contract plans are schematic. Contractor shall verify all information such as locations, specifications, construction restrictions, protection requirements and other data which shall be obtained by requesting the required information from the Engineer who will forward the written request to the Owner.

Installation of the traffic signal system and ITS civil works shall include all excavation and backfilling, all required foundations complete with anchor bolts, conduit as indicated on the Contract plans, and all ancillary and related work. Contractor shall verify the locations of the control system foundations, the sizes of the controller foundations, the sizes of pole foundations and the anchor bolt sizes, locations, and orientation for all foundations with the manufacturer and the Engineer before placement of any foundations. The Engineer's representative shall confirm the exact location of all traffic signal system and ITS equipment on site with the Contractor prior to installation.

This work shall comply with the applicable Sections in the following Chapters of these Standard Specifications:

- Chapter 2, Earthworks
- Chapter 4, Concrete Works
- Chapter 11, Utilities
- Chapter 12, Stormwater Drainage

9.2.3.2 Foundations

Foundations for the traffic signal system (various types – traffic signal poles, mast arms, pedestrian signal pole/pylons, and free right turn signal poles), traffic violation camera poles, VSS system (various types), traffic signal controller, ITS control cabinet, changeover switch, and UPS foundations shall be as indicated on the Contract plans. Number of anchor bolts, bolt locations, and anchor bolt dimensions shall be verified by the Contractor, as specified in these Standard Specifications or in the Particular Specifications. Projecting portion of the anchor bolts and the nut and washer shall be treated by hot-dip galvanizing. Raceway or conduit in various types of foundations for traffic signal and VSS support shall consist of PVC conduit or raceways with a bending radius as indicated on the Contract plans.

All concrete for the traffic signal system (various types) and the ITS (various types) shall be cast-in-place, Class C25/20. All concrete work shall comply with all applicable requirements of Chapter 4, Concrete Works. Foundations shall be allowed to cure a minimum of 7 days before erecting poles, cabinets, or traffic signal controllers.

All reinforcement steel in traffic signal system foundations and ITS system foundations shall be steel reinforcement bars complying with the requirements of Chapter 5, Reinforcing Steel. Reinforcing bars shall be uncoated plain deformed bars unless otherwise shown on the Contract plans.

Anchor bolts for the support poles shall comply with the requirements of ASTM A307, Grade A. The anchor bolts shall be capable of supporting the traffic signal supports and signal heads with the maximum bending moment. Bolts and nuts shall be hot-dip galvanized in accordance with ASTM A153.

All foundations shall be furnished with an earth electrode complying with Article 10.14.10.3 of Chapter 10, Lighting and Electrical Distribution Works, of these standard specifications. Type, size and installation of the earth electrode shall comply with Section 10.14.10.3 of Chapter 10, unless otherwise indicated on the Contract plans.

Holes for foundations shall be excavated to the dimensions required for construction. All excavating and backfilling shall comply with the requirements of Section 2.4 and 2.5 of Chapter 2, Earthworks. All unsuitable excavated materials shall be disposed of by the Contractor in accordance with Article 2.4.2.7, Disposal of unsuitable or excess material, of Chapter 2. Excavated materials that are unsuitable shall not be used as backfill. All backfill shall be approved material compacted, in layers not to exceed 15 cm, to at least 95 % of the material's maximum density in accordance with Section 2.5.3.2, Structural Backfill, of Chapter 2, Earthworks.

Numbers and dimensions of anchor bolts, diameter of bolt circles and sizing of base plates as indicated on the Contract plans are for description purposes only and shall be subject to the approval of the Engineer. Before placing concrete for any foundation, the Contractor shall verify size, location and related data of the foundation and anchor bolts with the Engineer.

PVC electrical raceways or conduit, of the size and bend radius indicated on the Contract plans, shall be installed in the support foundations as indicated on the Contract plans and as directed by the Engineer.

Anchor bolts, ground rods and PVC conduits (or raceways and ducts) shall be located securely in position by the use of templates during the placing of foundation concrete.

a. Foundations for Traffic Signals, Type C and D

Contractor shall include the furnishing and installing of all materials required for the construction of reinforced concrete foundations for traffic signals, Type C and D. Foundations shall be in accordance with dimensions as indicated on the Contract plans and in accordance with these Standard Specifications.

Number of anchor bolts, bolt locations, and anchor bolt dimensions shall be verified by the Contractor, as specified in these Standard Specifications or in the Particular Specifications. Projecting portion of the anchor bolts and the nut and washer shall be treated by hot-dip galvanizing. Raceway or conduit in traffic signal supports shall consist of PVC conduit or raceways with a bending radius as indicated on the Contract plans.

Traffic signal foundations type C and D shall be drilled or bored in the manner, at the locations and to the penetration or depth indicated on the Contract plans, as specified herein and as approved by the Engineer. Foundation construction shall meet the applicable requirements of Chapter 17, Drilled Piles, and as specified herein.

Prior to proceeding with any foundation work for traffic signals, type C and D supports, the Contractor shall submit to the Engineer for approval, shop drawings, complete details, calculations for temporary or permanent metal casings, equipment data, and related particulars concerning the completion of the proposed traffic signal foundations, type C and D. Shop drawings shall also indicate the proposed method of conduit installation in the foundation. Method of installation shall be subject to approval of the Engineer.

Lengths indicated on the Contract plans are the estimated lengths to be required for the traffic signal foundations, type C and D. Final lengths of foundations shall be approved by the Engineer based upon actual conditions encountered in drilling or boring. Contractor shall make his own analysis of the subsoil conditions and work that will be required to provide the drilled or bored concrete foundation as specified.

All traffic signal foundations, type C and D, shall be cast-in-place Class C30/20 concrete. All concrete work shall comply with the applicable requirements of Chapter 4, Concrete works. Foundations shall be allowed to cure a minimum of 7 days before erecting traffic signals on the foundations, type C and D.

All reinforcement steel in traffic signal foundations, type C and D, shall be in compliance with the requirements of Chapter 5, Reinforcing Steel.

Anchor bolts for the support poles shall comply with the requirements of ASTM A307, Grade A. Anchor bolts shall be capable of supporting the traffic signal supports and signal heads with the maximum bending moment. Bolts and nuts shall be hot-dip galvanized in accordance with ASTM A153.

All foundations for traffic signal and VSS supports shall be furnished with an earth electrode complying with Article 10.14.10.3 of Chapter 10, of these standard specifications. The earth electrode shall be located as near as practicable to the foundation, as directed by the Engineer. Size of the earth electrode shall comply with Article 10.14.10.3 of Chapter 10, unless otherwise indicated on the Contract plans.

Construction of all foundations, type C and D, for traffic signals shall comply with the following requirements:

1. All excavations for these foundations shall be made by drilling, boring or sinking a casing in accordance with Chapter 17, Drilled Piles.
2. Contractor shall be responsible for testing all soil at the bearing levels indicated on the Contract plans, and shall submit written reports to the Engineer as to the bearing capacity at the depth indicated on the Contract plans and the coefficient of lateral subgrade reaction over the proposed length of pile, and the acceptability of such soil to support the proposed foundation and appurtenances.
3. Contractor shall make boreholes to depths, locations and frequencies as directed by the Engineer. Frequency and depth of the boreholes shall depend upon the soil conditions encountered and shall be at the discretion of the Engineer. Total number of boreholes may or may not be equal to the total number of traffic signal foundations, type C and D. Report on each borehole made shall include all information as directed by the Engineer and specified in Article 2.1.3.2 of Chapter 2, Earthworks.
4. In the event unsuitable soil is encountered throughout the length indicated on the Contract plans for the traffic signal foundations, type C and D, the Contractor shall advise the Engineer as to the unsuitability of such soil materials. Contractor shall be responsible for designing the extension of the depth of such traffic signal foundations to acceptable bearing. Design of such foundations shall be in accordance with the applicable requirements of the "Drilled Shaft Manual", Volume II, Implementation Package 77-21, as published by the U.S. Department of Transportation Office of Research and Development, Implementation Division HDV-22, Washington, D.C. 20590, and as required in Chapter 17, Drilled Piles, of these standard specifications.
5. Contractor shall employ an independent chartered engineer or registered engineer as approved by the Owner or the Engineer to design the increased depth of any such foundations. Contractor shall submit design calculations and other data required by the Engineer for review before proceeding with extending the depth of such foundations.
6. Need for additional foundation depth shall be at the sole discretion of the Engineer.
7. Contractor shall not proceed with further construction of such foundations until receiving written directions from the Engineer. In the event the depths of the foundations are lowered below the elevations indicated on the Contract plans and as approved by the Engineer, the additional depths will be paid for as specified herein, or in the Particular Specifications, or the Bills of Quantities.
8. All drilled foundations shall be installed in the presence of the Engineer. Engineer shall be notified in writing a minimum of 48 hours in advance that the Contractor is commencing operations to install drilled foundations so that the Engineer can be present during the foundation work on a daily basis throughout the installation of the foundations. All foundations shall be located to the lines and spacing indicated on the Contract plans and shall be drilled vertically with a tolerance of one in fifty.
9. In cases where the intended bottom of foundation is in water, bailing will not be permitted by the Engineer. Contractor shall take measures to ensure that the ground beneath the base of the drilled or bored excavation is not disturbed by upward seepage pressure. In such cases the Contractor shall ensure the stability of the excavation base by maintaining a net positive hydraulic head within the casing. Concrete shall be placed by tremie in accordance with the requirements of Article 4.4.1.7 of Chapter 4, Concrete Works, of these Standard Specifications, all subject to the approval of the Engineer.
10. Foundations shall be drilled with a casing being installed such that the bottom of the casing is maintained below the bottom of the excavation at all times. If approved by the Engineer, the casing may be withdrawn as the concrete is placed provided the bottom of the casing is maintained below the top of the concrete while the concrete is being placed and if the reinforcement, anchor bolts, and conduit can be maintained in their correct position during the casing withdrawal. Otherwise, the casing must be left permanently in place unless alternative construction methods are approved by the Engineer.
11. In the event that conditions, during drilling of holes for the foundations, indicate that a drilled foundation is encountering an obstruction before reaching proper bearing stratum, the Contractor shall bore or drill through the obstruction (after confirming that it is not an

underground utility) or shall use whatever means are necessary to remove or circumvent the obstruction, without additional cost to the Owner.

12. In the event the Contractor excavates to an elevation below that indicated on the Contract plans or approved by the Engineer, the Contractor shall furnish and place Class C15 concrete up to the bottom of the foundation as indicated on the Contract plans or as directed or approved by the Engineer at no additional cost to the Owner.
13. Reinforcement steel cage shall be placed and secured symmetrically about the axis of the foundation and shall be securely blocked to clear the sides of the casing.
14. Unless tremie methods for concrete placement are approved by the Engineer, the casing shall be clean and free of water before the reinforcement steel and concrete are placed.
15. Drilling of holes for foundations, installation of reinforcement, placement of concrete and all appurtenant work shall be carried out in a continuous, uninterrupted operation. Once a foundation hole has been started, work shall be continuous so that concrete placement shall be completed on the foundation without interruption of the Contractor's operation and so that at no time shall work on a foundation be stopped or the drilled hole left open for any reason unless specifically approved in writing by the Engineer.
16. Method of storing and handling of casings shall be such as to avoid damage to the casings.
17. All exposed parts of the concrete foundations extending above the natural or finished ground line shall be given a Class 1 finish in accordance with Section 4.4.3 of Chapter 4, Concrete works. Foundations, type C and D, for traffic signals shall not extend more than 100 mm above the finished grade unless otherwise indicated on the Contract plans. Top of the foundations shall be constructed level to provide a proper horizontal surface for erecting all traffic signals.
18. PVC electrical raceway or conduit, of the size and bend radius as indicated on the Contract plans, shall be installed in the support foundations as indicated on the Contract plans and as directed by the Engineer.
19. Anchor bolts and PVC raceway or conduit shall be located securely in position during the placing of foundation concrete.

9.2.3.3 Cable and Conduit (Direct Bury)

This work shall consist of constructing a trench for the accommodation of the electric cable or PVC conduit (or ducts) and backfilling it at the locations indicated on the Contract plans. Included is the furnishing of the backfill materials and disposing of the surplus materials all in accordance with Sections 2.4 and 2.5 of Chapter 2, Earthworks. Trenches shall be excavated to a depth and width as indicated on the Contract plans, but in no case shall the depth be less than 534 mm and the width be less than 400 mm unless otherwise directed by the Engineer. All trench and backfill shall comply with the requirements of Section 2.4 and other applicable Sections in Chapter 2, Earthworks.

Electric cable for the traffic controller shall be placed in the bottom of the trench and covered with backfill material as directed by the Engineer.

Backfill material shall be thoroughly compacted to a density as required by Article 2.5.3.4, Compacting embankments, of Chapter 2, Earthworks, and in such a manner as not to injure the electric cable.

Method and type of equipment to be used in compacting the backfill material shall be approved by the Engineer before any work is started.

Installation and handling of PVC conduit shall meet the additional requirements in Section 10.4.3 of Chapter 10, Lighting and Electrical Distribution Works, as applicable.

9.2.3.4 Conduit (Concrete-encased)

This work shall consist of furnishing and installing PVC conduit (or ducts) concrete-encased to provide and permit the future routing, by others, of electric cable required for the traffic control system under the roadway.

Ducts shall be encased in Class C25/20 concrete complying with the applicable Sections in Chapter 4, Concrete Works. Installation of conduits shall be as indicated on the Contract plans and as required in Section 10.12.3 of Chapter 10.

All excavating and backfilling shall be in accordance with applicable requirements of Sections 2.4 and 2.5 of Chapter 2, Earthworks.

Centreline of the duct shall be as indicated on the Contract plans.

9.2.3.5 Pullboxes (Manholes)

Contractor shall furnish and install pullboxes (manholes) of the various types for the traffic control system as indicated on the Contract plans, as specified herein and as directed by the Engineer. Locations of pullboxes shall be determined on the site to suit the existing conditions. Final locations shall be subject to the approval of the Engineer.

All excavating and backfilling shall comply with the applicable requirements of Sections 2.4 and 2.5 of Chapter 2, Earthworks. Pullboxes shall be reinforced, cast-in-situ Class C25 concrete complying with the dimensions and details indicated on the Contract plans. Concrete work shall meet the applicable requirements of Chapter 4, Concrete Works. Underside of the bottom slab and external faces of concrete walls shall be protected with Type A membrane complying with the applicable requirements of Section 28.2 of Chapter 28, Waterproofing.

All covers shall be of the dimensions required to fit the respective pullboxes as shown on the Contract plans. Pullbox covers and frames shall be installed level and square, cast-in-situ with the concrete work for the upper portion of the pullbox, or as shown on the Contract plans. All covers in traffic areas shall be checked to ensure that they are non-rocking and watertight. Contractor shall take any measures approved by the Engineer, if the covers and/or frames need to be modified to be non-rocking and watertight.

Installation of pull boxes shall meet the applicable requirements of 12.3.4, Pull boxes, service chambers and vaults and as specified herein

The conduits and pullboxes when completed shall be tested to the satisfaction of the Engineer for watertightness, straightness and continuity. The method of testing shall be determined by the Engineer. No additional payment will be made by the Owner for testing.

All pullboxes for the interconnection conduits installed within the service reservations shall be spaced a maximum of 100 m on centre unless otherwise indicated on the Contract plans or specified in the Particular Specifications.

Installation of metal conduit at pullboxes shall be in accordance with Section 10.12.4 of Chapter 10.

9.3 Pedestrian Poles

9.3.1 Description

Contractor shall replace existing pedestrian pylons where shown on the Contract plans and as directed by the Engineer. Existing pedestrian pylons shall not be reinstated after removal. Pedestrian pylons shall not be installed at new signalised intersections or midblock pedestrian crossings.

All pedestrian poles shall be complete, in place, with all components as specified, as indicated on the Contract plans and as required for the installation. Pedestrian poles shall be of the type as indicated on the Contract plans.

9.3.2 Materials

Pedestrian poles shall be as indicated on the Contract plans and as specified herein.

Pedestrian poles shall include, but not by way of limitation, electrical wiring and work within the poles to the handhole in the supporting base or post, and all appurtenances and incidentals required for the installation of the poles. All pedestrian poles shall be complete with all electrical lighting fixtures, lamps, ballasts, and internal wiring. Further, each pedestrian pole shall be provided with an electrical protective device such as a fuse. Protective device shall be located in a suitable, accessible location in the pedestrian pole.

Contractor shall submit to the Engineer for approval, detailed shop drawings, material samples and such other data as may be required by the Engineer for the pedestrian poles, in accordance with Section 1.15, Submittal Procedures, of Chapter 1, General Requirements. Accompanying the shop drawings, the Contractor shall submit colour samples on typical shapes for approval by the Engineer as well as certificates that the colour finish meets Specification requirements.

Based upon the data as approved by the Engineer, and prior to production of all units, the Contractor shall furnish and install a complete, operative and detailed prototype of the pedestrian pole for approval by the Owner as confirmed by the Engineer. No pedestrian pole shall be fabricated and delivered before the prototype has been approved by the Owner.

All materials shall be as indicated on the Contract plans and as specified. All metal shall be of suitable thickness and reinforced as required to ensure adequate structural strength and to prevent buckling, warping and/or denting. Pedestrian poles and pylons shall be internally illuminated with cut out messages and other signs if the type requires it, as shown on the Contract plans, and as directed by the Engineer. Locks on the access doors shall be approved by the Owner and shall be master keyed as directed by the Engineer or Owner. All keys shall be delivered to the Engineer to be forwarded to the Owner. All fasteners shall be concealed.

Materials of all parts used in the pedestrian pole shall be new and shall be the best of their respective kind and most suitable for the local climatic conditions, thus withstanding the variations of temperature and other prevailing conditions without distortion or deterioration of any part of the pylon. In every case where a standard has been established for a particular type of material in question, the material shall comply with the provisions set forth in the standard. Equipment included in these Specifications shall be so manufactured as to facilitate easy and proper erection and maintenance. Design of all equipment shall ensure satisfactory operation under the site conditions mentioned.

Pedestrian Poles shall be fabricated to comply with the requirements of the Contract plans and as specified herein. All members and plates shall be fabricated with eased or rounded corners as detailed. All assemblies shall be made by full welding in accordance with American Welding Society standards AWS with welds finished smooth and flush with adjacent surfaces.

Removable base plate enclosure boxes shall be as detailed, fabricated of 6 mm thick ASTM A36 steel, all welded construction, with welds ground flush and smooth. Enclosure boxes shall be galvanized, prime and finish painted as specified herein. Stainless steel fasteners shall be flat, phillips head, countersunk machine screws.

Aluminium members of the pylon shall be solid, sized, and formed as indicated on the Contract plans. Aluminium shall comply with the values stated in ASTM B221 and B209. Bar shapes shall be square cornered, extruded alloy 6061-T651 and/or 6063-T5. Aluminium plate shall be alloy 6061-T651. Aluminium welding alloy shall be the type best suited, and as recommended by the aluminium manufacturer. All base plate fastening hardware shall be stainless steel. Bolts shall comply with ASTM A193, Grade B8, Class 2; nuts shall comply with ASTM A194, Grade 8; and flat washers with ASTM A240, Type 302.

After compete fabrication, the pedestrian pole units specified to receive colour coating shall be factory chemically pre-treated, then receive a thermocured inhibitive primer, then a factory applied fluoropolymer resin colour coating complying with the requirements of AAMA 2605, followed by a clear, transparent protective topcoat.

Finish colour coating shall be matte finish and shall match the AAMA dark bronze anodized finish colour. Any surfaces or colour coating damaged during delivery shall be repaired or recoated to the satisfaction of the Engineer.

9.3.3 Construction Requirements

All signal heads, control mechanisms, cables, outside conduit not indicated on the Contract plans, appurtenant work and final hook-up of the poles will be by a specialist subcontractor pre-approved by the Owner.

Contractor shall include complete furnishing and installing of the pedestrian poles as included in the Bills of Quantities. Work for the pedestrian pole shall include all materials, labour, tools, equipment and appurtenances to complete the Pedestrian Pole installation. Holes shall be provided in the base plate to allow conduits to pass through same. Handholes shall be provided in the pedestrian poles to allow connection of all wiring.

Pedestrian poles shall be provided with a fuse of adequate capacity in the base. Electrical wiring within the pedestrian poles shall be earthed and bonded in accordance with the requirements of Section 10.11.10, Grounding and Bonding, of Chapter 10.

Contractor shall verify location and size of conduit, height of conduit above top of foundation and similar details with the Engineer and the manufacturer before proceeding with this work.

All conduit, cable and electrical wiring to the poles shall be included by the Contractor as a part of this Item and shall comply with the requirements specified in the applicable clauses of Chapter 10, Lighting and Electrical Distribution Works.

All exposed surfaces and message panels shall be suitably cleaned before approval by the Engineer and/or acceptance by the Owner.

9.4 Existing and Temporary Traffic Signals

9.4.1 Description

Maintenance, removal and disposal of the existing traffic signals and existing traffic signal controllers shall be as indicated on the Contract plans, as specified herein and as directed by the Engineer. This section applies only to temporary signals and those existing traffic signals that are to be removed/replaced by the Contractor. All other traffic signals to remain within the contract limits will be maintained by the Owner.

9.4.2 Materials

9.4.2.1 General

Contractor shall assume full maintenance responsibility for any temporary signals and for existing traffic signals and controllers that are to be removed and/or replaced within the contract limits. Contractor shall obtain all information from examination of the existing installations or from the installers of the existing traffic signals and controllers. Maintenance shall include, but not by way of limitation, the power to the units, controls for units, relamping as required, repair and replacement of damaged units or other maintenance as required for the continued operation of such existing units. Maintenance shall be round-the-clock (24 hours) and not during working hours only - necessary staff shall be on duty for this purpose till the need for the temporary signals is not required, as directed by the Engineer.

9.4.2.2 Technical Requirements

Temporary signal assembly shall have the following capabilities:

1. All temporary traffic signal controllers shall be similar. When there is more than one temporary signal in the project site, a master-slave controller concept shall be implemented.
2. All vehicular, pedestrian signal heads, and countdown counters shall comply with their respective specification mentioned elsewhere in these specifications.
3. It shall be installed on prefabricated concrete blocks as shown on the Contract plans or on other means as approved by the Engineer.
4. It shall include wireless communication capability in order to send/receive data to/from the nearby central control unit (master controller) up to 150 m. Wireless band shall fit within the license-free band available at that location.
5. It shall include a GPRS module for distant operations greater than 150 m.
6. System shall have MS-windows based software to program the signal timing plans. Timing plans shall support multiple times of the day and day of the week.
7. Contractor shall submit for review and approval signal timing plans including switching make any necessary changes to the signal timing plans as directed by the Engineer.
8. It shall support and control up to 32 groups.
9. It shall support and include vehicle sensors for sub road conditions.
10. It shall support and pedestrian signal applications.
11. It shall include and support 300 mm LED countdown clocks.
12. It shall include solar power supply kit according to the number of signal heads on each pole assembly as follows:
    i. 20 w for each signal head.
    ii. 20 w for each count down counter
    iii. Battery shall not be less than 150 Ampere-hour for 150 w assemblies and shall not be less than 250 Ampere-hour for 250 w assemblies.
    iv. Battery shall last for at least 3 continuous days at full capacity when solar supply is not available.

9.4.3 Construction Requirements

Contractor shall remove, clean, load, transport, unload, protect and store the existing traffic signals and controllers as indicated on the Contract plans, as specified herein and as approved by the Engineer.

Contractor shall provide all labour, tools, equipment and accessories to carefully remove the existing traffic signals, poles, controllers, foundations, and cables and to clean them, transport, unload and place in the Owners storeyards, as designated by the Engineer.

Contractor shall exercise care while removing the existing traffic signals, poles, controllers, foundations, cables and associated equipment so as not to damage any materials or equipment. Any materials or equipment damaged while removing, handling or transporting shall be replaced with new material or equipment or repaired as approved by the Engineer. All signal heads and similar equipment removed shall be cleaned, packed, protected and carted as approved by the Engineer. All traffic signals, poles, controllers and associated equipment shall be loaded, transported, unloaded and placed in the Owners store yards, as directed by the Engineer.

All traffic signal poles removed shall be cleaned of all concrete and deleterious material and suitably supported during handling and transporting and supported by blocking or other approved means when poles are placed in storage where directed by the Engineer or the Department. All poles shall be covered with an approved protective cover securely anchored or tied in place.

Contractor shall completely remove all foundations for traffic signal poles and controllers. Resulting excavation shall be backfilled with borrow material, as approved by the Engineer, in accordance with the applicable requirements of Section 2.5 of Chapter 2, Earthworks. Where backfilling occurs under pavement, walks, future pavement, or similar areas, the borrow material shall be placed and compacted in accordance with Section 2.5 of Chapter 2.

Prior to commencing removal of existing traffic signals and associated controllers and wiring or cables, or installation of temporary signals, the Contractor shall make all necessary arrangements with the electrical authority and include, as a part of the work of this Item, all work required to remove and dispose of the electric service to existing traffic signal controllers from the point designated by the authority or supply/remove electric service to temporary signals.

Removal of electric service to the existing traffic signals and controllers shall not commence until all temporary detours are in operation and approved by the Engineer.

9.5 Traffic Signal System

9.5.1 Description

These Standard Specifications cover descriptions and requirements of the components and materials forming part of the traffic signal system, to include all components, items, systems and sub-systems supplied and/or implemented under this Contract shall strictly comply with requirements and specifications stipulated in these documents. System shall be compatible to the existing system and operate in harmony with the existing system.

9.5.1.1 Subcontractor

All non-civil works required under this section shall be executed by an Owner pre-approved subcontractor (from herein referred to as Subcontractor). Subcontractor shall be a well established traffic control systems supplier and shall have carried out a number of works of similar nature and magnitude as this Contract. Subcontractor shall have previous experience in the hardware, software, principles and operational aspects of a computerized urban traffic control systems, and shall be technically capable of integrating the traffic signal controllers to be installed under this Contract with the existing traffic computer control system such that full compatibility is ensured.

Subcontractor shall have the necessary experience and resources to furnish, install, operate and maintain all components of the traffic control system such as signal poles and mast arms, vehicular and pedestrian signals, pedestrian pushbuttons and inductive loop detectors, automatic transfer dual power supply panels, local and master traffic signal controllers, audio and data communications system, cabling and wiring, and all other components as specified in the Particular Specifications.

Unit rates entered in the Bill of Quantities must include for all work as specified plus all on costs for the main Contractor's work, attendance, overhead and profit. Any other items necessary for the satisfactory completion of the works but not specifically mentioned in the Contract documents will be considered as subsidiary obligations to this Contract.

Main Contractor shall be responsible for the scheduling of the traffic signal works so that all works are completed by the authorized contract completion date.

9.5.1.2 Subcontractor’s Scope-of-works

Scope of work for the traffic control system subcontractor shall cover the following works and services:

1. Supply and Installation of signalized intersections, arterial progression (if required), and computer control as shown on the relevant Contract plans and in the Particular Specifications.
2. Maintenance of all installations as specified in the Particular Specifications.

9.5.1.3 System Overview

Traffic control system provides effective and progressive traffic flow conditions in the project area by utilizing the latest hardware and software, and up-to-date traffic engineering principles and procedures. Traffic system components provided under this sub-contract shall be integrated with the existing traffic control system as may exist in the project area, by providing safe, effective and progressive traffic flow conditions.

Hardware and software to be supplied and installed as part of this Project should be operationally compatible with any existing traffic control system. System to be provided as part of this Project shall consist of the following features as otherwise required in the Particular Specifications and approved by the Engineer:

1. Detection equipment shall be provided including vehicle actuation detectors, pedestrian actuation detectors and vehicle system detectors. Actuation detectors shall be used to identify demands, to assign phases and to provide information to control timing interval lengths. All vehicle loops shall be individually connected to the traffic signal controller. System detectors shall provide vehicle volume and lane occupancy information to the existing central computer in a format operationally recognizable by the existing hardware and software of the central computer.
2. Poles, mast arms, vehicular and pedestrian signals shall be provided to give specific and clear indications to motorists and pedestrians of their rights-of-way.
3. Local intersection microprocessor controllers with planning, timing, interconnection, coordination and emergency pre-emption equipment shall be provided to control and direct traffic flow at intersections. Each intersection shall be capable of stand-alone operation, subsystem interconnection and computer controlled coordination from the existing central computer. Each controller shall be capable of pre-timed, semi-actuated and fully actuated operation. Mode of operation shall be manually and remotely selectable at the controller without the use of special tools or equipment. Automatic transfer dual power supply panels shall be provided to supply power for the traffic signalling related equipment at an intersection.
4. Artery master controller may not be currently implemented in the area. Contractor shall implement an artery master controller as defined in these specifications, as directed by the Engineer and approved by the Owner. Artery master microprocessor controller shall be provided to supervise and maintain interconnection and progressive traffic flow among the designated intersections. Artery master controller shall accept information from system detectors and shall utilize such information to vary cycle lengths and offsets. Artery master microprocessor controller shall be interconnected to the local intersection traffic signal controllers by means of communication cables routed through concrete encased PVC conduits.
5. Audio transmission equipment which will provide voice communications between the central computer control centre and the designated local intersection controller cabinets shall be provided. Format and protocol of this audio communication system should be fully compatible with the existing audio communication system.
6. A data transmission system (communications system) shall be provided which shall carry commands from the central traffic control computer to the arterial master controllers and the local intersection traffic signal controller. This system shall carry controller status and traffic surveillance data from the local intersection traffic signal controllers to central traffic control computer. Data transmission system shall be fully compatible and able to be integrated with the existing central computer system and shall be connected to the central computer with cables. Cable shall be supplied and installed by the Subcontractor and Contractor in concrete encased PVC conduits. Data transmission system shall also be designed such that no more than four, 100 mm diameter ducts shall be used by the cable on any given cable run.
7. Local intersection traffic signal controllers shall be placed under the central computer control. All necessary software programming and additional hardware installation to the

central computer control system shall be done such that full compatibility and integration with the existing control programs of the central computer control system is ensured.

9.5.2 Materials

It is of great importance that all systems and sub-systems are standard products of the same manufacturer to ensure and guarantee proper interface and smooth operation of the complete system.

Subcontractor/Contractor shall submit an undertaking to guarantee the availability of the spare parts for all systems and sub-systems covered by his offer for a period of 10 years from the date of final handing-over of the system.

9.5.2.1 Standards and Codes

Traffic control equipment furnished and installed shall meet the requirements of the internationally known standards and governing codes of the regulating authority. Specific standards and codes used as a guide for the design are as follows:

AASHTO	American Association of State Highway and Transportation Officials (USA)
ASTM	American Society for Testing Materials (USA)
BSS	British Standard Specifications (UK)
CEE	International Commission on Rules for the Approval of Electrical Equipment
IEC	International Electrotechnical Commission
IMSA	International Municipal Signal Association
IPCEA	Insulated Power Cable Engineers Association (USA)
ITE	Institute of Transportation Engineers
NEMA	National Electrical Manufacturers Association (USA)
UL	Underwriters Laboratories, Inc. (USA)
NTCIP Protocol	National Transportation Communications for Intelligent Transportation System

9.5.2.2 Definitions and Abbreviations

Definitions and abbreviations used within this specification are as follows:

Actuation - shall mean the operation of a detector for placing a call or operation of an electrical circuit for transferring the right-of-way from one phase to another.

Cabinet - an outdoor enclosure for housing the controller and its associated equipment.

Detectors - are electrical devices used for indicating the approach of traffic to an intersection. And the provision of traffic counts, speeds, occupancy, queue, and classification data at per-lane and aggregate basis. Types of detectors are in-roadway (inductive loop) and over-roadway (microwave radar) detectors.

Flasher unit - a complete electrical mechanism for flashing traffic signals.

Interval - the part of signal cycle during which signal indications do not change.

Phase - the right-of-way and clearance interval in a cycle assigned to a movement or any combination of movements.

Signal face - a combination of signal sections each capable of displaying its indication in any one direction.

Signal head - an assembly containing one or more signal faces.

Traffic actuated controller - a timing device used for the control of traffic signal lights in which the intervals or phases are varied in accordance with demands of traffic as registered by the vehicle actuation of detector.

Master controller - a coordinating unit or units that governs 2 to 10 individual intersection controllers.

9.5.2.3 Submittals

Materials of all parts used in the traffic control system shall be new and the best of their respective kind and the most suitable for working under the weather and site conditions set out in these Specifications, thus withstanding the variations of temperatures and other prevailing conditions without distortion or deterioration of any part of the traffic control system.

Equipment included in these Specifications shall be so manufactured as to facilitate easy and proper erection and maintenance. Design of all equipment shall ensure satisfactory operation under the weather and site conditions mentioned.

In general, dissimilar metals in contact shall be avoided. When, however, they have to be used, the contact points of dissimilar metals shall be adequately protected against galvanic corrosion.

It is the intent of these Specifications that the Subcontractor shall be the manufacturer and/or supplier of the main items of the traffic control system meeting the requirements of the Specifications and Contract plans. All Subcontractor submittals required to be submitted to the Engineer, shall be made through the Contractor.

Subcontractor shall submit for review and approval a complete list of equipment, and the associated model numbers and materials that are proposed for use. List shall include descriptive literature, technical details and drawings sufficient to fully describe and explain the specified components of the traffic control system and its integration with the existing traffic system. Where specified herein or when directed by the Engineer, samples of any of the materials and equipment proposed for use shall be submitted for review and approval.

It shall be the responsibility of the Contractor to ensure that the performance of the Subcontractor complies with all requirements specified herein, and that all items supplied for use in this Project comply with the Specifications and approval of the Engineer. Contractor shall ensure that the Subcontractor does not deliver or install any equipment until the material submittal and applicable shop drawing has been approved by the Engineer.

This specification governs the procedures for documentation and approval of all materials and equipment proposed for use on this Project.

Subcontractor shall be responsible for the availability of the signal equipment and to ensure that all equipment shall be in strict adherence to the Specification, Contract plans and approved shop drawings.

All costs of work and materials required for satisfying these specifications shall be included in the Bill of Quantities under which the subject intersection or interchange type or material equipment shall be paid and no additional compensation will be allowed the Subcontractor for any incidental costs that may occur in fulfilling the requirements of the Contract Documents.

Subcontractor shall comply with the following requirements for the control of traffic signal materials.

a. Within 30 days after the award of Contract and before work is performed, the Subcontractor shall submit the following for approval by the Engineer:
    1. Complete descriptive literatures, wiring diagrams and instruction drawings and specifications of the traffic signal equipment that will be installed in accordance with the Contract.
    2. Complete shop drawings of the mast arm assemblies and poles, showing in detail the fabrication thereof and the description of any materials used in the fabrication, anchor bolts and reinforcing materials.
    3. Samples of all conduit and cable and sample of each type of cable splices that will be used in the work.

4. All the above items shall be collected by the Contractor and submitted to the Engineer at the same time.

b. Subcontractor shall provide samples and/or prototypes of all equipment, and components and parts thereof to the Engineer for his review and approval. Subcontractor shall not start the supply, procurement, manufacturing and/or assembly of any equipment, components and/or parts, until after the Engineer's approval of the samples and/or prototypes.

Engineer's approval of such samples and/or prototypes shall not relieve the Subcontractor/Contractor from his responsibilities of equipment performance under this Contract.

c. Owner and/or Engineer shall have the right to inspect any or all equipment, components and/or parts of the traffic control system during its manufacture, preparation and/or assembly at the manufacture’s plant and/or Subcontractor's home plant and/or at his local facilities. For this purpose the Subcontractor shall notify the Owner in writing at least two weeks in advance of the commencement of such manufacture, preparation and/or assembly. If the Owner elects to use his right of inspection, no manufactured, prepared and/or assembled equipment, component, and/or part shall be shipped to the job site without bearing the inspection approval tag of the Owner or Engineer.
d. Materials and signal equipment not complying with the above requirements that have been installed on the job will be done at the Subcontractor's own risk and may be subject to removal and disposal at the Subcontractor's expense.
e. Subcontractor shall be responsible for all commitments for the supply of materials and signal equipment so that he can complete the job within the specified time of the Contract. Delays in receipt of materials and signal equipment will not be considered as a valid reason for extension of time.
f. Subcontractor shall be responsible for the assembly and testing of the traffic controller system to make the system operational to the satisfaction of the Engineer.
g. All equipment, components and parts of the traffic control system shall continuously operate in satisfactory condition for one month on the job site before they will be conditionally accepted by the Engineer. Engineer shall be the sole judge as to whether the equipment has operated in satisfactory condition.
h. Subcontractor shall be responsible for the maintenance and repair work on the signal controller and associated equipment until final handover.

9.5.2.4 Conduit

All necessary conduits and pull boxes for the traffic system shall be supplied and installed in accordance with Section 9.2.

9.5.2.5 Electric, Communications and Audio Transmission (Telephone) Cable

Electric, communications, and audio transmission cables shall be rated 600 volts minimum and comply with the following requirements:

1. Conductors. Conductors shall be of soft copper, solid or stranded. Solid conductors shall meet the requirements of ASTM B3 or B189. Stranded conductors shall meet the requirements of ASTM B8 or B33.
2. Insulation and jacket. Electric cables shall be protected with either one of the following combinations of insulation and jacket. The average thickness of the jacket shall be as shown in Table 9-3, and the average thickness of the insulation shall be as shown in Table 9-4, with a minimum thickness 90 % thereof in each case.

Table 9-3 : Jacket thickness

	Calculated diameter of cable under jacket (mm)	**Jacket (mm)**
Multiple Conductor Cables:	10.8 or less	1.14
	10.8 – 18.1	1.52
	18.1 – 26.7	2.03
	Conductor size (AWG)	Jacket (mm)
Flat Twin cable:	14 – 12	1.14
	10 – 6	1.52

Table 9-4 : Insulator thickness

Conductor Size, AWG	**Polyethylene (mm)**	**Polyethylene plus nylon**	
		Polyethylene (mm)	**Nylon (mm)**
19	0.635	4.064	0.102
14	0.635	4.064	0.102
12	0.762	4.064	0.102
10	0.762	4.064	0.102
8	0.762	4.064	0.102

3. Polyethylene insulation with polyethylene or polyvinylchloride jacket. Polyethylene insulation compound shall conform to ASTM D1248 Type 1, Class B, Grade 4. Polyethylene jacket compound shall conform to ASTM D1248, Type 1, Class C, Grade 5. Polyvinylchloride jacket compound shall meet the following requirements when tested in accordance with ASTM D1047. This insulation shall have the following properties:
    1. Initial properties:
        i. Tensile strength - 1.055 kg/mm^2., minimum.
        ii. Elongation at rupture - 100 %, minimum.
    2. After 5 days in air oven at 100^o C:
        i. Tensile strength - 85 % of original, minimum.
        ii. Elongation at rupture - 60 % of original, minimum.
4. Polyethylene insulation, extruded nylon covered with neoprene jacket. Polyethylene insulation compound shall conform to ASTM D1248 Type 1, Grade 4, Class A or B. A covering of clean nylon shall be extruded directly over the polyethylene insulation. Nylon shall meet the requirements of ASTM D372 Type I. Neoprene jacket compound shall conform to the requirements of Insulated Power Cables Engineer's Association (IPCEA) Specifications "Neoprene Heavy Duty Black", and, in addition, shall have a tear strength of 0.021 kg/mm2 minimum.
5. Shielding. If shielded electric cable is specified, the conductors shall be stranded tinned-copper twisted approximately 50 turns per m. Insulation shall be of the polyethylene, 0.094 mm nominal thickness for AWG No. 12 cable and 0.81 mm nominal thickness for AWG No.

14 cable. Shielding shall be of aluminized mylar or polyester. One AWG No. 16 stranded tinned-copper drain wire shall be provided. Shielding shall be 100 % effective by providing a metal to metal contact between adjacent wraps. Jacket shall be of chrome vinyl, 0.94 mm nominal thickness for AWG No. 12 cable and 0.81 mm nominal thickness for AWG No. 14 cable. Another nylon sheath of 0.08 mm nominal thickness shall be applied over the vinyl jacket.

6. Capacitance measured between conductors shall be 25 micro-microfarads or less per 300 mm. Capacitance measured between the conductors with one conductor connected to the shield shall be 50 micro-microfarads or less per 300 mm.
7. Colour coding. Each insulated conductor shall be colour coded in accordance with the
8. Table 9-5, or as directed by the Engineer.

Table 9-5 : Insulated conductor colour code

Conductor number	Base colour	Tracer
1	Black	-
2	White	-
3	Red	-
4	Green	-
5	Orange	-
6	Blue	-
7	White	Black
8	Red	Black
9	Green	Black
10	Orange	Black
11	Blue	Black
12	Black	White

All electrical cable colour code shall be consistent throughout the system.

9. Fillers. Fillers, when used, shall be of a non-metallic moisture-resistant material, as directed by the Engineer.
10. Tape. Conductor assembly shall be covered with a spiral wrapping of a moisture-resistant tape applied so as to lap at least 12.5 % of its width.
11. Construction. Cables shall be of the twisted type of construction, except that 2-conductor cable may have the conductors laid parallel to one another. Conductors shall be individually insulated. Twisted conductors shall be laid up concentrically, and fillers shall be used, where necessary, to form a firm and uniformly rounded core. Each layer shall have a spiral lay in the direction opposite to that of adjacent layers. Cross section of the cable shall have all layers of conductors in concentric circles. Each conductor in each layer shall maintain its position relative to every other conductor in the layer throughout the entire length of cable. Formed cable shall be firmly bound together by a helically applied layer of tape, except when rubber compound is used for filling the interstices, the tape over the core may be omitted. Electrical cables connecting the controller to each signal lamp shall have spare capacity of at least two conductors.

12. Identification. Each shipping length of cable shall have a tape showing the name of the manufacturer and the year in which the cable is manufactured, placed over or under the tape covering the conductor assembly before application of outer coverings. As an alternate method of identification, the above information may be applied to the outer surface of the sheath. Sheath shall be marked at 10 m increments in ascending numerical order for measurement and payment purposes. Electric cables furnished shall not be dated more than 5 years prior to the time of installation.
13. Communications cable for interconnection, computer control, and audio transmission (telephone) shall be multipairs cable(s) with colour-coded twisted pairs and No. 19 AWG solid copper conductors. All colour coding for communications cable shall be consistent throughout the system.
14. Communications cable used in this Project shall be similar to the cable used in the existing system, i.e., conventional-type electric cable described above.
15. Installation. Cables shall be installed in number and sequence as approved by the Engineer.

9.5.2.6 Poles and Mast Arms

Vehicular and pedestrian signal poles and mast arms shall be designed to support the traffic signal loading as required by the Engineer, specified herein or shown on the Contract plans. Design and fabrication shall conform to the requirements of AASHTO LTS-5-12. Components of traffic signal poles and mast arms shall meet the requirements specified herein.

Vehicular and pedestrian signal poles and mast arms shall be of durable, visually acceptable design and visually compatible with the existing signal poles. Poles shall be installed on concrete foundations all as approved by th

e Engineer. Poles shall not have "breakaway-on-impact" feature.

Clearance between top of pavement and bottom of lowest vehicular signal head mounted on mast arms shall be no less than 6.20 m and no greater than 6.40 m, taking vertical wind deflection into account, unless otherwise directed by the Engineer.

Generally, vehicular and pedestrian signal heads shall be installed on traffic signal poles. However, in certain instances pedestrian signals may be installed on street light poles when shown on the Contract plans or as directed by the Engineer. In such instances the street light pole used shall comply with the material, construction and quality described in these Standard Specifications.

Poles and mast arms shall be made of galvanized steel and as approved by the Engineer with a minimum outside diameter of 114 mm. Poles shall be welded to the baseplate as shown on Contract plans. Baseplate of traffic signal poles shall be ASTM A36 structural steel. Shape and dimensions of the baseplate shall be as shown on the Contract plans.

Ground rods, if not supplied by others with the pole foundations, shall be 19 mm in nominal diameter and 2.5 m long. A ground clamp capable of accommodating a No. 6 bare copper wire shall be furnished with the rod.

All vehicular signal poles shall be equipped with a fuse of adequate capacity at the base.

All traffic signal poles shall have an identification tag that is fabricated from stainless steel or a suitable non-ferrous material as directed by the Engineer. The identification tag shall identify the manufacturer, and the date of manufacture.

9.5.2.7 Pole and Mast Arm Assembly

Steel mast arm assembly and pole shall meet the following requirements:

1. Steel mast arm assembly and pole shall consist of a mast arm assembly, a pole and a base, and other appurtenances. Configuration of the mast arm assembly, pole and base shall be in accordance with the details shown on the Contract plans.
2. Steel mast arm assembly and pole shall be designed to support one 36.3 kg signal with a projected area of 1.366 m^2 at the free end of the mast arm, one 22.7 kg signal with a projected

area of 0.81 m^2 mounted 3.7 m inward on the mast arm, and one 56.7 kg signal with a projected area of 0.70 m^2 mounted on the mast arm near the shaft, or the signal loading shown on the Contract plans, whichever is greater, based on a 120 km per hour wind velocity plus 30 % gust factor.

3. Design and fabrication of the mast arm assembly, pole, and base shall conform to the requirements of AASHTO LTS-5-12. No other design criteria are acceptable. Mast arm and pole shall be fabricated from steel of structural quality with specific ASTM designations, having minimum yield strength of 26.7 kg/mm^2., either of steel tubing or from welded sheets and plates. Base and flange plates, shall be of structural steel conforming to ASTM A36 or better or of cast steel conforming to ASTM A27, Grade 70-36 or better.
4. Mast arm and pole must be of single length design i.e. not of sectional design. A handhole with reinforced frame shall be provided on each pole near the base. Handhole cover shall be fastened with stainless steel screws. All mast arm assemblies, poles, and bases, except those fabricated from material conforming to ASTM A606, Type 4, shall be galvanized in accordance with AASHTO M 111.
5. Mast arm assembly shall be attached to the pole in an angle from the horizontal of 5^o unless otherwise directed by the Engineer and shall provide the minimum clearances specified herein. Mast arm connection to the pole shall be as shown on the Contract plans and shall be designed to fail in rotation upon impact while being able to withstand the specified loadings.
6. When fully loaded with signal heads as specified herein or as directed by the Engineer, maximum deflection at the free end of the mast arm shall not be more than 50 mm.

9.5.2.8 Vehicular Signal Heads

Vehicular signal heads shall be mounted on mast arms to increase visibility, and supported by pedestal mounted signal heads as shown in the Contract plans, as directed by the Engineer. Span wire mounting shall not be used. Although incandescent type signal heads are shown in this specification, only LED type signal heads shall be used in the Emirate of Abu Dhabi.

Vehicular signal heads shall be comprised of up to four signal faces together with necessary mounting devices capable of holding signal heads rigidly in place against wind and other external effects. Vehicular signal heads with four signal faces are not currently in use within the Emirate of Abu Dhabi. The installation of vehicular signal heads with four signal faces shall be as directed by the Engineer.

Vehicular signal faces shall be comprised of three sections as shown on the plans, specified herein or as directed by the Engineer.

Vehicular signal sections shall be placed vertically one on top of the other with Green indication at the bottom, Amber indication at the middle, and Red indication at the top. Arrow indications, if any, shall be placed immediately below the signal indication of the same colour.

All elements of the vehicular signal heads shall be properly grounded as specified herein and as directed by the Engineer.

a. Conventional Vehicular Signal Heads

Signal faces shall be modular and comprised of individual signal sections. Components of each signal section shall comply with the following requirements.

1. Housing and door shall be one of the following:
   i. Cast aluminium housing and door shall meet the alloy and tensile requirements conforming to ASTM B85 or B108. Door shall be attached to the housing with two stainless steel hinge pins, and shall be held closed with a stainless steel latching device. All access openings shall be provided with neoprene or rubber gaskets to make the housings waterproof and dustproof.
   ii. Polycarbonate housing shall be moulded in one piece and shall be capable of withstanding 31.8 kilograms of impact without fracture or permanent deformation. Polycarbonate resin shall be minimum 2.3 mm thick.

iii. Door shall be attached to the housing with two stainless steel hinge pins, and shall be held closed with a stainless steel latching device. All access openings shall be provided with neoprene or rubber gaskets to make the housing waterproof and dustproof. Ends of each signal face adjacent to the mounting hardware shall be reinforced with metal plates of adequate thickness to keep the signal face from vibrating in the wind.

2. Optical Unit: Conventional signal section shall have an optical unit conforming to the requirements of the latest ITE *Vehicle Traffic Control Signal Heads Standard* and the following requirements:
   i. Signal Lamp: Signal lamp shall be a nominal 100 watts luminaire suitable for use in traffic signal heads, capable of operating at 240 volts, and shall have an average rated life of not less than 6,000 hours. Lamp socket shall be heat-resistant, rotatable and have a lamp grip to prevent the lamp from working loose by vibration.
   ii. Reflector: Reflector shall be of parabolic silvered glass, metalized plastic or Alzak aluminium and shall conform to the Institute of Transportation Engineers Standards (ITE Publication No. ST-017).
   iii. Signal Lens: All vehicular signal lenses shall be antiphantom and 300 mm in diameter unless otherwise directed by the Engineer and shall conform to the Institute of Transportation Engineers Standards (ITE Publication No. ST-017). The components and circuit boards shall not be visible through the lens.
   iv. Signal Dimmers: When specified by the Contract plans or Particular Specifications, signal dimmers shall be provided for the amber signal sections. Dimmer shall allow the signal lamp to operate at full intensity under daylight conditions and to reduce proportionally to 25 ±5 % to full intensity at night. A dimmer shall not control more than one amber section for each direction.
3. Terminal Block: Each signal face shall contain a terminal block with at least 12 terminals.
4. Visor: The conventional signal section shall be furnished with a cut-away type visor over each aspect. The visor shall not be less than 1.3 mm in thickness. The visor for a 305 cm signal section shall be a minimum of 229 mm in length.
5. Mounting bracket: Mounting bracket shall be made of aluminium. Signal heads with more than one signal face shall be furnished with terminal compartments. Each terminal compartment shall contain a terminal block with at least 16 terminals.
6. Colour. Aluminium housing and bracket shall be painted with one coat of primer and finished with two coats of Federal Yellow (as specified by U.S. Federal Highway Administration) enamel, dark olive green enamel or as specified by the Engineer in consultation with the Owner. Aluminium signal door and visor shall be shop painted with one coat of primer and finished with two coats of dull black paint. For polycarbonate signal heads, the above specified colours shall be an integral part of the material composition.

b. LED Vehicular Signal Heads

Contractor shall furnish and install LED vehicular signal heads in accordance with all the requirements as per Article 9.5.2.8, as shown in the Contract plans and as approved by the Engineer, in addition to the following requirements:

1. Contractor shall submit to the Engineer at least 3 different types of traffic signal heads that shall be considered for installation in this project, similar to other traffic signal heads in the vicinity of the Project area, and in accordance with any existing Owner guidelines and regulations.
2. Engineer shall review the proposed materials and recommend the most suitable one to the Owner. Contractor shall not procure, deploy, or install any traffic signal head without obtaining the Engineer’s approval in advance.
3. LED signal module shall be capable of replacing the existing optical components or signal module in a signal housing, or shall provide a complete replacement of the signal head.
4. LED signal module lens may be a replaceable part, without the need to replace the complete LED signal module.

5. Assembly and manufacturing processes for a module shall be designed to ensure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration due to high winds or other local climatic conditions.
6. LED traffic signal heads shall comply with the applicable requirements of BS EN 12368.

c. Traffic Signal Backplate

Traffic signal backplate, if and when specified, shall be made of sheet aluminium or sheet ABS plastic. Sheet aluminium shall have a nominal thickness of 1.587 mm and shall conform to ASTM B209 Alloy 3003 H 14. Sheet ABS plastic shall have a nominal thickness of 3.968 mm and shall have a minimum tensile strength of 29.65 N/mm^2.

Backplate shall be designed to be attached to a signal face without interfering with the opening and closing of the traffic signal door. It shall be rectangular in shape with ground corners and shall be of such dimensions as to give an exposed margin of 127 mm on each side. Backplate shall not be composed of more than four pieces, and a minimum of three evenly spaced stainless steel bolts meeting the applicable requirements of ASTM A193, Class 1, Grade 8, shall be used to connect any two pieces.

Back plate screws and nuts shall be self lockable and resistant to vibration.

Traffic signal backplates are not applicable for decorative signal heads, as directed by the Engineer and approved by the Owner.

d. Traffic Signal Backplate Finishing

Aluminium backplates shall be painted with one coat of primer and finished with one coat of dull black paint. For plastic backplates, the black colour shall be an integral part of the material composition.

9.5.2.9 Pedestrian Signal Heads

Pedestrian signal head and faces shall be mounted as specified herein. Pedestrian signal heads shall have no more than two faces and shall be mounted in a vertical position. Use of span wire mounting will not be permitted.

Pedestrian signal heads and faces shall be mounted in one of the following ways as shown on the Contract plans and as approved by the Engineer:

1. On the vertical portion of the traffic signal poles.
2. On the top of poles as specified.
3. Installed within the sidewalk poles to be furnished and installed separately under this Contract.

Pedestrian signals shall allow pedestrians to cross the roadway within the pedestrian crosswalks during the same phases with through and right turning vehicles in the same direction, as shown on the Contract plans.

Pedestrian signals shall be mounted on the signal poles and top of post in an approved manner and so that the bottom of the signal head is no less than 2.4 m and no more than 3.0 m above the top of the curb. Pedestrian signals shall not be mounted out over the traffic lanes. In general, the pedestrian signals shall be no closer than 1.0 m from the edge of pavement unless otherwise shown on the Contract plans or approved by the Engineer. The Engineer’s representative shall confirm the exact location of all pedestrian traffic signal system equipment on site with the Contractor prior to installation.

a. Conventional Pedestrian Signal Heads and Mounting Accessories

Pedestrian signal faces shall be of a sectional design, completely compatible with signal head hardware and when mounted in any standard arrangement (i.e. other than with pole) the appearance of the pedestrian signal head will be compatible with the balance of the traffic signals.

All pedestrian signal poles shall be equipped with a fuse of adequate capacity at the base.

1. Poles for the top-mounted pedestrian signal heads shall conform to the following:
   i. Pedestrian signal pole shall consist of a nominal 100 mm diameter steel pole and a base, together with anchor bolts and other appurtenances. Configuration of the pole and base shall be in accordance with the details shown on the Contract plans and shall be subject to approval by the Engineer. Foundations for the poles shall be included and constructed under the respective civil works contract.
   ii. Steel pole shall be designed to support two pedestrian signal heads and withstand steady wind velocity of 120 km/hr. with a gust factor of 30 % plus taking into account the requirement imposed by the exposed surface area and total weight of signal heads and brackets.
   iii. Design and fabrication of the pole and base shall conform to the requirements of AASHTO LTS-5-12. Pole shall be fabricated from steel of structural quality with specified ASTM designations, having a minimum yield strength of 331 N/mm^2., either of steel tubing or from welded sheets and plates. Base and flange plates shall be of structural steel conforming to ASTM A36 or of cast steel conforming to ASTM A27, Grade 70-36.
   iv. Pole must be of single length design i.e. not of sectional design. A handhold with reinforced frame shall be provided on each pole near the base. Handhole cover shall be fastened with hexagonal head stainless steel screws. All poles and bases, except those fabricated from material conforming to ASTM A606, shall be galvanized in accordance with AASHTO M 111.
2. All pedestrian signal heads shall conform to the requirements for materials as specified under Article 9.5.2.8 and as follows:
   i. Pedestrian signal heads to be mounted on poles shall have one or two signal faces. In the case of two signal faces, they shall be placed either back to back or at an angle, as shown on the Contract plans.
   ii. Pedestrian signal heads to be mounted in poles shall have one signal face, or two signal faces placed at a right angle or back to back.
   iii. The pedestrian signal head shall be of sectional design completely compatible with vehicular signal head mounting assemblies and other hardware. When mounted on a pole or on the vertical shaft of a signal pole with mast arm, the appearance of the pedestrian signal head shall be compatible with the balance of the traffic signals furnished as part of the system.
3. Signal face and signal section shall conform to the following:
   i. Each pedestrian signal face shall have two signal sections each 360 mm x 360 mm in size and square in shape with the two signal sections placed vertically. One section shall have a WALK symbol in the shape of a walking person and the other section shall have a DON'T WALK symbol in the shape of a vertically placed human hand. The symbols shall be at least 230 mm high. Section with the WALK symbol shall be placed at the bottom directly below the DON'T WALK section and shall be illuminated in green. ALK symbol shall start flashing at the end of the pedestrian green interval.

   Section with the DON'T WALK symbol shall be placed directly above the WALK section and shall be illuminated in red.
   ii. Optical unit of the pedestrian signals shall be same as the vehicular signals except the lens which shall be square in shape and a nominal 300 mm in size.
4. All elements of the pedestrian signal heads shall be properly grounded as specified herein, and as approved by the Engineer.

b. Animated LED Pedestrian Signal Heads and Mounting Accessories

This item shall comply with all requirements Sub-article a of Article 9.5.2.9, except for Clause 3 which is revised to read as follows:

1. Signal face and signal section shall conform to the following:

i. Each pedestrian signal face shall have two signal sections each 360 mm x 360 mm in size and square in shape with the two signal sections placed vertically. One section shall have a WALK symbol in the shape of a walking person and the other section shall have a DON'T WALK symbol in the shape of a vertically placed human hand. Other symbols such as STANDING, WALKING, and Animated person may be installed as approved by the Engineer. The animated walking person is the preferred one for this project. Symbols shall be at least 230 mm high. Section with the WALK symbol shall be placed at the bottom directly below the DON'T WALK section and shall be illuminated in green. The WALK symbol shall start flashing (fast walking for the animated person) at the end of the pedestrian green interval. Flashing green may be substituted by animated green as approved by the Engineer. The section with the DON'T WALK symbol shall be placed directly above the WALK section and shall be illuminated in red.

ii. Optical unit of the pedestrian signals shall be same as the vehicular LED signals except the lens which shall be square in shape and a nominal 300 mm in size.

2. All elements of the pedestrian signal heads shall be properly grounded as specified herein, and as directed by the Engineer.
3. Pedestrian Animated LED signal heads shall comply with the applicable requirements of BS EN 12368.

c. LED Pedestrian Countdown Clock Counter and Mounting Accessories

Contractor shall furnish and install LED pedestrian countdown clock counter (CDC) including mounting accessories as directed by the Engineer. CDC shall comply with all requirements herein this specification as applicable and as directed by the Engineer.

Countdown clock counter (CDC) shall be furnished and installed at the rate of one countdown counter for every approach.

9.5.2.10 Pedestrian Actuation

Subcontractor shall supply and install pedestrian actuation detectors for pedestrian movements at intersections as shown on the Contract plans, required in the Particular Specifications, and approved by the Engineer.

a. Pedestrian Pushbutton

Pedestrian pushbutton (complete) shall consist of the installation of a pedestrian pushbutton, a sign displaying instructions for usage, arrow signs pointing to the crosswalk it controls, all necessary cabling and wiring, and the necessary programming of the intersection traffic signal controllers. In the case of two (2) or more pushbuttons on a single traffic signal pole, the Contractor shall attach the pushbuttons on suitably sized brackets that provide spacing between the pushbutton units as directed by the Engineer.

Pedestrian movements shall be serviced only when called and shall be either a separate phase or concurrent with the respective vehicular phase as shown on the Contract plans and as approved by the Engineer.

Instructions sign shall be in both English and Arabic languages and shall be on 3 mm aluminium plate with engineering grade reflective sheeting or similar material as directed by the Engineer. Signs shall be suitably mounted above the pushbutton unit on the pole or pylon using tamper-resistant clamps or industrial adhesive as approved by the Engineer.

Housing of the pedestrian pushbutton shall be fabricated out of diecast aluminium. Pushbutton unit shall be extremely sturdy, tamper-resistant, and weatherproof. It shall be securely attached to the pole or pylon. Unit shall be completely sealed and all wiring connections shall be from the back of the unit through a compression type cable entry gland. Pushbutton unit shall have an illuminated indicator panel to show the state of operation i.e. wait/walk of the respective pedestrian signal.

Programming of the signal operations to accommodate pedestrian pushbuttons shall not disallow the coordinated operation of the local traffic signal controller, whether it is under arterial progression control or under the central computer control.

b. Audible Tactile Facility

Contractor shall furnish and install pedestrian push buttons with audible speaker and tactile indicators as applicable, as shown on the Contract plans and as approved by the Engineer.

Pedestrian push button station shall allow pedestrians both regular and with disabilities including visually, and hearing impaired people to use the push button to allow them to cross roadways safely.

9.5.2.11 Vehicle Actuation and System Detectors

Subcontractor shall supply and install vehicle actuation detectors for intersection controls and data collection, and system detectors for the central computer control systems as shown on the Contract plans, required in the Particular Specifications and approved by the Engineer.

Location of the system detectors shall be in areas of free flow between intersections, are not affected by recurrent traffic queues, as approved by the Engineer. Basic hardware for both vehicle actuation detectors and system detectors shall be the same and they shall be interchangeable.

Contractor shall submit to the Owner for field test and evaluation 2 detectors of the same type and manufacture to be installed under this Contract. Contractor shall also submit a certificate verifying that the detectors conform to the requirements defined herein and that these same detectors have been thoroughly field-proven and time-tested as to their reliability and maintenance characteristics.

Each detector shall consist of three elements: the detector amplifier unit, the roadway loop and the lead-in to the amplifier unit. All units shall be interchangeable without any wiring or component changes. Field tuning shall not require a meter, circuit changes, substitutions, modifications, or additions to the sensing unit. Unit shall not drift with time or environmental changes after initial tuning. Unit shall be housed in a nonferrous, plug-in case. All component parts shall be readily accessible with the case removed. Detector amplifier unit shall be mounted in the local controller cabinet.

a. Loop Detectors

Subcontractor shall supply and install vehicle actuation loop detectors for use in conjunction with the installed systems at locations as shown on the Contract plans, where deemed necessary by the system requirements, as specified herein, as approved by the Engineer

Subcontractor shall specify the quantity and location of loop detectors to allow the traffic control system to operate fully and satisfactorily in consultation with the Employer.

Subcontractor shall install detectors in roadway pavement by neat saw cutting of the pavement to the nearest curbstone conduit. Subcontractor shall restore the pavement after detector installation to the satisfaction of the Engineer. Curbstones, sidewalks, etc. disturbed for detector installation shall be similarly restored. Maximum depth of loops shall not exceed 200 mm under the lane surface.

Subcontractor shall take extra care at curb side to protect existing loops' cables and avoid cutting them. Subcontractor shall be responsible to reinstall any existing loop which may be damaged due the installation of new loops. Subcontractor shall restore the pavement, kerbs, sidewalks, etc., after detector installation to the satisfaction of the Engineer.

Subcontractor shall extend where necessary all loop lead-in cables to reach the field control cabinet as required by the traffic signal controller specifications and directed by the Engineer. Subcontractor shall supply all required cable extensions, joints, connectors, etc.

Subcontractor shall use elastomeric fuel resistant joint sealant to seal pavement cuts after the installation and accepted testing of the loops.

1. Technical Requirements

Detector amplifier unit shall be a complete, functional unit and planned so as to operate on 240 volt, 50 hertz, single-phase alternating current. Variations in voltage of ±20 % or ambient temperature changes between -5° C and 90° C shall not affect the normal operation of the unit nor shall false calls be issued when input voltage fluctuates between the above limits.

Power supply shall be made an integral part of the unit. Incorporated in the design of the unit shall be a fail-safe feature which, in the absence of power, places a continuous call on the sensing circuit. Following power failure the unit shall restore to operation within one second.

A manual switch shall be provided on the front of the unit for the selection of either motion or presence sensing. In the "presence" position, the unit shall sense the presence of a vehicle within the loop up to a minimum of 15 minutes after which it cancels the call. A minimum of three operating frequencies shall be provided to avoid crosstalk between adjacent detectors, and a minimum of three sensitivity ranges shall be provided.

Each detector loop shall be comprised of at least three turns of loop wire. Each loop shall be individually connected to the lead-in cable. Each loop shall be linked to a different channel in the traffic signal controller.

Sensor circuits shall be of the microprocessor based type. Unit shall operate when connected to an inductance of 50 - 1000 micro-henries and shall render reliable detection when a conductive mass affects a 0.02 % change in inductance and shall be neither position nor attitude sensitive. Unit shall be capable of operating properly when connected to field loop feeder length up to 152.4 m and total loop area up to 37.2 m2.

An indicator lamp shall be permanently mounted to the front of the unit and shall indicate each actuation. Necessary connectors shall be supplied with each unit for connection to the external circuitry. The manufacturer shall furnish certification that the detector conforms to the requirements of these specifications.

2. Surge Protection

All loop detector connections to the detector terminal shall be protected from lightning by using 20 volt zener diodes back-to-back across the loop leads or by a device that has been field proven and approved by the Engineer.

3. Roadway Loop Wire

Loop wire shall be 600 volt single conductor and shall conform to the requirements of IMSA 51-3, 1984 of the Specifications for Signal Cable of the IMSA (International Municipal Signal Association. Manufacturer's name and the identification of the type of wire shall be plainly marked on the outside jacket and certification shall be furnished that the wire conforms to the requirements of the designated specifications.

Conductor shall be insulated, uncoated copper, stranded wire and shall retain its critical properties with no adverse effects to its functional capabilities while conforming to the requirements of Table 9-6.

Table 9-6 : Roadway loop wire parameters

Maximum diameter (AWG number)	12
Maximum diameter (AWG number)	14
Maximum resistance at 20° C (ohms/304.8 m)	2.650
Maximum breaking strength (kg)	56.3
Minimum tensile strength (kgs/sq. cm)	2706.6

Loop wire shall be insulated with a chemically cross-lined polyethylene insulation conforming to the requirements of Table 9-7.

Table 9-7 : Roadway loop wire polyethylene insulation

Maximum thickness (mm)	0.76
Maximum operating temperature (degrees C)	88
Minimum emergency overload temperature (degrees C)	127
Minimum installation temperature (degrees C)	-23
Minimum elongation (megohms/304.8 m)	350
Minimum insulation resistance (megohm/304.8 m)	5,000
Maximum dielectric constant	3
Minimum tensile strength (% of original)	75
Minimum elongation (% of original) after 7 days in an air oven at 120°C	75
Maximum mechanical moisture	5
Absorption (mg/cm^2) Change in specific inductive capacity (% of maximum) after 1 to 14 days in water at 74° C.	4
Retention of critical properties (% of minimum) after 80 days at 120° C.	80
Minimum breakdown voltage	15,000

4. Lead-In-cable and Sealer

Lead-in-cable shall consist of a twisted pair of number 12 or 14 AWG stranded conductors, insulated for 600 volts and shielded in conformance with the requirements of IMSA 50-2. Insulated conductors making up the cable shall be colour-coded. Manufacturer's name and the identification of the type of cable shall be plainly marked on the outside jacket and the manufacturer shall furnish a certification that the cable conforms to the requirements of these Specifications.

Sealer shall be a suitable epoxy and capable of curing in a maximum time of 4 hours at 10° C. Curing is defined as capability of withstanding normal traffic loads without degradation.

Lead-in-cable and roadway loop wire shall be securely connected in a suitable loop detector splice encapsulation kit approved by the Engineer.

5. Field Tests

Prior to applying the loop sealant, the Subcontractor shall perform the following tests. Tests shall be recorded for each of the detectors.

1. Megger Test - Resistance to ground not less than 1 megohm.
2. Inductance Test - Inductance between 50 - 1000 micro-henries at 50 kHz.
3. Continuity Test - Closed electrical loop.
4. Circuit Resistance - Resistance shall not exceed 2 ohms.

Each test shall be repeated at the local controller cabinet to include the loop lead-in. No test shall be considered acceptable unless performed in the presence of and to the satisfaction of the Engineer.

6. Additional Loops for Traffic Violation Recording Equipment

At certain locations, where shown in the Contract plans or directed by the Engineer, the Subcontractor may be required to provide for the installation of traffic violation recording equipment in the future. At such locations, it is necessary to install the detection equipment in the form of inductive loop detectors embedded in the pavement, and with the lead-in cable installed up to the foundation of the traffic violation recording equipment. Equipment shall comply with the requirements of the applicable authority.

Additional loops for traffic violation recording equipment item covers the supply and installation of the detection equipment as described above for one approach covering two lanes of traffic. Loop wire and lead-in cable shall fully comply with the specifications in Paragraphs 3 and 4 of Sub-article a of Article 9.5.2.11.

b. Alternative Detection Technology

Contractor may propose alternate detection technology (such as video detection, laser based, ultrasonic, infrared, and fibre optic based detection, etc) to inductive loop detection specified herein. Contractor shall include in his proposal technical justification and feasibility of the proposed technology compared with the specified technologies. Engineer shall review the proposed technology and, if found suitable to this Project, shall forward his recommendations to the Owner for approval. Contractor may not procure or deploy any alternate detection technology without obtaining the Engineer approval in advance.

9.5.2.12 Local Intersection Traffic Signal Controllers and Associated Equipment

Local intersection control equipment shall perform all functions necessary for the control of traffic signals such as to safely assign rights-of-way to vehicular and pedestrian traffic. Intersection control equipment shall be uniform throughout the Project unless otherwise approved by the Engineer.

Local control equipment shall include but not by way of limitation the following major components:

1. Local intersection controller
2. Local intersection controller cabinet
3. Solid state load switches
4. Security unit (conflict monitor)
5. External flash device
6. Communications interface unit as required to interface with the central computer control.
7. Detector amplifier units

Descriptions for each of the major components above are provided herein except for detector amplifiers which are described earlier in Paragraph 1 of Sub-article a of Article 9.5.2.11. Subcontractor shall provide any additional equipment necessary to make the system perform in accordance with the object of the Contract, in full compatibility with the existing system, with good traffic engineering practices, and to the approval of the Engineer.

a. Local Controllers

All local controllers shall be microprocessor based devices and shall provide equivalent functionality of the legacy traffic signal controllers, or as shown on the Contract plans, required in the Particular Specifications, approved by the Engineer and approved by the Owner. Subcontractor shall supply all devices necessary to fully program the microprocessors for the traffic control programs. All microprocessor memory shall be non-volatile. Timing shall be digital in nature and based on a 50 hertz supply frequency. All controllers shall be capable of fully traffic actuated operation, semi-actuated operation or pre-timed operation. Mode of operation shall be selectable at the controller without rewiring or without the need for special tools. Number and sequence of phases at each intersection shall be as shown on functional drawings to be supplied by the Engineer, as required by the traffic patterns and traffic volumes, and as approved by the Engineer. Controllers shall include all circuitry necessary to provide the specified phases and phase sequences. Number of phases and phase sequencing shall be selectable at the controller without the need for special tools.

Where necessary to ensure safe operation of the controller, a hardware watchdog timer shall be provided. In the event the watchdog timer is not reset within a pre-set time period, the controller shall be deactivated and the external flash device shall be activated.

It shall be possible to change controller timing parameters manually from the front of the controller cabinet. These changes shall be made either by inputs via the front panel of the controller or through use of a portable readout device. In the event a portable readout device is used it shall be connected to the controller via a plug-in on the front panel. In the event the portable readout device is used, a minimum of two shall be provided. All controllers shall provide the following features:

1. Signal indication sequence: Vehicular signal indication sequence shall be Green-Flashing Green-Amber-Red-Green. No Amber indication shall appear between Red and Green indications. Capability shall be included to provide all-red clearance intervals for each phase. Pedestrian signal indication sequence shall be Green-Flashing Green-Red-Green.
2. Number of phases: Capability to accommodate a minimum of eight separate phases with skip-phase capability shall be provided as directed by the Engineer (see Figure 9-1, the numbers in Figure 9-1 indicate the phases).
3. Rings are timed independently but concurrently. Both rings must cross barriers simultaneously. The controller shall comply with BS EN 12675, as approved by the Engineer, and shall be housed in a matching traffic signal control cabinet. Controller type shall be proven with at least one thousand units operating worldwide.
4. Controller shall be able to communicate via fibre optic transceivers using open communication protocols (including IP). Proposed communications protocols between the head-end traffic control system and the field controllers shall be submitted to the Engineer for review and approval.
5. Cycle length range shall be 45 to 240 seconds, adjustable at 1 second steps.

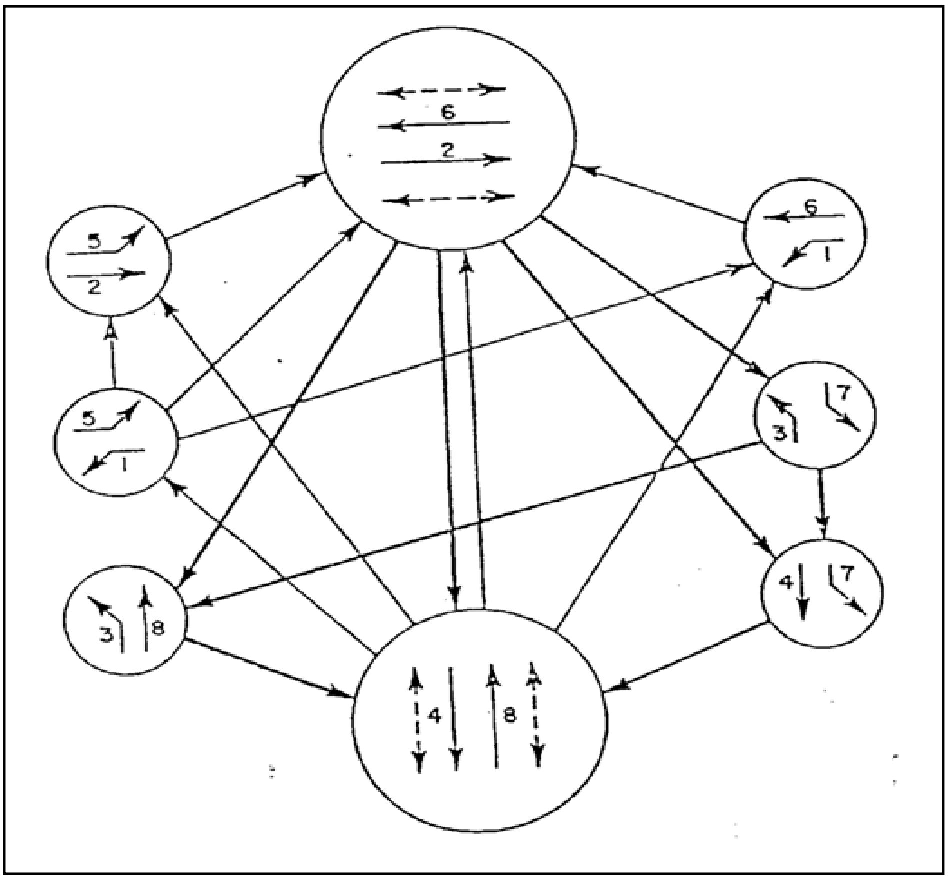

Figure 9-1 : Traffic movement diagram

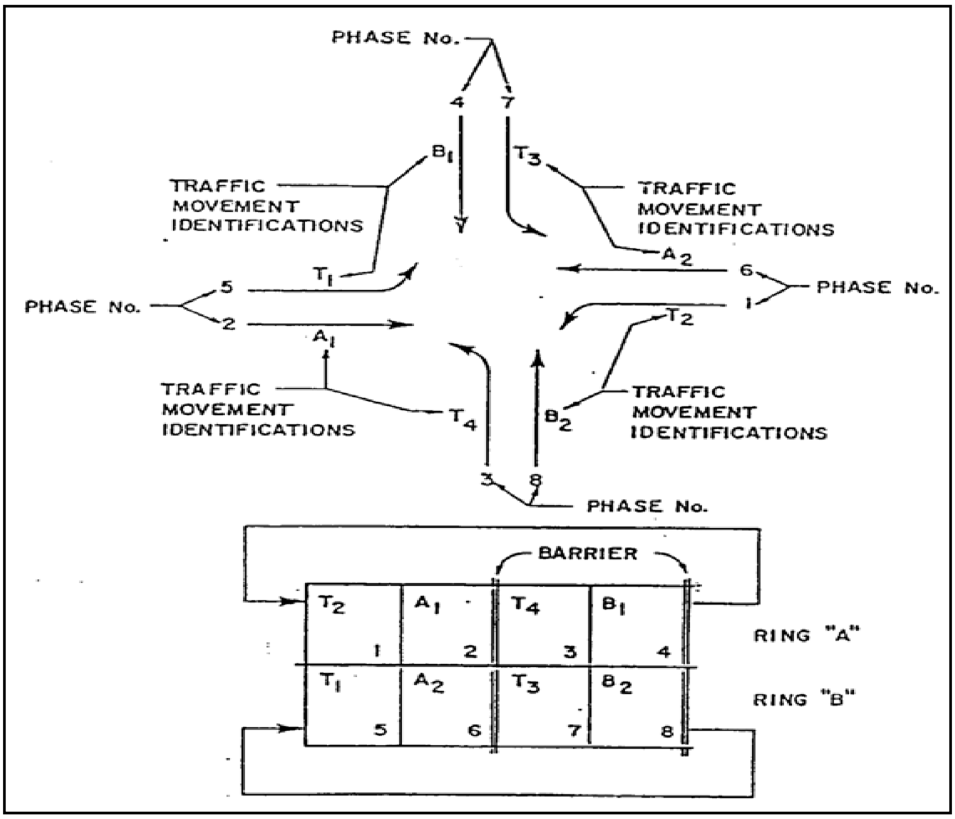

Figure 9-2: Local intersection phase designations

6. Controller shall be equipped to interface to 32 detectors with expandability to 64 detectors simultaneously and shall report the detector counts and actuations periodically to the central

control system at frequency ranges from 1 to 15 minutes. Controller shall store detector counts and other vital data for a period of time in the case of communication failure with the central control system. Type of data and duration of local storage shall be submitted to the Engineer for review and approval. Grouping of detectors into one channel is not allowed.

7. Controller shall be equipped with a GPRS device to allow for wireless link with adjacent controllers in case of failure to communicate with central control system. Controller shall be capable of communicating via GPRS with the central unit as a fixed line alternative or in cases of fixed-line communication failure with the central unit. Subcontractor shall be responsible for GPRS system costs including subscription with local telecommunications providers, recurring fees and operating costs, and management costs during the construction an operation phases of the Contract.
8. Controller shall be able to store 16 independent timing plans in a 24 hour period in its internal memory, or in a memory expansion inside the controller cabinet.
9. Controller shall be able to store all data internally in the case of power failure without any loss.
10. Controller shall be programmable via a local connection (LAN or serial links to a laptop) and through the by central control system. All parameters and settings shall be possible to be edited from the local and central connections.
11. Controller shall be able to accept sensor data from loop detectors, video detectors, radar vehicle detectors (RVD), and other detection technologies as approved by the Engineer. Additionally, it shall be possible to transmit images and video from the video detector to the Control Centre without any measurable delay.
12. Controller shall contain control intelligence to optimize local parameters such as green time adjustment and phase transitions inside the frame conditions received from the central control system. For example, the controller shall be able to take local green light priority requests into account without violating the global control strategy received from the central control system.
13. Controller software shall have an open software architecture
14. Controller software shall calculate cycle lengths based on detector inputs as appropriate
15. Traffic controller software shall be easily upgradeable without removing or replacing the controller
16. Controller software shall process detector data locally and shall calculate traffic density
17. Controller software shall allow definition of detectors as local and/or system types
18. Controller software shall provide a UTCS-compatible adaptive control mode. It shall implement real time adaptive control without any new hardware components.
19. Controller software shall generate stage transitions automatically when in isolated mode as appropriate
20. Controller software shall calculate cycle lengths based on detector inputs as appropriate
21. Controller software shall detect faults by monitoring all inputs and outputs every 10 seconds or less
22. Controller shall categorize the faults and take the appropriate action(s)
23. Software shall organize groups (Signal groups) of vehicle movements into phases, intervals, and sequences
24. To control Actuated operation, minimum intervals shall be set by users for each phase
25. Controller shall react to pedestrian and vehicular traffic demand in all phases
26. Controller shall rely on its timing tables and TOD and DOW clock. System-wide controller clock update software shall be provided
27. Controller shall be suitable for the configuration of the intersection, with 50% spare capacity, per the following:
    - i. Up to 4 signal groups.
    - ii. Up to 16 signal groups.
    - iii. Up to 32 signal groups.
28. Controller shall be suitable for the total number of vehicle loop detectors implemented at the intersection, and shall be sized as follows with 50 % spare capacity.
    - i. Up to 16 vehicle loop detectors.
    - ii. Up to 32 vehicle loop detectors.

iii. Up to 64 vehicle loop detectors.

29. General I/O channels: the controller should be expandable to accommodate up to 48 general inputs and up to 24 general outputs. I/O channels are equipped with terminals to hardwire with hi and low logical states. The controller firmware should have the ability to create programs utilizing the I/O channels for proper interface with different kind of devices (above ground detection, pre-emption, TVR etc).
30. Controller shall have an ethernet port connection.
31. Controller should be capable to run the following type of signal time plans:
    i. Fixed time plans.
    ii. Vehicle actuated time plans using ground loop detectors input and/or general I/O inputs. Vehicle actuated time plans should be capable to extend individual green phases on demand and/or skip green phase when no demand.
    iii. Provide pedestrian green on pushbutton demand only.
    iv. Provide minimum pedestrian green or more whenever it is not conflicting with vehicular green.
    v. Provide pedestrian green according to a fixed time schedule.
32. Lamp load monitoring: the controller should monitor the lamp load on all colours in each group. Controller should be able to issue a warning or go to failure mode when lamp failure is detected. When multiple lamps are monitored on the same group the controller should be able to issue warning or go to failure mode based on the number of failed aspects. Lamp monitoring should be possible for the range of 5W minimum to 100W maximum on each colour in each group.
33. Log files: Controller should keep in its internal memory log files for the following:
    i. Error log.
    ii. Event log.
    iii. Detector log.
    iv. Lamp log.
    v. Plan log.
    vi. Historical temperature limits log.
    vii. Historical voltage limits log.
34. Controller shall keep in its internal memories traffic counts generated by the vehicle detectors. Traffic count data should be kept in the controller memory for a period of 10 days.
35. Controller should be available in versions to work with a SCOOT, SCALA, SCATS, OMNIA/UTOPIA and NTCIP central systems.
36. Traffic signal controller design: Traffic controller shall be designed for traffic signal control and shall include:
    i. 32-bit or greater microprocessor (to ensure currency of design submittals and long term support for the traffic controller main component, the microprocessor, as follows:
    ii. A 32-bit or greater data and memory bus.
    iii. Adequate Dynamic RAM for the functions performed.
    iv. Adequate Flash RAM for the functions performed.
    v. Flash Ram shall be capable of 100,000 Read/Write cycles without degrading.
    vi. 1 MB minimum of Static RAM
    vii. Solid-state Real-Time Clock
    viii. Provision of authentication protocols to verify network connections.
    ix. Minimum 10 year parts and service availability from the manufacturer.
    x. Serial communication ports (RS-232)
    xi. Ethernet interface ports (RJ45)
    xii. USB interface
    xiii. Integrated GPRS interface
    xiv. Assignment of functions to controller hardware contained herein represents only a typical configuration. Alternative functional assignments are permitted.
37. Traffic controller shall be a modular design to facilitate rapid maintenance and repair.
38. Traffic controller's internal diagnostics shall be capable of identifying a controller fault to the lowest replaceable unit (LRU), generally a replaceable module or printed circuit board.

39. Mean time between failures (MTBF) of the installed controller shall be greater than 100,000 hours.
40. Volume - density operations: Microprocessor controllers shall provide for volume- density operation. In this mode of operation, the green interval in each phase shall consist of a minimum green and a vehicle extension.
41. Minimum green time shall be guaranteed irrespective of whether vehicle demand exists or not.
42. Vehicle actuation: Full vehicle actuation shall be provided as specified herein. However, signals shall also be capable of operating in a semi-actuated mode with a selected phase given priority whereby signals shall rest in that phase until vehicular demand is recorded for another phase. It shall be possible to place any or all phases on recall at the local controller without the use of special tools. Signals shall also be capable of operating in a pre-timed mode with phasing and sequencing shown on the Contract plans.
43. Vehicle extension (passage). The vehicle extension (passage) shall be reset by vehicle actuations on this phase when the signal is green (after minimum green has expired) and shall commence timing when the actuation is removed. This period shall change by reducing the allowed gap between successive vehicle actuations from the maximum gap to the minimum gap parameters which shall also be capable of being loaded into the controller through the front panel. Gap reduction increment and frequency shall be as prescribed by the parameters Reduce Gap By and Reduce Gap Every which shall also be capable of being loaded into the controller through the front panel. Gap reduction shall begin with arrival of the first vehicle actuation on an opposing phase after minimum green has expired. Upon expiration of the allowed gap (gap timer) the green interval shall be terminated. Vehicle extension portion of the green shall also be terminated if the maximum extension has been exceeded. Amount of the maximum extension shall be capable of being loaded into the controller through the front panel.
44. Pedestrian signal control: Pedestrian signals shall be controlled by the local intersection controllers. Pedestrian signal intervals shall be capable of being timed concurrently with vehicular phases as well as being timed as independent phases. Appropriate pedestrian Red Clearance shall coincide with the later part of vehicular Green indication and vehicular Amber indication. Pedestrian actuation of signals will be required. Capability for full pedestrian actuation shall be provided in each controller.
45. Pedestrian intervals and termination of green: Pedestrian timing shall be concurrent with the above vehicle intervals (Minimum green time and Vehicle extension). Pedestrian intervals shall consist of a walk indication, a flashing walk indication, and a solid don't walk indication. Vehicle green interval shall normally terminate if the minimum green has expired, the pedestrian cycle has completed, an opposing call is present and one of the following events has occurred:
    i. Extension time has expired
    ii. Gap timer has expired
    iii. Maximum extension has expired
46. Clearance intervals: Following the green interval, there shall be a flashing green and yellow (amber) change interval which is timed in accordance with the setting for that phase. There shall be provision for an all red interval following the yellow interval.
47. Ranges and increments: Ranges and increments of the volume-density timing intervals for each phase shall be as shown in Table 9-8.

Table 9-8 : Ranges and increments

Interval	Range (sec)	Increment (sec)
Minimum green	0 - 199	1
Extension (passage)	0 - 19.9	0.1
Maximum extension	0 - 199	1

Interval	Range (sec)	Increment (sec)
Added per actuation	0 - 19.9	0.1
Maximum gap	0 - 19.9	0.1
Minimum gap	0 - 19.9	1
Reduce gap every	0 - 19.9	0.1
Reduce gap by	0 - 19.9	0.1

48. Signal indication ranges and steps: Signal indications shall have controls for each phase as shown in Table 9-7

Table 9-9 : Ranges and steps

Vehicular green	Range (sec)	Increment (sec)
Minimum green	0 - 199	1
Extension	0 – 19.9	0.1
Maximum	0 – 199	1
Vehicular amber clearance	0 – 19.9	0.1
Vehicular red clearance (all red)	0 – 19.9	0.1
Pedestrian green (walk)	0 – 199	1
Pedestrian clearance (flashing walk)	0 – 199	1

49. Manual control: Manual controls shall be provided to permit vehicular and pedestrian signals to switch to any related phase, or to display red indication in all directions, or to switch from one time plan to another.
50. Stand-alone operation: Stand-alone operation shall consist of two modes as follows:
    i. Free running mode: In this mode the controller shall not be coordinated and shall operate as a fully-actuated controller.
    ii. Time-base Coordination Mode. In this mode signals shall operate on a stand-alone basis in accordance with a minimum of seven different timing Drawings.
    iii. Change from one mode to the other and among different timing plans in Mode (b) shall be automatic and pre-programmable on a time-of-day and day-of-week basis. However, capability to switch manually from one mode to the other or from one timing plan to another shall also be provided.
51. Coordination operation: Controller shall be capable of following the commands of the artery master controller and/or the existing central computer control. In this mode, each controller's timing parameters shall be as dictated by the artery master controller or the central computer control. All clearance intervals shall be preset at the local controller. The duration of clearance intervals shall not be overridden by the artery master controller or the central computer control.
52. Flashing mode: Signal shall have the capability of operating in a flashing mode whereby vehicular signals controlling the main road shall show flashing yellow and vehicular signals controlling the turning movements and cross roads shall show flashing red indication, and

pedestrian signals in all directions shall be turned off. Capability shall be provided for an alternative flash mode whereby vehicular signals controlling the main road shall show no indication, vehicular signals controlling the turning movements and cross roads shall flash showing amber indication, and all pedestrian signals shall be turned off.

53. Voice communications: Audio communications equipment shall be included in each controller cabinet to provide voice communications between the intersection controller, the artery master controller, and the central computer system.

Subcontractor shall bring electric power to the automatic transfer dual power supply panels and on to the local controllers in accordance with the authority requirements. A fuse shall be provided to protect the controller circuitry against surges in the electric power.

b. Controller Cabinets

All local control equipment at a given intersection shall be mounted in a single waterproof cabinet made of fibre-glass reinforced polyester housing or similar approved materials. All cabinets shall be sized to yield 20 % unused shelf space when all equipment necessary for proper operation including communication equipment is installed and operating.

Cabinet shall provide a door, complete with all hardware, of sufficient size to permit easy access for maintenance of the enclosed equipment. Hardware shall include but not by way of limitation a latch type handle, mortise lock (master-keyed), stainless steel or other durable hinges and appurtenant materials. Inside of the controller door shall be equipped with a built-in documentation pocket to house a complete set of operating and maintenance documents. It shall be possible to operate the controller in a manual mode without opening the large door (e.g., via a "police panel" or a remote panel attached to the cabinet).

All equipment necessary to properly mount the cabinets (including mounting poles if required) and to install the local control equipment in the cabinet shall be provided by the Contractor.

Lightning arrester (thyrector) shall be installed in each cabinet adjacent to the terminal strip used for grounding. Arrester shall be installed between the live wire and the ground on the supply side of the circuit breaker or fuse. Live wire shall be connected directly to the lightning arrester. Connection between the arrester and the grounding terminal strip shall be made by a number 8 AWG insulated copper wire and shall be as straight and short as possible. Lightning arrester shall be of the self-restoring type and shall be designed to operate when a potential from the live wire to ground exceeds 300 volts.

An electric power outlet shall be provided in each controller cabinet. Adequate screening facilities shall be provided to protect all sensitive devices in the controller, so as to be immune to the electrical noise and spikes generated by the switching operation and/or induced on the power side from any source whatsoever.

Each cabinet shall be provided with a fan rated at a minimum of 2.8 m3 per minute. The fan or cooling system shall be capable of operating continuously for a minimum of 6,000 hours in a 50o C environment, without the need for after-installation maintenance. Each cabinet shall be provided with a thermostat to control the operation of the fan or cooling system. Thermostat turn-on point shall be manually adjustable from 33° C and 45° C, with a differential of not more than 6° C between automatic turn-on and turn-off.

Cabinets shall be factory wired to include all equipment harnesses and terminal facilities for field wiring including computer communication cables, arterial communication cables, audio communication cables, traffic violation recording equipment cables, lead-in loop wires from all system and local detectors and signaling cables. All terminals shall be labelled and leads wired to the terminal strips shall be identified with marked aluminium or plastic sleeves. Cabinet shall include a radio interference suppressor which shall meet Underwriters Laboratories Inc. standards. Minimum attenuation shall be 50 decibels over a frequency range of 200 kilohertz to 75 Megahertz when used in connection with normal installations.

Interference suppressor shall be hermetically sealed in a substantial metal case filled with a suitable insulating compound. Terminals shall be nickel-plated with brass studs of sufficient external length to provide for a suitable connection.

c. Solid State Load Switches

Signal light circuits shall be controlled by solid state load switches. Each circuit shall have a minimum rating of 600 watts for tungsten lamp or gas tubing transformer load at 240 volts, AC.

Solid state load switches shall be functionally unaffected by transient voltages. Fail-safe operation for all signal lamp circuits shall be provided. The external load switches shall be wired so that all opposing and conflicting traffic movements shall have red indication prior to the display of the green indication on the phase which is to receive the right-of-way. Each load switch shall be mounted in the controller cabinet on a plug-in base by means of a plug-in mounting and shall be designed for continuous duty. Outputs of the load switches shall provide a Red, an Amber, and a Green indication for the vehicle and overlap use; and a WALK and a DON'T WALK for pedestrian use. Flashing Red and flashing Amber indications for vehicles, and flashing WALK indications for pedestrians shall also be provided as specified herein.

d. Security Unit (Conflict Monitor)

A security unit (conflict monitor) shall be provided which shall monitor the output of the Green, Amber, Red and Walk load switches. In the event a conflict condition exists, the security unit shall cause the intersection to go to the emergency flash condition by performing the following functions:

1. Energize the external flash unit.
2. Disconnect or otherwise interrupt any coordination commands, whether they are from an Artery Master or from the central computer.
3. Disconnect the local controller output from the load switches.
4. Hold and display the conflict conditions until reset.

Designation of conflicting phases shall be programmable without the use of special tools.

Intersection shall also go to the emergency flash condition under any of the following occurrences:

1. Absence of required Red or Amber signal
2. Absence of security program.
3. Signals "hanging" indefinitely in one state (except the semi-actuation mode when there is no vehicular demand in the cross road).
4. Processor fault condition.

e. External Flash Units

Each local controller cabinet shall contain a solid state flasher unit to drive the signal lights during periods of controller maintenance or controller malfunction. When operating, the flasher shall flash the red and amber indications in designated directions at a rate of 60 flashes per minute. Ratio of the illuminated period to the dark period shall be as much as 60-40 but not less than 50-50.

It shall be possible to remove control of the signal lights from the local controller and give control of the flasher unit in the following manner:

1. Manually changing position of a single switch.
2. Through automatic programming.
3. Action of a conflict monitor.
4. Action of a watchdog timer, as applicable.
5. By command from the central computer.

All switches, solid state components and other ancillary equipment required to provide the operation just described shall be provided and installed by the Subcontractor.

f. Watchdog Timer

A watchdog timer shall be provided and installed, and shall be used with microprocessor based controllers. Purpose of this timer is to prohibit faulty controller operation from causing the signal light indication to "hang" indefinitely in one state (except the semi-actuation mode when there is no vehicular demand in the cross road).

When used, the controller shall reset the timer periodically. If allowed to time out, the watchdog timer shall cause the signal lights to be put in the flash mode by performing, or causing to be performed, the following actions.

1. Energize the external flash unit
2. Disconnect or otherwise interrupt any coordination commands, whether they are from the Artery Master Controller or a Central Computer Control.
3. Disconnect the local controller output from the load switches.
4. Hold and display the conditions until reset.

Watchdog timer may be either part of the hardware of the local controller or an external device. All switches, solid state components and other ancillary equipment necessary to provide the operation just described shall be provided and installed by the Subcontractor.

g. Communications Interface

It shall be possible to interface all controllers with an artery master controller and the central computer control system. All equipment necessary to interface a controller with the artery master controller and the existing central computer control shall be provided and installed as part of this Project.

All local controller interface equipment required for the interface with artery master controllers and the central computer control system shall be mounted in the local controller cabinet.

h. Communication Standards

System shall support internationally accepted standards for data transmission between the system components at the central level, between the central level and the intersection level as well between the units operating at the intersection level.

i. Communications Modules Rack

Communications modules rack shall be compatible with, and shall house, all fibre optic transceivers and components at the TSS. Transceivers shall comply with the traffic signal control system manufacturer requirement as specified herein. Transceivers are furnished separately from the communications modules rack. Rack transceivers shall communicate with the local controller transceivers. Rack dimensions and configuration shall be compatible with requirements of the transceivers manufacture’s recommendations, as approved by the Engineer.

9.5.2.13 Artery Master Controller

If shown on the Contract plans or required in the Particular Specifications, an artery master controller shall be installed by the Subcontractor. Artery master control equipment shall perform all functions necessary to provide interconnection among individual intersections along a designated artery.

Artery master control equipment shall include but not by way of limitation the following major components:

1. Master controller
2. Master controller cabinet
3. Interconnection (system) detectors
4. Communications interface equipment

Descriptions for each of the above-mentioned components are provided herein. The Subcontractor shall provide any additional equipment necessary to make the system perform in accordance with the requirements of these Specifications, with good traffic engineering practices, in full compatibility with any existing traffic control system, and to the approval of the Engineer.

a. Master Controller

Master controller shall be a microprocessor based device. Master controller shall be capable of coordinating up to 10 fully-actuated local intersection controllers. Master controller timing shall be digital in nature and based on a 50 hertz supply frequency.

Master controller design shall be fully compatible with the design of local intersection controllers and shall include all necessary features to operate the local intersection controllers in the progressive mode as well as the independent (free) mode. Interconnection of local intersection controllers to a master controller for progressive traffic flow shall not negate the full actuation feature of local intersection controllers.

It shall be possible to change master controller timing parameters manually from the front of the master controller cabinet or remotely from the central computer. Those changes shall be made either by inputs via the front panel of the master controller or through use of a portable readout device. In the event a portable readout device is used it shall be connected to the master controller via a plug-in on the front panel. In the event the portable readout device is used, a minimum of two shall be provided.

Master controller shall provide the following features:

1. In the event that more than one model of local intersection controller exists in a designated artery, the master controller shall be capable of coordinating any such combination of local controller models.
2. Master controller shall be capable of providing a minimum of eight pre-programmable coordination time plans to accommodate changing traffic conditions.
3. Master controller shall be capable of coordinating local intersection controllers based upon automatically obtained volume-occupancy data. Below a pre-selected level of volume and occupancy, the master controller shall switch to independent (free) operation mode.
4. Master controller shall be capable of providing a minimum of three background cycle lengths with each cycle length adjustable between 45 to 240 seconds at 5 second steps.
5. Master controller shall be capable of providing a minimum of three offsets per cycle. Each offset shall be adjustable from 0 to 99 percent of cycle length in steps of one second.
6. Master controller shall have a built-in fail-safe system to assure proper functioning of local controllers in cases of interruption in the communication system or any other system failure.
7. Audio communications equipment shall be included in the master controller cabinet to provide voice communications between the master controller, the computer control centre and intersection controllers.

Subcontractor shall, as part of this Contract, bring electric power to the artery master controller in accordance with the authority requirements. A fuse shall be provided to protect the master controller circuitry against surges in the electric power.

b. Master Controller Cabinet

All master controller equipment shall be mounted in a single waterproof, dust resistant, and climate resistant cabinet made of approved materials. Cabinets shall be sized to yield 20 % unused shelf space when all equipment necessary for proper operation is installed and operating. Equipment required to interface with the central computer control system shall be considered as necessary for proper operation (i.e., the central computer control interface equipment shall not require any of the 20 % spare shelf space).

An electric power outlet shall be provided in the master controller cabinet.

All materials, fixtures and appurtenances of the master controller cabinet shall be similar to that of the local controller cabinets as described in Sub-article b of Article 9.5.2.12.

c. Interconnection (System) Detectors

If the artery master control system to be installed under this Contract requires interconnection (system) detectors at locations other than those shown on the Contract plans, the Subcontractor shall provide and install the necessary detector amplifiers, loops, lead-in wires and conduit. Such equipment shall conform to the Specifications and requirements set forth in Article 9.5.2.11. Any other ancillary equipment required for the artery master control system to operate according to the object of this Specification and to good traffic engineering practices shall be provided and installed by the Subcontractor.

d. Communications Interface

All equipment necessary to interface a master controller with the central computer control shall be provided and installed as part of this Contract.

Interface should be capable of transmitting and receiving all necessary data in a format which is fully compatible with the existing central computer control system.

All master controller interface equipment required for the interface with the central computer control system shall be mounted in the master controller cabinet.

9.5.2.14 Communications, and Intersections Placed under Central Computer Control

Subcontractor shall provide all necessary communications means and equipment required for the proper and satisfactory operation of the traffic control system and its parts and components. Communications equipment and protocol shall be IP based and fully compatible with the existing traffic control computer system.

Communication system shall connect specified arterial master controllers and specified local intersection traffic signal controllers to the central traffic control computer. Information carried by the communications system shall consist of commands issued to local controllers by the central control computer. In addition, the communications system shall carry local traffic signal controller status information and traffic flow information from system detectors through each signal controller to the central computer.

Commands from the central computer to each local controller shall accomplish the following functions:

1. Place controller under computer control
2. Release controller from computer control and place controller in free running mode.
3. Release controller from computer control and place controller in time based coordination mode.
4. Release controller from computer control and place controller under arterial master control.
5. Stop and start controller timing.
6. Step controller to next phase.
7. Issue yield command to local controller.
8. Issue force-off phase command to local controller.
9. Alter phase sequence of local controller.
10. Alter timing interval durations.
11. Synchronize controller clock.
12. Respond to request to return controller status and surveillance data.

Data to be carried by the communications system emanating from each local controller shall provide for displaying the following information at the central control room:

1. Current controller phase
2. Traffic flow surveillance data sensed by the system detectors and consisting of volume, speed, occupancy, stops and delay.
3. Indication that vehicle violation recorder sensed a vehicle crossing the violation detector during the red interval.

4. Any messages regarding malfunctioning of controller.

Communications system protocol including polling rate, polling sequence, data message format, and bit transmission rate shall guarantee that traffic signal timing plans generated and/or implemented by the central computer shall have a maximum granularity of one second. That is, phase durations, interval durations, cycle lengths, and offsets shall be designated and commanded in increments of one second.

Local intersection traffic signal controllers shall be programmed such that any command issued from the communications system which is unrecognizable will be ignored. If successive commands are received which are unrecognizable, or if no commands are received over a prescribed duration of time, the controller shall automatically release itself from control of the computer and subsequently operate in the standalone, Time based coordination mode. Controller should be capable as a standalone controller, to store a time schedule to switch between stored signal time plans for a schedule of up to 7 days.

Local intersection traffic signal controllers shall also be programmed such that force-off commands issued from the communications system shall be ignored by the controller if the minimum green has not expired or if the controller is in a clearance sequence.

All clearance intervals shall be timed and commanded by the local intersection controller in accordance with the clearance interval times (inter-green times) contained in memory of the controller. It shall not be possible to override the local controller clearance times through information received from the communications system.

Central traffic control computer shall be programmed such that the receipt of erroneous controller status data, or the non receipt of data, from the data communications system for a prescribed period of time shall cause the Central Control Computer to automatically cease attempting to command the local intersection controller. Operator intervention shall be required to reattempt commanding the local controller under these circumstances.

Placing a full-actuated, or semi-actuated, local intersection controller under central computer control shall not disallow the actuation capability of the local controller. A cycle length shall be maintained through controlling the duration of time between issuances of successive yield commands. Phase durations at the local controller shall be governed by local vehicle actuations except when the maximum phase times allocated by the central traffic control computer are reached. Under these circumstances the central computer shall issue a force-off command to the local controller to be transmitted over the data communications system to advance the controller to the next phase.

Communication equipment installed shall provide prompt, accurate, effective, and fail-safe communications among signals, local controllers, master controllers, central computer control system components, and shall include cable, communications interface equipment and other such elements as shown on Contract plans, the Subcontractor's shop drawings, as specified herein and as approved by the Engineer for satisfactory operation of the traffic control system.

All pullboxes, junction boxes, and conduits shown on the Contract plans shall be supplied and installed by the Contractor if included in the Particular Specifications and the Bills of Quantities.

Due to limited space in the utility service reservations, no more than four, 100 mm diameter, concrete encased PVC conduits will be available for the computer to controller communications link on any given conduit run. All communications must be accomplished using cables.

Wireless radio signal communications are subject to the regulating authority approvals. .

Voice communications from intersection to intersection, from intersections to artery master controllers, and from intersections and artery master controllers to the central computer control system shall be provided as an integral part of the communications system. Wireless radio signal communications are subject to the regulating authority approvals.

All communications cable used in this Contract shall be installed underground and protected by conduit. No overhead cable or underground cable without conduit will be allowed.

Requirements and constraints of the data communications system described in this Specification shall be accommodated using conventional-type insulated electric cable as described in Article 9.5.2.5 and by employing a multiplexing communications system which is compatible with the existing system.

a. Intersection Placed under Central Computer Control

When specified that an intersection shall be placed under central computer control, it means that all necessary communications interface equipment shall be provided and installed such that to/from data communication between the local traffic controller at the intersection and the central computer shall take place. Data communication shall be in a format which is fully compatible with the existing central computer control system and which consists of commands from the central computer and data from the local controller as described in Article 9.5.2.14. It includes all necessary hardware additions to the central computer control equipment, all cable and wiring (except communications and audio transmission cables between the central computer and the local intersection signal controller), interfacing with and updating of the wall map display in the computer centre, and interfacing with all necessary central computer components and peripherals.

It also includes software programming to integrate the intersection operations with the traffic engineering software and the existing area control and group control programs, and development and implementation of necessary traffic signal plans in the central computer control system. All of the above shall be performed such that full compatibility and integration with the existing central computer control system is ensured and it is to the approval of the Engineer.

9.5.2.15 Automatic Transfer Dual Power Supply Panels

Automatic transfer power supply panels shall be of the plinth mounted free standing type equipped to provide power supply for the traffic signalling related equipment at an intersection. Automatic transfer power supply panels shall be fed from two different substations to enhance the availability of the power supply system and shall be equipped to connect a standby genset automatically on power failure as detailed below. Panel shall be equipped, but not by way of limitation, with the following:

a. Main incoming feeders: There shall be two numbers of main incoming feeders each equipped with a 40 A moulded case circuit breaker, a 45 A contactor, a voltage sensing relay, a set of interlocking control and time delay relays, a healthy feeder indication light, a feeder `on' indication light, and an on/off switch for manual operation.
b. Power Backup and Generator feeder: There shall be a generator feeder equipped with a 40 A moulded case circuit breaker, a 45 A contactor, a voltage sensing relay, a frequency sensing relay, a generator running indicator light, a feeder `on' indicator light, an on/off feeder control switch for manual control, a generator shutdown time delay relay, a set of auxiliary interlocking and time delay relays, and a weather proof 5 pole socket outlet installed in the side wall of the panel to plug in the mobile standby generator. Mobile standby generator is not included in this item.
c. Common control equipment: Common control equipment in the panel consists of a voltmeter (0 to 250 V), a voltmeter selector switch having 4 positions (off/feeder 1/feeder 2/generator set), a key operated master selector switch for selection of manual or automatic operating modes, PVC slotted raceway for installation of the control and power wiring, and facility for installation of the utility metering equipment as required by the regulating authority for monitoring the total energy consumed by both feeders.
d. Outgoing feeders: Outgoing feeders shall be equipped with a 25 A single pole circuit breakers for the traffic signal controller, 5 Nos. 10 A single pole circuit breakers for other traffic related or future systems (e.g. VSS), a 10 A two pole circuit breaker with earthed socket outlet for local power supply and maintenance/measuring equipment, and a set of neutral and earth busbars each with twelve numbers of sliding terminals together with insulators and accessories.

a. Component Specifications

Specifications for the components mentioned in Article 9.5.2.15 are as follows:

1. Panel housing: Panel housing shall be hot moulded from fibre glass reinforced polyester and shall be made sturdy by ribbing the rear portion and the door. The panel housing shall be IP55 rated. Enclosure shall be protected against dust deposits and shall be splash proof. Single door shall be equipped with three hinges and shall be locked by a central bolt locking device with three locking points to ensure that the door is held tight against the housing. Bolt closing system shall be locked by means of a rainproof cylinder lock with a master key system.
2. Moulded case circuit breakers: Moulded case circuit breakers shall be of the thermal magnetic type and shall be equipped with quick make, quick break, trip free, toggle operated mechanism to prevent breakers being held in against overloads or faults. Breakers shall have the characteristics shown in Table 9-10.

Table 9-10: Moulded case circuit breaker characteristics

Rated current	63 A
Delayed thermal over-current release	36 – 50 A
Instantaneous magnetic release	480 A
Ambient temperature	25^o to 55^o. C
Breaking capacity	42 kA at 415 volts, category P2

3. Contactors: Contactors shall be of the magnetic operated type with contact surfaces made of silver alloy and contact bridges designed to minimize contact bounce and shall induce a wiping action on contact surfaces to ensure long life with no overdue pitting. The contactors shall have the characteristics shown in Table 9-11

Table 9-11 Contactor characteristics

Rated operating current	45 A at category AC2 and AC3 duty, 80 A at ACI duty
Insulation rating	660 volts
Permissible temperature	Up to 55^o C.
Rated coil voltage	24 V ±10 %
Auxiliary contacts	As required
Rating of auxiliary contacts	10 A

4. Time delay relays: Time delay relays shall be of the electronic delayed pick-up or dropout type as required in accordance with Table 9-10.

Table 9-12 : Time delay relay characteristics

Insulation rating	250 volts
Rated operating voltage	240 V ±10 %
Permissible temperature	+55º C
Setting accuracy	±5 %
Time setting range	0.6 - 6 sec. for change over 0.6-6 min. for gen. set changeover to utility and gen. set cooling
Contacts	1 No. delayed pick-up/drop out contact as applicable.

5. Voltage sensing relays: Voltage sensing relays shall be of the electronic type designed to monitor the system voltage failure or disturbance to effect the change over command, and shall be capable of low and overvoltage detection. Relays shall have front knob operated potentiometers with relevant scale for pick-up and drop-out setting characteristics shown in Table 9-13.

Table 9-13 : Voltage sensing relay

Insulation rating	250 volts
Rated operating voltage	240 volts
Pick-up setting	80 to 105 % of rated voltage
Drop out setting	5 to 35 % below pick-up voltage
Setting accuracy	±2 %
Permissible temperature	+55º C
Contacts	1 No. change over contact rated 10 A 250 V AC

Frequency sensing relays: Frequency sensing relays shall be of the electronic type designed to monitor the generator frequency and effect the changeover after the generator set has reached its rated frequency. Relays shall have front knob operated potentiometers with relevant scale for pick-up and drop-out setting characteristics shown in **Table** 9-14 .

Table 9-14 : Frequency sensing relay

Insulation rating	250 V
Operating voltage	240 V
Pick-up setting	90 to 105 % of rated frequency
Drop out setting	0.5 to 2 % below pick-up frequency
Setting accuracy	±0.5 %
Permissible temperature	+55º C

Contacts	1 No. change over contact rated 10 A 250 V AC.

6. Manual control switches. Manual control switches shall be of very sturdy construction designed for semi-flush mounting in 22 mm diameter mounting knock-outs. Contacts mechanisms shall be designed for bounce free reliable operation, to meet the requirements of IEC 337-1 and have the following characteristics in Table 9-13:

Table 9-15 : Manual control switch

Insulation rating	660 V AC
Actuators	Twist lever operated for the 2 position maintained and 3 position momentary selector switches.
Contacts	Changeover make before break contacts.
Ambient temperature	Upto 60^o C.

7. Master selector switch: Master selector switch shall be of very sturdy construction as the manual control switches and shall be key operated having 2 positions: Position 1 for auto control and position 2 for override manual control. It shall be possible to remove the key only in the auto position. The switch shall be as shown in Table 9-14.

Table 9-16 : Master selector switch

Insulation rating	660 V AC
Actuator	Key operated with key removed in auto position.
Contacts	5 sets of each of make before break normally open and normally closed. contacts
Contact rating	10 A at 240 V AC
Ambient temperature	Up to 60^o C

8. Voltmeter: Voltmeter shall be of the (direct connection) flush mounted type having front dimensions of 96 x 96 mm equipped with a moving - iron mechanism that has the characteristics shown in Table 9-15.

Table 9-17 : Voltmeter

Indication range	0 – 250 V
Accuracy	Class 1.5
Overload capacity	1.2 times continuously, and 2 times for 1 minute

b. Mode of Operation

Automatic transfer dual power supply panels shall be designed to be connected to 2 utility feeders from different substations as well as to a mobile generator set via the weather proof plug provided on the side of the panel. Interlocking and operating logic shall perform as follows:

1. Supervise and monitor the voltage level of all feeders and connect one of the two healthy feeders to the system load. Status of each feeder shall be indicated by the healthy feeder indication light.

2. Upon failure of the connected feeder and/or its rated voltage below the pre-set level, the system logic will transfer the load automatically to the second utility feeder after the pre-set time delay of 0.6-1 second.
3. In case the mobile generator set is connected (during the scheduled utility maintenance) the system logic will start the gen. set automatically and connect it to the system load immediately upon failure of both utility feeders. Upon restoration of any utility feeder the system will monitor the feeder for the pre-set time delay (adjustable between 1-6 minutes) and then transfer the system load to this feeder. Generator will continue to run for a pre-set cooling time (tem. stabilizing) of 0-2 minutes then shut down automatically. If the utility feeder fails again during the cooling down time the system will cancel the shut down command and reconnect the load to the generator.
4. Upon failure of both utility feeders due to a fault on the HT or EHT system which could take a few hours to restore, the mobile gen. set can be brought to the site and plugged into the panel which then will start up automatically and perform as described above.

9.5.2.16 Free Right Turn Signal

Free right turn signals shall consist of a signal pole, a complete single aspect signal head, necessary cabling from the controller to the signal head, and a dedicated flasher unit in the local traffic signal controller.

Specifications for the components are as described below:

1. Signal pole: Signal pole shall be 3.2 m in overall length and shall be manufactured from a 100 mm inner diameter and 5.4 mm thick structural steel tube and shall be a single piece. Base plate shall be 16 mm thick and have dimensions of 300 mm x 300 mm. Pole shall be welded to the base plate by a continuous deep penetration weld. Pole shall be closed off at the top by a pole cap. Pole shall be galvanized and painted in black and white with suitable chlorinated rubber or epoxy resin based paint. Pole assembly (including signal head) shall withstand 120 km per hour wind velocity plus a 30 % gust factor after installation.
2. Single aspect signal head: Single aspect signal head will display a flashing amber signal. All components including the housing, signal lamp, reflector, signal lens, visor, etc. shall comply with all requirements as detailed in Article 9.5.2.8.
3. Cabling: Cabling shall be installed from the flasher unit in the local traffic signal controller to the signal head of the Free Right Turn Signal. Cable shall comply with all requirements as detailed in Article 9.5.2.5 .
4. Flasher unit: Flasher unit shall be of heavy duty solid-state type and shall be a dedicated unit for all the free right turn signals at the intersection. It shall be housed in the local traffic signal controller. It shall be capable of flashing at a rate of sixty flashes per minute (1 Hz). Solid-state flashes shall have no contact points or moving parts.

a. Free Right Turn LED Signals and Mounting Accessories

This item shall comply with all requirements of Article 9.5.2.16, except for Clause 2 which is revised to read as follows:

Single aspect signal head shall display a flashing amber signal. All components including the housing, LED panel, reflector, signal lens, visor, etc. shall comply with all requirements as detailed in Article 9.5.2.8.

9.5.2.17 UPS for Traffic Signal Power Back-up System

The design, specification, calculation, manufacturing, testing, shipment, installation and performance of UPS for Traffic Signal Power Back-up system shall be in accordance with the applicable requirements of the Owner’s and as specified herein. The UPS shall be designed to operate continuously at the specified ambient temperature and humidity with special attention given to the effects of direct sun-exposure during the day and the occasional sand storms and dusty weather in designing the enclosure. The UPS shall provide a minimum of 2 hours backup time, at any time during the operations and maintenance phase. The manufacturer shall guarantee adherence to this Specification and the performance of UPS under all the required design conditions.

Specifications for the UPS are as follows:

1. Charger: The nominal AC voltage shall be 230V. The input voltage tolerance shall be within the limit of +20% to -35% with a frequency of 50Hz. Frequency tolerance shall be within the range of 47-62Hz. The maximum input power shall be selected as per the load connected with the system. The nominal power factor considered shall be 0.9. The float voltage and charge voltage shall be selectable. The charger nominal current shall be maximum 10amps. Maximum heat dissipation shall be 0.6KW.

2. Battery: The nominal Battery voltage shall be 12volt block, 48V string with the following parameters:

Output voltage at 25^0C	:	230V AC
Capacity (Ah)	:	94 Ah Batteries
Number of cells	:	As necessary
Float temperature compensation	:	5mV/deg C/cell
End of discharge voltage	:	1.75 V/cell
End of discharge current	:	92A
Charging current	:	Up to 30A max

3. Inverter: The inverter shall have the following design Parameters:

Nominal Power at 50deg C	:	As required with the connected load
Nominal Voltage	:	230V
Nominal frequency	:	50Hz.
Reserve supply nominal	:	48V.Dc
Max. heat dissipation	:	0.6KW
Overload for 5 sec	:	>200%
Overload for 10 sec	:	>120%
Overload for 3 min.	:	>100%
Short circuit of 300% at 50 Hz	:	8ms
Short circuit of 150% at 50 Hz	:	8ms
Output THD	:	<3%
Crest factor	:	3:1

The UPS efficiency shall be minimum 95%. Maximum allowable noise level at one meter shall be 48dBA. EMC class shall be FCC level A. The cooling method shall be by two fans with thermostat controlled. Necessary protection shall be provided against short circuit for the incoming power supply. The following protection and alarms shall be included in the system:

a) AC input phase under voltage.
b) Rectifier failure
c) DC under voltage
d) DC over voltage
e) Charge failure/battery discharging
f) Battery disconnected
g) Inverter over current
h) Inverter failure
i) Inverter output voltage deviation
j) Cubicle fan failure
k) Cubicle/inverter stack over temperature.

Necessary fault and alarm conditions shall be transmitted to the Traffic Management Centre as directed by the Engineer.

The contractor shall submit detailed shop drawings showing the electrical wiring diagrams for the UPS. The single line diagram showing the inter connection of the UPS with the Electrical power supply shall be detailed in the shop drawings.

4. Battery: The battery shall be gel type, valve regulated lead acid. The contractor shall submit a detailed report on the operating features of the battery such as:
    i. Effect of temperature on service life of the battery.
    ii. Effect of temperature on capacity of battery.
    iii. Effect of temperature on charging current.
    iv. Effect of temperature on charging voltage.

    The design life of the battery shall be ten years.

    The enclosure shall be glass reinforced polyester, high impact, UV stabilized, fire retardant with internal metal frame to house UPS and batteries. The protection of the enclosure shall be IP55 with wall thickness 4mm and point of stress 6mm. The colour shall be plain semi gloss, light grey, gel coat finish, if not advised by the Engineer. The enclosure doors shall be able to open 120 degree in fixed position and to be provided with appropriate stopper. The material submittal shall include details about manual by pass switch, MCB's, cables and all accessories for Engineers review and approval.

9.5.3 Construction Requirements

9.5.3.1 Testing, Operation & Maintenance and Training

Testing, compliance and operation & maintenance requirements shall meet the requirements of Article 9.6.3.1 and Article 9.6.5. Training shall meet the requirements of Article 9.6.5.2.

9.5.3.2 General

Subcontractor shall be responsible for the complete installation of traffic control system at the designated intersections and/or interchange, including local intersection controllers, artery master controllers, placing intersections under central computer control and all other related components, materials, equipment, systems and appurtenances. Subcontractor shall include all labour, materials, tools, equipment and appurtenances and shall perform all work required to complete the installation, to the approval of the Engineer, of the traffic control system.

9.5.3.3 Location of Equipment

Equipment and components of the traffic control system shall be located as shown on Contract plans, and in accordance with the requirements of the intersections and/or interchanges and relationship of various subsystems and the various control systems.

The Subcontractor shall verify the locations of all traffic control system equipment with the Engineer's representative, as well as the final locations of all foundations, conduit and similar work installed or being installed under the various roadway contracts.

9.5.3.4 Installation

Subcontractor shall be responsible for the complete installation of all wiring, distribution of power from the power source to the control foundation and to all equipment and components of all systems, the specified components of the traffic control system with all subsystems, control systems, and all related work as specified herein, as required for the complete installation, and as approved by the Engineer.

Subcontractor shall contact the electrical authority to arrange for 3 phase, 415v/240v, 4-wire, 50 Hz electrical supply for the controllers and all related traffic control system equipment. Two sources of power supply are required for the automatic transfer dual power supply panel at each intersection/interchange that will be signalized.

Subcontractor shall comply with the requirements of the electrical authority for the service connection. There shall be no separate payment for the service connection. Cost of service connection work shall be an incidental part of the bid prices of other items of work in the Bills of Quantities.

Unless otherwise approved by the Engineer in writing, no installation shall take place without the Engineer's presence and supervision. Such presence and supervision of the Engineer shall in no way relieve the Subcontractor from his responsibility of installing the traffic control system components properly and according to proven engineering standards and practices so that the traffic control system will function and operate to the satisfaction of the Engineer after installation.

If the Engineer determines, as the sole judge of such determination, any time prior to the issuance of the written final acceptance certificate, that any subsystem, equipment component part and/or appurtenance of the traffic control system is improperly installed or not fully compatible with the existing traffic control system, such subsystem, equipment, component part and/or appurtenance shall be removed and reinstalled, with new parts and components if necessary in the judgment of the Engineer, by the Subcontractor at his own expense.

9.5.3.5 Performance Evaluation

Each item included under this Project including but not by way of limitation all poles, mast arms, signal heads, controllers, detectors, control systems, communication hardware and all other related equipment, components and materials shall be subjected to actual performance evaluations if required by the Engineer and/or the Owner. For this purpose, the Subcontractor shall submit samples or prototypes of each type of major equipment and component, construct prototype conditions for field and/or laboratory testing as specified and as directed by the Engineer. Components and subsystems shall be approved by the Engineer before equipment and system manufacturing and assembly.

9.5.3.6 Reliability Requirements

Equipment and components employed in the traffic control system shall meet stringent requirements on reliability and mean-time-before-failure. Subcontractor shall employ good design practices and design equipment and components for long life. Subcontractor shall furnish satisfactory evidence that multiple sources of supply are available for components and equipment as directed by the Engineer. Equipment and components shall be designed for ease of maintenance with as much modularity and parts commonality as feasible.

Subcontractor shall perform all required performance and reliability tests, as specified in Article 9.6.3.1.

9.5.3.7 Other Subsystem Configurations

Descriptions and detailed Specifications that are included in the Contract Documents are intended to be as definitive as possible. However, they are not meant to preclude other possible subsystem configurations. Subcontractors who have well-developed hardware or software subsystems that differ from those described or specified shall submit with their Tender all details and particulars of their subsystems. Consideration will be given to alternative configurations, provided that they show major advantages without a sacrifice in performance, compatibility with the existing traffic control system, maintainability or reliability. However, after the execution of the Contract, no substitution shall be made unless approved in advance by the Engineer in writing.

9.5.3.8 Installation of Pedestrian Signal Heads

Under this Contract the Subcontractor shall furnish and install all pedestrian signal heads, control mechanisms and cables within sidewalk pylons or on poles as provided and installed for the respective intersection, interchange or roadway construction as directed by the Engineer.

To ensure correct positioning of the equipment installed under this Contract, the Subcontractor shall be responsible for coordination with the work executed under separate contracts in accordance with the requirements of respective Clauses under Department of Transport Conditions of Contract and Further Requirements in the Contract Documents.

9.5.3.9 Installation of Controller Communication Cables

All cable shall be installed, spliced, connected to terminal strips, tested and connected to the proper equipment to produce a complete and operating traffic control system. Cables shall be pulled through the conduit with a cable grip designed to provide a firm hold on the exterior covering of the cable. All cable shall be pulled with a minimum of dragging on the ground or pavement.

Cable feeders shall be used. Powered soapstone, talc or other approved lubricants shall be used to facilitate the pulling of the cable through the conduit.

Cable ends shall be taped to exclude moisture until the connections are made or the terminals attached. Cable shield shall be connected to terminals to provide electrical continuity. Cables shall enter junction boxes through the bottom only. Drop loops shall be provided in cables.

9.5.3.10 Installation of Electrical Components and Accessories

Installation of all electrical equipment for the traffic control system shall meet the requirements as specified in this section as well as the applicable sections and clauses of Chapter 10, Lighting and Electrical Distribution Works.

9.6 Intelligent Transportation Systems

9.6.1 Description

This Specification covers descriptions and requirements of the components and materials forming part of the intelligent transportation systems. All components, items, systems and sub-systems supplied and/or implemented under this Contract shall strictly comply with requirements and specifications stipulated in this Specification and the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*. System shall be compatible, and capable of integration with any existing system, and operate in harmony with the existing system.

All non-civil works required under this section shall be executed by an Owner pre-approved Subcontractor (from herein referred to as Subcontractor). Subcontractor shall be a well established ITS contractor and shall have carried out a number of works of similar nature and magnitude as this Contract. Subcontractor shall have previous experience in the hardware, software, principles and operational aspects of ITS, and shall be technically capable of integrating the ITS equipment installed under this Contract with a new or existing central system, such that full compatibility is ensured.

Subcontractor shall have the necessary experience and resources to furnish, install, operate and maintain all components of the intelligent transportation system such as equipment, cabinets, poles, gantries, power supply panels, video and data communications system, cabling and wiring, and all other components as may be specified herein, shown on the Contract plans or required in the Particular Specifications.

Unit rates entered in the Bill of Quantities must include for all work as specified plus all on costs for the main Contractor's work, attendance, overhead and profit. Any other items necessary for the satisfactory completion of the works but not specifically mentioned in the Contract Documents will be considered as subsidiary obligations to this Contract.

Main Contractor will be held responsible for the overseeing of the Subcontractors work, including the scheduling, submittals, procurement and the ultimate acceptance of the ITS works so that all works are completed by the Contract completion date.

9.6.1.1 General System Overview

Intelligent transportation systems (ITS) provides monitoring, detection, verification, traveller information and response for traffic and transport related incidents, events, and accidents as may be existing or proposed new in and adjacent to the Project area by utilizing the latest technology, hardware and software, and up-to-date traffic engineering principles and procedures.

ITS provided under this Contract shall be fully compatible with any existing ITS system deployed by the Owner at the time of project initiation, or planned system expected to be deployed at project completion at the discretion of the Owner. ITS central system and subsystems deployed in this Contract shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

9.6.2 Materials

9.6.2.1 General

Materials of all parts used in the ITS shall be new and the best of their respective kind and the most suitable for working under the weather and site conditions set out in these Specifications, thus withstanding the variations of temperatures and other prevailing conditions without distortion or deterioration of any part of the ITS.

Equipment included in these Specifications shall be so manufactured as to facilitate easy and proper erection and maintenance. Design of all equipment shall ensure satisfactory operation under the weather and site conditions mentioned.

In general, dissimilar metals in contact shall be avoided. When, however, they have to be used, the contact points of dissimilar metals shall be adequately protected against galvanic corrosion.

It is the intent of this Specifications that the Subcontractor shall be the supplier and installer (or manufacturer and installer) of the main items of the ITS meeting the requirements of the Specifications and Contract plans. Subcontractor shall submit for review and approval a complete list of equipment, and the associated model numbers and materials that are proposed for use. The list shall include descriptive literature, technical details and drawings sufficient to fully describe and explain the specified components of the intelligent transportation system and its integration with the existing traffic control system, if required, and the existing or new central system as approved by the Engineer and the Owner. Where specified herein or when required by the Engineer, samples of any of the materials and equipment proposed for use shall be submitted for review and approval.

It shall be the responsibility of the Subcontractor to ensure that all items supplied for use in this project comply with the Specifications and approval of the Engineer. Subcontractor shall not procure any equipment until the material submittal and applicable shop drawing has been approved by the Engineer.

This Specification governs the procedures for documentation and approval of all materials and equipment proposed for use in this Contract. All materials shall comply with the requirements of the *Department of Transport ITS Design Manual*, Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual* as directed by the Engineer.

Subcontractor shall be responsible for the availability of the ITS equipment and to ensure that all equipment shall be in strict adherence to the Standard Specification, Particular Specifications, Contract plans, and approved shop drawings.

All costs of work and materials required for satisfying these specifications shall be included in the Bill of Quantities under which the ITS works and material equipment shall be paid, and no additional compensation will be allowed for the Subcontractor for any incidental costs that may occur in fulfilling the requirements of the Contract Documents.

9.6.2.2 Submittals

All of the submittals in this section must be submitted as soon as possible after the award of Contract and before any work is performed. Subcontractor shall submit the following for approval by the Engineer:

1. System and equipment design: Contractor shall be responsible for final system and equipment design. In accordance with the Project schedule, the Subcontractor shall produce a system design document (SDD) within 90 days from Project commencement date, which details the hardware and software configuration of all equipment items, provide interface control details, and documents compliance with the detailed system requirements as provided in these Specifications, as shown on the Contract plans and required in the Particular Specifications. SDD should include presentation of all supplied systems requirements, and comply with the following requirements: Subcontractor shall supply a complete list of the make and model of all equipment detailed in the SDD. All the equipment types that cannot be specified at the completion of the SDD, shall be listed and submitted with the SDD. If more than one type is to be considered, all proposed types shall be submitted with their evaluation criteria and compliance to the Specifications.
2. SDD shall contain the concept of operation, the communications scheme, and the major features of the proposed systems in comparison to the Specifications. Subcontractor shall not proceed with work until this document has been approved by the Engineer. Following the Owners review of the SDD the Subcontractor shall conduct a presentation of the SDD within 45 days of the Owners review or as required by the Engineer. Presentation shall be held at the Owners premises at time and location as directed by the Engineer, and conducted by the senior engineering personnel responsible for its preparation of the SDD. Purpose of this review will be to permit the Owner and the Engineer to assess conformance of design details with the Specifications, in order that any deviations can be detected and corrected. SDD will form the basis on which detailed work can proceed. Subcontractor shall not, without the specific approval in writing by the Engineer, submit materials or shop drawings for approval, place any material or equipment on order, commence manufacture of any items of plant, nor develop software until the Engineer has approved the SDD. SDD shall serve as the basis for the system development.
3. SDD shall be accompanied by appropriate system hardware and software documentation, including integrated user manuals, laptop screen shots, and a final Interface control document defining the data structure, meta data, latency, relevant object definition remote process calls, and performance characteristics associated with each of the systems. Subcontractor shall include a matrix with references demonstrating compliance with the Specifications; and any deviations shall be explicitly noted. Engineer's approval of the SDD and any directions to revise the SDD will be submitted to the Subcontractor in writing. Any oral directions received by the SDD will not be considered valid.
4. Should the Subcontractor wish to modify the approved SDD, he shall submit the changes or additions to the Engineer for approval. Subcontractor shall not implement any changes or additions until approval has been received. SDD shall be updated regularly to reflect changes agreed with the Engineer, as the project proceeds.

5. Integration staging plan: Subcontractors proposed integration staging plan shall be submitted at the same time as SDD and it shall contain a detailed listing of the order and schedule for the installation and the testing of outstation and in station equipment. Staging plan shall clearly show the Subcontractor's proposed order of field site installation and site acceptance testing and shall show when the central control equipment of the system is to be installed and tested and made operational.

9.6.2.3 Video Surveillance System (VSS)

a. Digital Video Management System (DVMS)

If a DVMS is required for the Contract, the Subcontractor shall supply, install, configure, and test the DVMS, including the head-end server that is compatible with any systems currently implemented by the Owner in the traffic control centre. On completion of the installation and connection of new cameras, and taking into account all existing and planned cameras, the DVMS shall have 25 % spare capacity for additional cameras. DVMS shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

The DVMS shall provide video surveillance management, video distribution within the Traffic Control Centre/Control Room, to the video walls and workstations, and to external stakeholders as directed by the Engineer and approved by the Owner.

The DVMS shall manage the storage, retrieval, and provide for processing of the video. The DVMS shall be an IP network based, open platform, fully distributed digital video system which shall integrate different brands of cameras as directed by the Engineer. The DVMS shall utilize local area networks (LAN) as a transmission medium for video, configuration, as well as storage of all data. The DVMS shall provide full video control of all connected cameras and shall be able to interface with the existing DVMS at the existing control room locations, with additional full selection capability at any point within the network from a workstation or a video wall display.

b. Digital Video Storage System (DVSS)

If a DVSS is required for the Contract, the Subcontractor shall supply, install, configure, and test a DVSS, including server, that is compatible with any systems currently implemented by the Owner in the traffic control centre. DVSS shall be integrated with the video surveillance system to record and store video streams via an Ethernet network. DVSS shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

DVSS shall be compatible with the proposed DVMS and all other video surveillance system and video analytics system hardware and software.

DVSS shall be configured to record video from the DVMS channels at 25 frames per second per video, at 4CIF and megapixel resolutions using MPEG4 and H.264 compression for a minimum of 90 continuous days and archiving for the triggered events for one year. Compression factor shall not exceed 30 % and shall not compromise the video quality in any way. Storage system shall be sized based on the expected video stream bandwidth for H.264 video, at full resolution (D1) and full frame rate (25 fps) of a scene with high level of change (roadway).

c. Network PTZ Camera Assembly

Network camera shall be a domed, compact, day/night within a rugged enclosure unless otherwise authorized by the Engineer. All circuits shall be totally solid state with silicon transistors and integrated circuits. All modules shall be plug-in type. Part adjustments, and test point circuit symbols shall be silk-screened on the circuit boards for easy identification. Markings shall be in English and Arabic language. Back box of the camera unit shall have built-in memory to store camera and location specific dome settings, including labels, presets, patterns, and zones. These settings shall be automatically downloaded when a new dome drive is installed.

Camera shall have a built-in 100 Base-TX network interface for live video streaming to any network application as approved by the Engineer. Cameras shall be equipped with SFP port. Type of each camera port/communication module (100TX or 100 FX) shall be chosen as per the site condition, camera position and as directed by the Engineer to reduce the requirement for the media converters. The communication modules shall be considered as a part of the camera. Dome system shall also feature open architecture connectivity for third-party software recording solutions allowing integration into any IP-based system, and allowing the system to record, manage, configure, and view multiple live streams. Network camera shall automatically adjust for optimized image quality and bandwidth efficiency and shall allow viewing and control of network IP video by users with the appropriate permissions. Network dome camera shall consist of a black box, a dome drive, and a lower dome. Dome drive shall feature low light technology allowing the camera to operate in scenes where minimal light is present. Camera shall automatically compensate for scenes where large contrasts in lighting are present. Electronic image stabilization shall digitally reduce blurring of the camera images due to vibration.

Video shall comply with the following requirements:

1. Digital compression: MJPEG, H.264 (MPEG-4 Part 10)
2. Video streams: 3, simultaneous
3. Video resolutions:
   i. PAL
   ii. 4CIF
   iii. 2CIF
   iv. CIF
4. Frame rate
   i. H.264 at least 25 fps per port
   ii. MJPEG at least 25 fps per port.
5. Web user interface: HTTP
6. Progressive scan
7. Wide dynamic range
8. Supported protocols: IPv4/v6, HTTP, QoS, FTP, SMTP, UPnP, TCP, UDP, IGMP, RTP, ICMP, DHCP, ARP, unicast IGMP, multicast IGMP, DNS, NTP
9. Electronic image stabilization

Dome drive features shall comply with the following:

1. Image enhancement
2. On-screen compass, tilt, and zoom display
3. Password protection
4. Rotating discreet liner with sealed fixed bubble
5. Masking zones (programmable in size) shall be able to be labelled.
6. Proportional pan/tilt: Continually decreases pan/tilt speeds in proportion to depth of zoom
7. Variable scan speed: Scan speed shall be programmable from 1-40°/sec or greater
8. “Auto flip” shall rotate dome 180° at bottom of tilt travel
9. Programmable zoom speeds
10. Freeze frame during presets
11. Full 360 degrees continuous camera rotation with auto flip features.
12. Minimum of 99 preset positions.

13. Equipped with heater/blower
14. Sensitivity of less than 0.01 lux for 30 IRE (B/W) and less than 0.1 lux for 30 IRE (colour).
15. White balance of at least 10,000 K for MJPEG and H.264.
16. Automatic video focus.
17. Minimum 35 x optical, 12 x electronic zoom.
18. Video buffer of at least 36 MB (pre-and post alarm)
19. Electronic image stabilization
20. Freeze frame during presets
21. 4 alarm inputs, and 4 outputs.
22. Internal scheduling clock

Mechanical (dome drive only) shall comply with the following:

1. Pan movement 360° continuous pan rotation
2. Manual pan/tilt speeds
   i. Pan 0.1° to 80°/sec or greater under manual operation,
   ii. 150°/sec turbo tilt 0.1° to 40°/sec or greater under manual operation
3. Automatic preset speeds
   i. Pan 400°/sec or greater
   ii. Tilt 200°/sec or greater

Electrical shall comply with the followings:

1. Input voltage: 18 to 30 VAC; 24 VAC nominal.
2. Input power: less than 100 Watts, Fuse 4.5 A at rated voltage
3. Power supply: 220 VAC fused with 1.5 A fuse (shall comply with reliability requirements)

Reliability requirements shall meet the following:

1. Environmental design requirements: Equipment shall meet all of its specified requirements during and after subjecting it to any combination of the following requirements:
   i. Mean time between Failures (MTBF) shall not be less than 100,000 hours.
   ii. Ambient temperature range of -10ºto 60ºC.
   iii. Relative humidity from 0 % to 95 % non-condensing.

Camera control software shall comply with the following:

1. Pan and tilt system shall include a preset position controller which, upon reception of control signals from the control centre, shall automatically preset pan/tilt position, zoom and focus of the lens. A minimum of 99 preset positions shall be provided for each camera. In addition, each preset shall have its own title of up to 20 alphanumeric characters.
2. Each camera shall be capable of responding to pre-programmed tours of multiple sequential presets. Events that may be programmed as steps in a tour include preset positions, alarm acknowledgment, alarm or preset dwell periods, auxiliary activation, repeating the tour or calling up another tour (chaining tours).
3. Pan and tilt controller shall be operable from the surveillance workstations' graphical user interface and/or a joystick keypad at the control centre. Acceleration of camera motion shall be proportional to joystick displacement from a central software-defined dead zone.

Video delay: Video delay from the camera imager in the field to the operator monitor in the operations room shall not exceed 150 ms. Control loop delay from the original camera image to a control action by an operator to the time the image changes as a result shall not exceed 300 ms.

Mediation of video permissions: All video images shall be titled with the organization, ID and priority level of the operator observing the image. Other operators requesting control of the camera from the operator with current control privileges shall have their priority compared to that of the current operator. Control shall be automatically assigned to the operator with highest priority, and that operator's organization and priority level will then be titled on the video image. Priorities within an organization shall be event dependent to avoid inappropriate assignments. Organizations shall be the Owner and other agencies as may be directed by the Engineer.

Panning, tilting, zooming and iris control shall be smooth and rapid, whether automatic or manual. Focus shall be automatic. Colour camera shall be sensitive to low levels of illumination and shall have many presets to which it can return with high accuracy. Camera assembly shall include a camera controller and a communications interface. Dome enclosure shall be weatherproof to keep out moisture and dust.

Zoom lens: Each VSS field subsystem camera shall be equipped with a remotely controlled, variable focus, motorized zoom lens. The iris shall have an automatic control. The lens shall have a flat field with high resolution. An adjustable lens adapter ring shall be used to provide focus tracking.

Environmental housing: Housing shall be aesthetic to view, compact, vandal-proof, rugged and environmentally resistant. It shall be moisture, salt, sand and dust proof and suitable for operation in a hot and humid atmosphere. It shall be manufactured of polymer technology for rigidity and long service life. Housing shall have weather-resistant cable connectors as required for video, power and remote controls. Housings shall consist of a double upper shell and a double lower viewing dome. Housing shall be equipped with a heater and a blower that are controlled by a thermostat to maintain an optimum environment within the housing. Housing shall comply with IP-66 standards.

d. Camera Coaxial Cable

All outdoor coaxial cables shall be of 75-ohm RG-6/U type. Centre conductor shall be an 18 AWG 100 % solid bare copper (BC) conductor. Shield shall be 100 % tinned copper, braided, and shall provide 95 % efficiency, minimum. Outer jacket shall be black PVC. Cable shall have maximum 2.4 dB per 100 m attenuation at 10 MHz. Nominal capacitance shall be 53 pf per m. Nominal velocity of propagation shall be 82 %., Nominal impedance shall be 75 ohms. Coaxial cable shall be terminated with 75-ohm BNC nickel-plated connectors with 50 microns gold plated centre contacts.

All indoor video termination applications shall use a subminiature RG-59/U type, having 1 coax, 25 AWG, stranded (19x37) BC - bare copper conductors, foam PE-gas injected foam polyethylene insulation, aluminium foil-polyester tape-aluminium foil (Duofoil) shield with 100 % shield coverage plus tinned copper braid shield with 95 % shield coverage. Nominal capacitance shall be 16.3 pf per 300 mm, the nominal velocity of propagation shall be 83 %, and the nominal impedance shall be 75 ohms.

e. Camera Control Cable

If used in this Contract, all control cables shall be 2-pair, STP, tinned stranded copper conductors with aluminium/polyester shield, 100 % coverage and S-R PVC jacket.

1. Hybrid Cable

Proposed hybrid cable by the Subcontractor shall meet most of the Specifications of the video coaxial cable, control cable and power cable, as approved by the Engineer. This cable shall be capable to transmit the control and video signals and also to feed the camera with power at the same time using the same hybrid cable. Proposed cable shall be sufficient for outdoor use and shall be provided by a recognized manufacturer in cabling industry. Outer jacket shall be black PVC. Cables shall comply with the following specifications and requirements:

i. Video cable shall be 75-ohm RG-6/U type and as follows:
a) Conductor: Single bare copper
b) Conductor diameter: 1.02 mm
c) Insulation dia (±0.15 mm): 4.6 mm

d) Shield: Al-Pet- Al shield > 125 %
e) Braiding layer: Tinned copper
f) Braiding coverage: 95 %
g) Outer jacket: LSZH
h) Jacket colour: Black
i) Jacket diameter (± 0.20 mm):6.6 mm

ii. Power cable will be 3 core @ AWG 18 and as follows:
a) Conductor: 3X bare copper
b) Conductor diameter:1.22 mm
c) Insulation dia (±0.10 mm):1.6 x 3C twist
d) Voltage rating 300V
e) Voltage drop for 20 m @ 24 V dc: 0.61 V dc
f) Outer jacket: LSZH
g) Jacket colour: Grey
h) Jacket diameter (± 0.15 mm):4.1 mm

iii. Control cable will be twisted pair STP and as follows:
a) Conductor: Stranded tinned copper
b) Conductor size: AWG 22
c) Conductor diameter: 0.77 mm
d) Insulation dia: (±0.01 mm)1.2 x 2C twist
e) Shield: Al-Pet-Al shield (on each pair) > 115%
f) Outer jacket: LSZH
g) Jacket diameter: 3.8 mm
h) Jacket colour: Grey

iv. Characteristics as follows:
a) 6+PE
b) Current carrying capacity: 13 A at 55º C
c) Operating temperature -40º C, +125º C
d) Gold plated contacts

9.6.2.4 Vehicle Detection System

Subcontractor shall furnish, install, integrate, configure, and test a vehicle detection system (VDS), including the head-end server, for the purpose of obtaining traffic data and possible use in other subsystems. VDS shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

a. Microwave / Radar Vehicle Detector

Owner prefers a road vehicle detector system (RVDS) that is a non-loop based and non-intrusive such as radar and video, but will consider alternate vehicle detection solutions, provided that the achieved accuracy meets the requirements of the RVDS specified herein, and the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

When required in the Contract Documents, the Subcontractor shall supply and install a RVDS for the purpose of obtaining traffic data and possible use in other subsystems. RVDS shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

b. Field Equipment

Subcontractor shall furnish, install, integrate, configure, and test vehicle detection equipment in accordance with the following:

1. Capabilities: System shall provide counts, speeds, occupancy, queue and classification data at per-lane and aggregate basis. Candidate technologies are:
   i. Inductive loop detectors (least preferred).
   ii. Video vehicle detection.
   iii. Radar vehicle detection.
   iv. Laser vehicle detection.

   v. Any other Owner or Engineer approved method

2. Accuracy requirements. Following accuracy criteria shall apply:
   i. Self-calibration (count and occupancy). The system shall be able to achieve 85 % or higher accuracy for vehicle counts and lane occupancy for each lane.
   ii. Manual calibration (count and occupancy). System shall be able to achieve via manual tuning accuracy of 95 % or more for count and occupancy on a per-lane basis when measured against ground truth.
   iii. Speed. System shall be able to achieve 90 % or higher speed measurement accuracy when compared to ground truth.

All field equipment shall utilize IP network for communication to the traffic management centre or local control room as approved by the Engineer.

All RVDS equipment shall be installed on poles along the roadway, embedded in pavement or on attached to the sign gantries. Use of multi-purpose poles is encouraged to reduce the total number of poles/structures; however such use is acceptable only if it does not in any way compromise the operation of the collocated systems. If a separate structure is used it shall be suitable for the size of the provided equipment and shall be capable of supporting all required equipment plus 50 % increase in equipment weight with an appropriate safety factor.

c. Vehicle Detector Pole and Foundation

Pole foundations shall be consistent with the manufacturing requirements, and shall comply with theses Specifications and the Contract plans. RVDS detectors shall be mounted on poles or other structures of sufficient height and of construction similar to that Specified elsewhere for video surveillance camera poles. Mounting systems provided by the system manufacturer shall be preferred.

9.6.2.5 Traveller Information System (TIS)

Subcontractor shall furnish, install, integrate, configure, and test a TIS, including the head-end server, as indicated on the Contract plans, specified herein, and in accordance with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*, as approved by the Engineer. TIS includes dynamic message signs, directional electronic devices including lane and speed control signs, and the subset of variable message signs mounted on the gantry, pole, and other similar structures for queue warning, travel time purposes etc. Signs shall comply with the applicable requirements of BS EN 12966.

a. Field Equipment

General requirements shall be as follows:

1. All dynamic message signs (DMS) shall be full-colour graphic matrix type, regardless of their intended use. Minimum dimensions for the DMS signs shall be as follows:
   i. Full Size DMS signs shall have minimum dimensions of 6000 x 2000 mm (Type A2) for major roadways and 9000 x 3000 mm (Type A1) for major roadways with more than four lanes of transportation. Full DMS signs shall have minimum dimensions of 4000 x 2000 mm (Type A4) for all secondary roadways. For all locations where the transportation envelope may be restricted the minimum dimensions of the signs shall be 6000 x 900 mm or 9000 x 900 mm if there are four or more lanes of Transportation.
   ii. Full size DMS signs shall provide critical information to drivers in English and Arabic and shall be able to contain graphic symbols. Minimum size of displayed characters shall be sufficient to allow the characters to be easily discernable (5 minutes of arc) from a distance of at least 300 m by an operator having the lowest visual acuity which allows the operator to legally operate a vehicle in the area.

2. Travel time (TT) signs shall be used to display point-to-point travel time information. These signs shall be mounted on the side of the roadway. These signs may be either fixed signs with a full colour graphic matrix DMS insert or full colour graphic matrix DMS signs as approved by the Engineer and approved by the Owner. Minimum size of TT Signs shall be

4000 x 2000 mm. The same character size rules applicable to the full DMS signs shall apply. All locations shall have one (1) travel time sign on each side of the carriageway.

3. Queue warning /travel time DMS (Type A3) shall be used to provide point-to-point travel information and other travel related information on the lane control and speed control sign gantries (such as queue information). Signs are overhead mounted and shall be full colour graphic matrix signs. The minimum size of these signs shall be 2000 x 2000 mm. The same character size rules applicable to the full DMS shall apply.
4. Lane control and speed control signs (LCSCS) shall be used to provide lane and speed control. All LCSCS shall be full colour graphic matrix signs with ability to display required graphic images. LCSCS may be single signs (preferred) or two separate signs (one lane control sign and one speed control sign). Minimum dimensions for LCSCS signs shall be 900 x 900 mm.
5. All provided signs shall be produced by a single manufacturer who shall be approved by the Owner and/or the Engineer.
6. Refer to the Department of Transport ITS Design Manual regarding the DMS and LCSCS gantry types:
   i. 6 lane and 4 lane type gantries with cladding
   ii. 6 lane and 4 lane standard truss type gantry
   iii. 6 lane and 4 lane standard monotube type gantry

DMS display technology shall comply with the following:

1. Sign shall be light emitting diode (LED) technology based with full graphics display and shall be capable of displaying both English and Arabic alphanumeric characters as well as custom characters and symbols of various sizes.
2. European Norms, EN 12966 defines several optical parameters to evaluate DMS optical performance. Each optical parameter is associated with a class of performance. These parameters are luminance, luminance ratio, beam width, and colour coordinates.
3. The display shall be a full graphics matrix display meeting the following requirements:
   i. LEDs per pixel – 3 blue, red, and green LED (minimum).
   ii. Visual height of display – As specified herein this Specification.
   iii. Visual length of display – As specified herein this Specification
   iv. Number of colours per pixel –equivalent to 16 levels for each main colour.
   v. Time to switch between different sign aspects and displays shall not exceed 1.0 second. This time is defined as the delay between sign controller's reception of a valid signal and complete display of the aspect.
4. Dot pitch shall be fully compliant with BS EN 12966, Annex C graphics requirements, as approved by the Engineer. Dot pitch shall produce luminance L3 and a luminance ratio equal or better than R2 as per BS EN 12966.

LCSC display technology shall comply with the following:

1. Sign shall be LED technology based with graphics display and shall be capable of displaying both numbers and custom characters and symbols of various sizes. Changing from one message to another shall be instantaneous without visual disturbance. Visual uniformity of LED colour(s) across the entire display shall be ensured and no visible difference in the luminous intensity of any pixel in the display at any luminance level for a given colour shall be noticeable. Display shall meet the following requirements:
   i. Visual height of display – As shown on the Contract plans but shall not be less Than 850 mm unless otherwise approved by the Engineer.

   ii. Visual length of display – As shown on the Contract plans but shall not be less than 850 mm unless otherwise approved by the Engineer.
   iii. Enclosure front size – 1000 x1000 mm unless otherwise shown on the Contract plans unless otherwise approved by the Engineer.
   iv. Time to switch between different sign aspects and displays shall not exceed 1.0 second.

2. All LEDs of the same colour proposed for use in the sign shall come from the same LED component manufacturer's bin and have the same component reference for LED's of the same type. The subcontractor shall submit written assurances and an explanatory document from the manufacturer that such requirements can be met. The written assurances and explanatory document shall be included with the material submittal.

3. LCSC dot pitch definitions shall comply with BS EN12966, Annex C requirements, as approved by the Engineer.

   Subcontractor shall furnish and install queue warning/travel time DMS on the LCSCS gantries. These signs are overhead mounted and shall be full colour graphic matrix signs. The minimum size of these signs shall be 2000 x 2000 mm. DMS shall comply with the same requirements applicable to the full DMS.

   Subcontractor shall furnish and install travel time signs as shown in the Contract plans. These signs shall be mounted on the side and median of the roadway as indicated in the Contract plans. These signs are fixed traffic signs with a full colour graphic DMS inserts. Minimum size of the travel time signs shall be 4000 x 4000 mm. DMS inserts shall comply with the applicable requirements of the full DMS signs. All locations shall have one travel time sign on each side of the road as indicated in the Contract plans.

   DMS and LCSC shall be compatible with BS EN12966, CE or equivalent specifications as certified by a governmental body and as approved by the Engineer. As a minimum, the certification shall apply to the design, fabrication, and maintenance of the LED DMS/LCSCS.

Enclosure designs shall comply with the following:

1. Structure of the DMS and LCSCS housings shall be IP55 rated or better for the housing, and IP54 or better for the ventilation openings. Structure shall be weatherproof and corrosion resistant. Signs shall comply with BS EN12966, Class T2 requirements for resistance to temperature change. Control cabinets shall be rated for IP56 protection.

2. Enclosures shall be fully welded to protected against the entry of dust, dirt, water and undesirable elements and shall be manufactured in rust resistant aluminium and/or aluminium alloy corresponding to European Aluminium Standards, EN AW 1050, EN AW 6063, EN AW 6005 A and/or EN AW 6060 materials and grades.

3. For overall weight consideration steel enclosures of any type shall not be considered for designing the DMS enclosure unless otherwise approved by the Engineer. Mass of the DMS and enclosure shall not exceed 2,300 kg.

4. Enclosure shall be resistant to WL7 class wind pressure (1.4 kN/m2) and TDB2 class temporary deflection (5 mm.m-1). Subcontractor shall furnish evidence of compliance such as BS EN 12899 certification in this regard.

5. DMS and LCSC power supplies shall be 220 V AC, 50 Hz with AC/DC converter as per sign manufacturer requirements. DMS enclosure shall contain at least 2 of 16 Amp 220 V AC power outlet receptacles and one 100 W fire rated light source for maintenance purposes. LCSC enclosures shall contain a 13 Amp 220 V AC power receptacles for maintenance purposes. Maximum power consumption used by the DMS including fans and controller shall not exceed 3 kW.

6. Front Face of enclosures and front protective grids shall be protected by a flat, resistant and profoundly black finish. Paint quality shall comply with ISO 9227 500 hours salt spray test Gt0 value.

Display visibility and viewing angle: DMS and LCSC visibility angle (visual angularity), known as "beam width", B4 in BS EN 12966 shall be 20o minimum (±10 horizontal, 10 vertical). Face of the signs shall be capable of being inclined or declined from the vertical following installation on site by a minimum of 3o for DMS and 5o for LCSCS, and shall be adjusted as necessary to suit site conditions to optimize viewing by approaching vehicles as approved by the Engineer.

Luminance control: Sign contrast values shall be compliant with BS EN 12966 standard Class R2 or R3 for appropriate installation conditions. DMS luminance values shall meet at least BS EN12966 class L3 luminance level requirements. All LED colours intensity shall comply with BS EN 12966 class C2 standards as approved by the Engineer.

Communications: DMS and LCSC shall communicate with the central control unit via the communication system architecture. Compliance with the latest version of applicable NTCIP communication protocols is required and shall be used in this Contract in addition to other communications protocols as approved by the Engineer. As a minimum, IP over 100 Mbps Ethernet communications shall be provided as part of the DMS and LCSC communication protocols.

b. Installation of Dynamic Message Signs

Outdoor dynamic message signs (DMS), including travel time, lane control and speed control signs (LCSCS) shall be mounted on an overhead support structure as per the site conditions, at location shown on the Contract plans, and as approved by the Engineer. Where applicable the LCSCS shall be mounted on special mounting structures as per the site conditions and as approved by the Engineer.

Service platform (catwalk) between supports for the DMS shall be from end to end, and shall have easy access by service ladder attached to the upstream side of the structure of the road side gantry.

Subcontractor shall conduct the detailed design of the DMS and LCSCS mounting structure, mounting structure foundation, and the sign mounting details in accordance with the sign manufacturer requirements, the sign installation site details, and as approved by the Engineer.

Subcontractor shall submit to the Engineer for review and approval sign mounting details, mounting structure foundation details, structural analysis calculations, and vibration analysis of the mounting structure as per each site and sign specific requirements and in accordance with sign manufacturer recommendations prior to installing the mounting structure. All mounting structures shall be made from hot dip galvanized steel or from stainless steel. All drawings and calculations of the sign mounting structure as well as its proposed materials and components shall be submitted to the Engineer for approval prior to commencing any manufacturing or construction work on the structure.

An analysis shall be submitted to the Engineer for approval prior to manufacturing of the sign mounting structure, and include the following:

1. Overall analysis of structure as per BS EN 12899.
2. Vibration analysis of gantry structure as per BS EN 12966.
3. Wind resistance analysis according to 120 km/h wind load.
4. Seismic analysis of structure according to UBC 97
5. Analysis of welding points and their thicknesses
6. Analysis of bolts and screws located at main joints of structure
7. Fatigue analysis of welding, bolts and nuts and overall gantry structure for a 15 year DMS and LCSCS system life.

All outer parts of frame shall be aluminium, stainless steel, or as approved by the Engineer. All gantry structures shall have cladding as shown on the Contract plans. Cladding, colour, pattern, size and materials if it is part of the structure, shall be as approved by the Engineer. Paint shall be UV resistant and certified by an independent laboratory according to ISO 9227, 500 hours salt spray test as Gt0.

All fasteners, screws, nuts, bolts and washers etc. used in the gantry frame and cladding shall be provided in stainless steel or suitable nonferrous A4 quality material.

Subcontractor shall conduct all subsurface geotechnical borings for each DMS/LCSCS sign final location to determine soil features used in conjunction with sign mounting structure foundation designs. The findings shall be submitted to the Engineer for review and approval.

If requested by the Engineer and depending on the exact location details of each sign, the Subcontractor shall ensure that the gantry or cantilever design has a vertical angle adjustment mechanism adequate to adapt the DMS/LCSCS to the local roadway geometry.

Gantry height at the lowest point of arms shall not be less than 6.5 m, or as indicated on the Contract plans, as approved by the Engineer.

Projecting portion of the foundation anchor bolts and the nut and washer shall be treated by hot dip galvanizing.

All anchor bolts, ground rods and PVC raceways or conduits shall be located securely in position by the use of templates during the placing of foundation concrete.

Once the DMS/LCSCS is installed, several types of civil works may be required by the main Contractor to remediate any disturbance to the DMS installation site, as approved by the Engineer. These include, but not by way of limitation, site grading, landscaping and planting, and/or concreting.

c. Portable Variable Message Signs

Contractor shall provide and install portable variable message signs (PVMS) as part of his maintenance of traffic requirements (per Section 1.19.14, Traffic control, detour schemes and pedestrian safety, of Chapter 1) to warn drivers about construction and construction detours ahead. Display area of the PVMS shall be 3 m² (usually sized 2 x 1.5 m) at least. Characters shall be 360 mm high minimum. It shall have a high-resolution full graphic display with single colour and variable brightness levels with low energy consumption and at least 30° wide viewing angle. It shall have control options through a local keyboard, through cable and/or wireless LAN, or through GSM and modem remote control. It shall be solar powered with mandatory battery backup and with a local power source and generator source option. It shall have a minimum of 99 Arabic and English user-programmable and pre-programmed messages and pictograms, with all international traffic signs graphically preloaded.

PVMS shall be rugged, made of galvanized steel and easy to operate, maintain, and manoeuvre. Trailer shall have a proper suspension system, parking brake, corrosion protected mechanical equipment, properly configured hydraulic mechanism, and an adjustable hook height for use with different types of puller vehicles. Battery and hydraulic boxes shall be of durable fabrication, lockable, hinged, ventilated, and mounted to the trailer frame to protect batteries and hydraulic components from weather and vandalism. Control box shall be of durable fabrication, lockable, hinged, ventilated, and mounted to the trailer frame to protect the instrument panel and electronic controls from weather and vandalism.

PVMS shall not weigh more than 1,300 kg. Typical dimensions shall not exceed 5,500 x 1,750 mm.

9.6.2.6 Installation of Portable Variable Message Signs

The Contractor shall furnish and install LED-based portable variable message signs (PVMS) during various stages of the project to alert drivers to construction activities and hazards.

PVMS shall be mounted on a trailer that can be towed and placed at the work zone location as directed or approved by the Engineer. PVMS may be also known as mobile variable message signs, mobile dynamic message signs, trailer-mounted variable message signs, and mobile changeable message signs.

The sign shall be equipped with an electro-hydraulic raising/lowering mechanism. A manual brake winch and pulley system shall also be provided for emergency cases. The sign shall be able to be securely locked either during transport or in the display height position. The sign shall be able to rotate and securely lock in any position. The sign height in the “raised” position shall not exceed 4m.

The sign shall be delivered with a complete remote control system including, but not limited to, laptop, all required operation and maintenance manuals and software, as well as hands-on training for the operator. The PVMS shall be equipped with a GPS system to confirm its location to the project construction operations manager.

The PVMS power supply shall include internal sensing capability to adjust LED brightness in all visibility conditions and times of the day.

Lighting: A twofold halogen warning light system shall be attached to the top of the mobile advance digital board.

Warning light shall have the following salient features:

1. Two (2) fold halogen warning lights in accordance with WL7, EN 12352 L9 350mm diameter lamps
2. Automatic day and night adjustment
3. 12/24 Volt rechargeable battery power supply
4. The two fold halogen warning light system shall be furnished with rechargeable batteries, 12V, 230 Ah and an auto charger device for lead and lead gel accumulators, complete with replacement bulbs, lenses and other associated ancillary items to ensure continuous operation of the warning light system.

9.6.2.7 Overheight Vehicle Detection System

Subcontractor shall deploy an overheight vehicle detection system (OHVDS) that provides detection of overheight vehicles approaching height-limited structures, as shown on the Contract plans, required in the Particular Specifications and included in the Bills of Quantities. System shall be able to provide warning to operators of such vehicles, and to provide a safe exit from the roadway prior to the height-limited structure. In addition, the system shall detect and record violations and shall be able to implement secondary protection measures where necessary. Overheight vehicle detection system shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual*.

Incident prevention shall function as follows:

1. OHVD shall detect the presence of an over height vehicle on the roadway leading to the height-restricted area. Traffic control centre shall be notified electronically and immediately of the offending vehicle.
2. A combination of audible alarms, alternating variable message sign, flashers and a backlit warning sign shall be triggered in a timely manner to warn the driver of the potentially hazardous vehicle and to provide directions for immediate route exits prior to impacting a low clearance overpass ahead.
3. If the offending vehicle continues to approach the height-restricted area past the initial OHVD detector, a second OHVD station shall report the threat instantly to the traffic control centre and shall deploy secondary protection measures if they are considered necessary

a. Field Equipment

Alternate detection technology of overheight vehicles (such as overhead laser scanners) may be proposed by the Contractor for review. Procurement or deployment of alternate detection devices or system shall not be allowed without written approval by the Engineer. Otherwise, the Subcontractor shall comply with the requirements of this section.

Subcontractor shall furnish, install, integrate, configure, and test an overheight vehicle detection system with the following components:

1. Overheight vehicle detector system (including transmitter and receiver units with direction of travel determination capability). These shall be placed on opposite sides of the roadway for light beam emission. Detection of offending vehicles shall occur when the said beams are broken by an overheight vehicle. The OHVDS shall have built-in safeguards to minimize false alarms. The detector shall include the following items:
   i. Sensor: Sensors shall be placed ahead of the warning sign at a sufficient distance to allow the offending driver to observe the sign for at least 3 seconds at the maximum roadway speed.
   ii. Mounting: OHVDS sensors and equipment enclosure shall be mounted on poles or other structures of sufficient height and of construction similar to that specified elsewhere for CCTV poles. Mounting systems provided by the system manufacturer shall be preferred.
   iii. Foundations: Pole foundations shall be consistent with manufacturing requirements and shall conform to these Specifications and Contract plans.
2. Variable message signs (VMS) for displaying warnings and directions to motorists. These shall be as specified herein these Specifications for the traveller information systems for Type 4 DMS (4,000 mm x 2,000 mm). However, full range of capabilities shall not be required as directed by the Engineer. The warning VMS signs and associated gantry, pole, and foundations shall be compatible with the general VMS specifications given elsewhere in this specification with the following exceptions:
   i. Sign type: Sign shall be blankout type intended to display a single message. As a result there is no requirement for full graphic matrix or for full colour.
   ii. Sign activation: Sign shall be activated automatically by OHVDS sensor.
   iii. Additional warning features: VMS sign shall be equipped with flashing strobes and beacons.
3. Alarm bell for audible warning shall have a parabolic shield for sound direction and reduction as necessary. Bell shall provide sound output of 100 dB or higher at 3 m. Sound output to the sides and rear shall be reduced by the use of shield by at least 50 %. Equipment shall be compatible with mounting and power provided to the warning sign location.
4. Maximum height limit and high vehicle exit sign shall comply with the requirements of the Abu Dhabi Traffic Signals and Electronic Warning and Information Manual. Maximum height limit sign shall be placed ahead of the height-limited structure in a location which allows for a safe exit of an overheight vehicle. Sign shall be placed prior to the overheight vehicle exit at a distance sufficient to allow time for the offending vehicle to change lanes if necessary and take the provided exit. High vehicle exit sign shall contain audio and visual overheight indicators and provide a clear exit direction to motorists. Sign shall comply with the following items:
   i. Mounting: Signs shall be mounted on poles or other structures of sufficient height and of construction in accordance with the requirements of the Department of Transport Manual of Uniform Traffic Control Devices. Mounting systems provided by the system manufacturer shall be preferred.
   ii. Foundations: Pole foundations shall be consistent with manufacturing requirements and shall conform to the Article 9.2.3.2 and the Contract plans.
5. Secondary protection devices shall be provided in cases where height restricted structure is sensitive and requires additional active protection measures as shown on the Contract plans, as required by the Particular Specifications and where included in the Bills of Quantities, as approved by the Engineer.

9.6.2.8 Roadway Weather Information System

Subcontractor shall furnish, install, integrate, configure, and test a roadway weather information system (RWIS), including the head-end server, for the purpose of monitoring roadway atmospheric and pavement environmental conditions. RWIS shall incorporate continuous monitoring and measuring of air pollutants in accordance with the relevant authority. Subcontractor shall co-ordinate with the relevant authority about installing and operating weather stations. RWIS shall comply with the requirements of the Abu Dhabi *Traffic Signals and Electronic Warning and Information Manual.*

RWIS shall provide the following measurements as directed by the Engineer:

1. Air temperature (high / low / current)
2. Humidity
3. Solar radiation
4. Wind speed and direction (gusts and sustained)
5. Precipitation
6. Visibility
7. Fog detection
8. Noise measurement
9. Pavement condition
10. Air quality – CO, NOx, H_2S, CH_4, HC, BETX, PM_{10}, $PM_{2.5}$

a. Field Equipment

RWIS shall include a sensor tower used for mounting of all sensors, video surveillance camera, local fence and equipment enclosure, local data logger for data storage, and the necessary site and traffic management centre/control room hardware and software to transfer the weather and air quality data to other agencies such as Environment Agency Abu Dhabi (EAD) or other applicable authority. Weather sensors shall be placed at least 3 m above ground for added security and protection against vandalism".

b. RWIS Tower and Foundation

Each weather station shall be provided with a self supporting tower, including foundation, which provides mounting space for the weather sensors, ground clearance to facilitate sensor accuracy, and some degree of physical security for the sensor equipment. Tower shall also provide mounting capability for the data logger/network interface equipment.

Tower shall be designed to support the static load from the weather station equipment, and the dynamic load resulting from wind speeds of up to 120 km/hr.

Subcontractor shall include the necessary signal and power conduits, connections to backbone communications network, utility power connections, pole and tower foundations, guard rails, fencing, bollards, etc as required for an operation roadway weather information system communications system

c. Communications Subsystem

All communications for the RWIS shall be primarily based on a single mode (SM) fibre optic backbone communications system. Communications system cables shall be routed from individual intersections in dedicated, concrete encased conduits, as shown on the Contract plans and as approved by the Engineer.

Communications backbone shall be compliant with communications industry international standards. As a minimum, the following communications interfaces shall be provided, including PAL video, 10/100/1000 Mbps Ethernet, and low speed RS-232/422.

In the case of Fiber Optics (FO) used, the Subcontractor shall install a backbone communications system based on active access nodes linked by optical fibres forming a reliable and redundant high speed medium for the transparent transport of voice, data, LAN and video services.

As the transmission system will be used as a backbone network, the system shall have following characteristics:

1. High availability
2. High reliability

3. Dual ring configuration to the extent possible
4. Easy to install and operate
5. Compact design

A digital transmission system, based on state-of-the-art fibre optic technology, shall be required to carry all voice, data, LAN and video information, as shown in the Contract Plans and directed by the Engineer. Usage of copper cable for long-distance transmission purposes that exceeds 90 m shall not be allowed due to the inherent disadvantages of copper cable (attenuation of signals, susceptibility to electromagnetic influences and high costs for cable sizes necessary to carry the required amount of signals).

An IP-based transmission system with Ethernet switches shall carry all channels for voice, data, LAN and video communications. As virtually all information is transmitted via the IP network, the system shall be implemented using two physically independent cable routes wherever applicable and possible and as approved by the Engineer. In case of a partial network failure, this will ensure that the remaining part is not affected. The network shall be logically configured by VLANs (virtual local area network) which allow separation of the various types of flow (video, voice, data, order, etc.) and allows affecting a different priority level to them so that there is no disturbance in the transfer of information as approved by the Engineer.

9.6.2.9 Network Management System

Subcontractor shall furnish, install, configure, and integrate a network management system (NMS) to monitor, manage and administrate the traffic management system communication network (TMSCN) as shown in the Contract plans, as directed by the Engineer. The NMS shall be compatible with the Employer's legacy NMS. The NMS shall be a powerful and flexible open platform network infrastructure (hardware and software) management tool, providing enhanced features to manage the TMSCN connected systems and components, and shall include all necessary NMS equipment - servers, switches, routers, firewalls, etc as shown on the Subcontractor's approved Drawings. Such as system fibre and Ethernet switches regardless of the model, shall deliver customizable network management capabilities that scale to meet the needs of the largest and advanced networks.

NMS shall include network configuration and change management functionality, giving control over bulk configurations and scheduling. It shall be able to create detailed audit trails of network changes, to perform firmware upgrades and to manage the software configuration of the networked devices. NMS shall be able to represent the status of the network using several graphics approach. NMS shall be fully client-server and supports multiple distributed users with varying access levels and individualized network resource control.

NMS shall be supplied with enough capacity and licenses to cover all the TMSCN systems with additional spare capacity of 50 %.The NMS shall be integrated as ATMS component so that the operator in the control room can see and take action on the alarm coming from NMS. NMS shall support open protocols to permit the control of multiple suppliers. NMS shall visualize, monitor and pro-actively manage the network, including analyzing traffic loads and generating statistical trend reports. NMS shall support multiple vendors, softwares and ensure compatibility with major suppliers including but not limited to: Cisco, Moxa and Juniper.

a. Field Equipment Cabinet Remote Switch

Subcontractor shall furnish, install, and configure a field equipment cabinet remote switch (FRS) – access field switch - in field equipment cabinets (FEC) to interface the ITS field devices with the fibre optics or Ethernet communication backbone as directed by Engineer.

FRS switch shall be an industrial class, fan less, modular and layer 2 managed fibre Ethernet switch. As a minimum, standard layer 2 switches are required, however, layer 3 switches are acceptable or desired. Switch shall be of reconfigurable model in which the type of ports and modules of each switch can be configured as needed based on the location of the switch as approved by the Engineer and as shown in Contract plans. Subcontractor will be requested to keep some modules as spare to be used when needed as directed by the Engineer. FRS shall comply with the following requirements:

1. General requirements:
   i. FRS shall include, as minimum, three of one (1) Gbps single mode fibre ports for the interface with the fibre backbone.
   ii. FRS shall include, as a minimum, a combination of four (4) ports or more to connect the ITS devices on the field. This combination might vary from one location to another as following: four (4) fibre ports (8 fibre cores) 100 BaseF(x), and 4 RJ45 ports100 BaseT(x) or combination of Fibre and RJ4 ports based on every site condition and as approved by the Engineer. Switch shall be capable to accept at least another module with four (4) additional fibre (8 fibre cores) or four (4) additional RJ45 ports as required.
   iii. Ports configuration of the FRS switch may vary from one location to another as needed and as approved by the Engineer. However, in most cases, a combination of two (2) fibre ports (4 fibre cores) and two (2) RJ-45 ports will be required per each module. Wherever only 2 RJ-45 ports or 2 fibre ports will be used, the other two (2) spare ports shall be fibre. For the spare modules, 65 % shall be supplied with 4 fibre ports (S.M), 30 % with combination ports, two (2) ports RJ-45 and two (2) ports fibre, 5 % all RJ-45 ports as approved by the Engineer.
   iv. For Signalized junctions, the FRS shall include, as a minimum, a combination of eight (8) ports or more. This combination might vary as directed by the Engineer.
   v. Power supply adaptors and accessories of the FRS switch shall be provided by the same manufacturer and shall be considered within the FRS switch cost.
   vi. Power supply and fibre modules environmental specs shall be the same as the switch environmental specs.
   vii. 1 Gbit fibre port shall be capable of aggregating and transmitting at a minimum distance of 30 km.
   viii. Fibre modules cost shall be considered within the FRS switch cost.
   ix. Spare fibre modules shall be supplied and kept as spare at locations as directed by the Engineer.
   x. Fibre modules shall be supplied by the same switch manufacturer and shall comply with the environmental specs of the switch or as directed by the Engineer.
   xi. FRS switch shall be capable to function in ring and star topologies.
   xii. FRS switch shall require no infield electrical or optical adjustments or inline attenuators to ease installation.
   xiii. FRS switch shall provide power, link speed, and fibre port status indicating LED's for monitoring proper system operation. Switch shall also provide a contact closure for a loss of fibre-fibre alarm.
   xiv. Support IEEE 802.1X (authentication). Moreover, other static port lock solutions shall be implemented as approved by the Engineer. Switch shall be configured to protect static MAC address for a specific port.
   xv. Support IEEE 802.1Q (VLans).
   xvi. FRS switch shall provide automatic resettable solid state current limiters and independent voltage regulators fibre to reduce the chance of a "single point of failure" of the system.
   xvii. FRS switch shall have a dual power supply inputs.
2. FRS switch shall provide a console connection for local management of the device. Data specifications:
   i. Data interface: Ethernet IEEE802.3
   ii. Data rate: 10/100 Mbps
   iii. Port: RJ45
3. Optical specifications: Optical fibre: 100 BaseFX, 1000 BaseSFP 9/125 micron single mode (duplex) or SFP+ as approved by the Engineer.
4. Electrical specifications

   i. Power supply unit: less than 50 W
   ii. Industrial model dual power supply
   iii. AC or DC operation
5. Environmental specifications:
   i. MTBF: at least 150,000 Hours
   ii. Operating Temp: 0^o C to $+75^o$ C.
   iii. Relative humidity: 10 % to 95 % no condensing.
6. Regulatory agencies/approvals and listings: As a minimum, FCC Part 15 Class A, EN 55022 Class A, EN 50121-4, safety: UL 508, UL Class1 Div2 and EN 61000-4-(2 to 6)
7. Technology standards and protocols: Shall support open standards and protocols. Proprietary protocols shall not be used. As a minimum, SNMP V1/V2/V3, HTTP/TFTP, DHCP, Port security IP and MAC, 802.1x, IEEE 802.1Q, GMRP, IEEE 802.3x, IEEE 1588, IEEE 802.1D, IGMP Snooping, PIM-DM, PIM-SM, RSTP, QoS
8. Physical features:
   i. Industrial fanless switch
   ii. Minimum housing protection shall be IP20

b. Ethernet Fibre Transceiver

Subcontractor shall furnish, install, configure, and test device Ethernet fibre transceivers as approved by the Engineer, to convert the RJ45 port of the ITS device to a fibre port in order to connect with the access field switch if the distance between them is more than 90 m. It shall be industrial type and capable to survive under a temperature of 75^o C as a minimum. This item will not be required if the ITS device will be facilitated with SFP module port.

c. Wireless Ethernet Bridge

Subcontractor shall furnish, install, configure, and test a high speed wireless Ethernet bridge (WEB) as directed by the Engineer. WEB shall be a microwave system that operates on an approved frequency channel, and shall include an in-door unit (IDU), an out-door unit (ODU), a microwave antenna, a RF cable and network management tools (NMT). ODU shall include radio data transmitter/ receiver modules and may be integrated with an IDU that is compliant with the requirements in this specification. WEB shall be compliant with the IEEE 802.3, 802.3u and 802.3d Ethernet standards.

WED can also be supplied as an integrated assembly including the ODU and microwave antenna. If supplied as such, this item shall include outdoor Category 6 cable to connect the assembly to the cabinet and Ethernet switch.

Assembly shall include provision for system configuration, setting for antenna alignment, ability to set up tools for network management, and ability to monitor the system alarm and system performance testing. Subcontractor shall provide a fully operational assembly with all cabling and terminations matched to support the selected components.

d. Fibre Optic Cable

Subcontractor shall furnish, install, splice and test all the required fibre optic cable as shown on the Contract plans and as approved by the Engineer. All splicing kits, splice machines, OTDR machines, fibre optic cable caps, moisture/water sealant, terminators, splice trays, pigtails and accessories to complete the fibre optic network shall be provided as incidentals.

All equipment for installation, splicing and testing shall be provided by the Subcontractor. In general 96, 48, 24, 12, and 6 core single mode fibre (SMF) optical cables are used in the Emirate of Abu Dhabi. Typically a 48 core S.M fibre cable will be required for the backbone and 12 S.M as access cable as directed by the Engineer.

Fibre optic cable shall be suitable for installation in an underground conduit environment including constant immersion in water. All cables shall be loose-tube, non-metallic construction. Cables shall include a double armoured outer jacket layer to provide environmental protection from the weather and rodents.

All fibres in the fibre optic cable shall be spliced and/or terminated as indicated on the Contract plans and as specified herein. Fibre cuts and splices shall only be made at the pullbox nearest the traffic signal controller, ITS equipment, field equipment cabinet, communications hub, as directed by the Engineer.

Quantity of fibres within the cable shall be as shown on the Contract plans, as required in the Particular Specifications or as indicated in the Bills of Quantities.

Fibre optic cable shall be provided in continuous lengths. Each fibre shall be pulled from the same optical waveguide form and shall be free of splices. Each optical fibre shall consist of a doped silica core surrounded by a concentric silica cladding. Use of any other materials is not allowed unless otherwise approved by the Engineer.

Subcontractor shall perform all necessary works to provide a complete end to end cable connection between the field device and the nearest field equipment cabinet as per the manufacturer requirements and as approved by the Engineer. Subcontractor shall establish fibre optic links between the field equipment cabinet to the nearest splice pull box. Subcontractor shall perform the required splicing to connect to the nearest field equipment cabinet that shall house the fibre remote switch, and that shall be connected directly to the traffic control centre through the fibre optic network as shown in the Contract plans and as approved by the Engineer.

Subcontractor shall install additional fibre segments in case the existing segment exceeds 60 % of fibre usage. For all new cables/segments, the fibre usage shall not exceed 40 % of the total fibres per each cable.

Subcontractor shall conduct a study for the required fibre usage in the locations for all new installations and prepare all fibre optic connection diagrams, splice tables, and fibre usage sheets to reflect available, reserved and used fibres in each segment that shall be submitted to the Engineer for review and approval. At least 2 dark fibres shall be reserved in each fibre segment for other agency uses unless otherwise approved by the Engineer. Optical fibre cables shall also comply with the following requirements:

1. Attenuation: Nominal attenuation shall be 0.4 db/km maximum at a wavelength of 1300 nm. Attenuation shall not exceed 0.3 db/km maximum at a wavelength of 1550 nm.
2. Bandwidth: Single mode fibres shall have a maximum dispersion of 3.5 pico seconds/nanometre km at 1300 nm.
3. Testing: All optical fibres shall be proof tested by the fibre manufacturer at a minimum load of 100 kpsi. All optical fibres shall be 100 % attenuation tested at the factory for compliance with performance specifications described herein. The attenuation of each fibre shall be provided with each cable reel.
4. Fibres: Quantity of fibres contained in the fibre optic cable shall be 48 in 4 fibres × 12 tubes configuration unless otherwise approved by the Engineer, and 12 in 4 fibres x 3 tubes the fibres shall have a nominal core diameter of 8 to 10 microns. Fibre outer diameter shall be 125 plus or minus 3 microns. Inside Abu Dhabi City Island, the Quantity of fibre optic cable shall match the existing fibre cable in the city to easy the interface as directed by the Engineer.
5. Core/clad concentricity error: Core/clad concentricity error shall be within plus or minus 0.5 micron.
6. Primary coating: Each fibre shall have a high density polymer coating of a minimum of 250 micron to prevent abrasion of the fibre surface or as approved by the Engineer.
7. Buffering: Cable shall be of gel-filled, loose tube construction with up to 12 buffer tubes wrapped around a dielectric central strength member. All fibre(s) shall be contained within buffer tubes, and each buffer tube shall have an inside diameter much greater than the total diameter(s) of the fibre(s) it supports.
8. Each fibre or group of fibres shall be free-floating within the tubes such that all mechanically or environmentally induced stress placed upon the cable is de-coupled from the fibres. Air within the buffer tubes shall be displaced with a gel to prevent entry by water and to facilitate free movement of the fibre(s) within.

9. Tensile strength/crush strength: Cable shall be capable of withstanding a pulling tension of 2700 N under load conditions and 600 N under static conditions and a crush resistance of 5000 N/m (length of cable), without changing the characteristics of the optical fibres. Requirements for a higher pulling tension may be accepted as approved by the Engineer.
10. Bend radius: cable shall be capable of withstanding a bending radius of 15 times its outer diameter during operation and 15 times its outer diameter during installation without changing the characteristics of the optical fibres.
11. Cable configuration: Fibre-optic cable shall have a reverse oscillation or planetary stranding structure. Cables constructed of less than six fibres shall have a buffer tube provided for each fibre; cables constructed of more than six fibres may have several fibres occupy a buffer tube, with equal distribution of fibres as far as practical. Jacket construction and the configuration of the groups shall be such that they can easily be separated at splice points, permitting one set of fibres to be cut and spliced while the others remain continuous.
12. Subcontractor shall submit proposed cable designs for the Engineer's approval prior to procurement and installation of cable plant.
13. Cable shall have a water-block tape between the buffer tubes and throughout the remainder of the cable to prevent entry of water. A binder wrapping strength member of aramid fibres shall be provided as a final layer prior to application of the outer jacket.
14. Subcontractor shall demonstrate crush and abrasion resistance of final cable design and adequacy for conduit installation under full tensile loads and multiple bends.
15. Diameter: Outer diameter of each cable shall be less than 20 mm.
16. Colour coding: Each fibre buffer jacket shall be colour coded separately. Within unit tubes or sub-bundles, each fibre shall have a distinctly different colour coding. Buffer tubes shall be colour coded in compliance with EIA/TIA-598 "Colour Coding of Fibre Optic Cables". All fibres shall be colour coded in compliance with EIA/TIA-598 "Colour Coding of Fibre Optic Cables". In buffer tubes containing multiple fibres, the colours shall be stable during temperature cycling and not subject to fading or smearing onto each other or into the gel filling material. Colours shall not cause fibres to stick together.
17. Cable jacket: The outer jacket shall be yellow in colour unless otherwise approved by the Engineer.
18. Outer jacket shall be constructed of medium density polyethylene with minimum jacket thickness of 1.4 mm. Jacketing material shall be applied directly over the tensile strength members and flooding compound. The outer jacket shall be UV and fungus resistant.
19. A permanent marking shall be employed on the outer jacket of the cable which shall show the date of manufacture and the manufacturer's name. A numerical sequence shall be marked on the outer jacket, at intervals no greater than 3 m, to facilitate determination of length of cable and amount of cable remaining on the reel. Height of the marking shall be 2.5 mm nominal. In addition, cable tags with permanent markings shall be provided that include the words "Owners Name - Fibre-Optic Cable" at all pullbox and cable access locations.
20. Optical connectors: All permanent connector installations shall utilize factory installed/tested connectors. Field installed connectors shall not be allowed.
21. Optical connectors furnished for installation on optical patch cords and pigtails shall be compatible with the connector sleeves on the fibre distribution panels.
22. Connectors shall meet, as a minimum, the following specifications:
    i. Attenuation: (average, 3 readings, 120 degree spacing): 0.4 dB/km, maximum @ 1300 nm
    ii. Mechanical stability: 0.3 dB change, maximum
    iii. Tensile stability: 0.3 dB change, maximum
    iv. Thermal stability: (5 cycles, -20º to +60º C) 0.4 dB change,
    v. Maximum splice losses shall not exceed 0.02 dB
23. Environmental: Cable shall be capable of withstanding the following environmental conditions:
    i. Installation: -30º to +70º C
    ii. Storage/operation: -40º to +70º C
    iii. Humidity: 0 to 100 %
24. Fibre optic testing:

i. Fibre optic splices: Splice losses shall not exceed 0.02 dB. Subcontractor shall provide evidence of each splice performed and submit to the Engineer for approval.

ii. Optical time domain reflectometer (OTDR) testing: All fibre links shall be tested bi-directionally after splicing and termination. All fibres shall be tested for attention loss using an OTDR set to 2-point loss measurement parameters. Marker points shall be placed at the beginning and end of each backscatter signature recorded by the OTDR machine in accordance with the OTDR machine's manufacturer instructions.

iii. Each fibre shall have a unique identification and numbering sequence which shall be submitted to the Engineer for review and approval. Each trace shall contain as a minimum:
   a) Cable/sheath length. This is not the same as optical fibre length
   b) 2-point dB loss
   c) Attenuation in dB/km
   d) Fibre type
   e) Wavelength used
   f) Pulse width selection
   g) Fibre/cable identification

iv. Stored fibre trace shall allow full manipulation of the trace when viewed with the PC emulation software. Both a hard copy and a soft copy of each trace shall be submitted to the Engineer for review and approval.

v. Proper pulse width selection is required to minimize attenuation dead zone effect (10 ns pulse: SM dead zone=10m). Any links which fail the above tests shall be replaced and retested by the Subcontractor at his own expenses.

vi. All links which contain splice points or interconnect points shall also contain and additional "Events Display Table" to accompany the OTDR trace. This display shall show the distance to the events, distance between multiple events, loss of each event in dB, and a description of the event (reflective, non-reflective, gains, and cable end).

e. Fibre Optic Patch Panel

Subcontractor shall furnish, install, splice and test a 24-port (12 duplex ports) or 48-port (24 duplex ports) fibre optic patch panel to be located in each field equipment cabinet, as approved by the Engineer.

Subcontractor shall furnish, install, splice, and test a 12-port (6 duplex ports) or 6-port (3 duplex) fibre optic patch panel with IP-66 protection on or within the video surveillance camera pole and wherever needed, as directed by the Engineer.

Each panel shall be equipped with all required patch cords, pigtails, connectors, mounting accessories as an integrated part of the panel. In addition, 25 % additional spare patch cords shall be furnished as part of each patch panel. No separate measurement or payment shall be made for patch cords and any costs incurred by the Subcontractor in so doing shall be considered incidental to the cost per fibre optic patch panel.

f. Fibre Optic Patch Cords

Fibre optic patch cords shall be a rugged type provided to cross connect the fibre patch panel to the fibre-optic transmission equipment. These jumpers shall be orange in colour for multimode fibre, yellow in colour for single-mode fibre and shall have strain relief on the connectors. Fibre shall have a 900 micron polymer coating with tight buffer tube, Kevlar strength member and a PVC jacket.

Patch cords shall be sufficient in length plus 1.0 m spare length or as approved by the Engineer.

Optical patch cords shall consist of a section of single fibre, jacketed cable equipped with factory installed optical connectors at both ends, in single-fibre simplex, dual-fibre duplex or multi-fibre configurations as required.

Each jacketed fibre shall have a tensile strength in excess of 222 N.

g. STP CAT-6 Cable

Category 6 (CAT-6) cables shall meet TIA/EIA-568-B.2-1 requirements. CAT-6 cable shall be connected to all IP copper interfaces for all Ethernet devices. For all outdoor installations the cable jacket shall be durable, high-density polyethylene insulation, PVC jacket. CAT-6 cable shall be compact for ease of installation and be able to connect high speed local area networks (LANs) to transmit video and data. CAT- 6 shall be STP for outdoor/field Installations and shall be UTP for indoor installations.

CAT-6 shall meet or exceed the following features:

1. Physical characteristics:
    - i. Conductors: 23 AWG solid copper
    - ii. Insulation:
        - a) Plenum: low smoke flame retardant
        - b) Thermoplastic (FEP)
        - c) Riser and LSZH: polyolefin (PE)
    - iii. Cable core: Four twisted pairs cabled around a centre member
    - iv. Jacket with rip cord:
2. Cable jacket shall be printed at intervals indicating:
    - i. Cable code
    - ii. AWG
    - iii. Listings (NEC code)
    - iv. Verification
    - v. Date
    - vi. Manufacturing traceability code
3. Temperature: 5° C to at least 60° C
4. Transmission characteristics: At least 300 MHz are minimum guaranteed values
5. DC resistance @ 20° C, max.: 9.38 ohms/100 m
    - i. DC resistance unbalance, max.: 5 %
6. Mutual capacitance, max.: 5.6 nF/100 m
7. Capacitance unbalance pair to ground, max.: 330 pF/100 m
8. Input impedance:
    - i. 100 ± 15 ohms from 1 to 100 MHz
    - ii. 100 ± 22 ohms from 101 to 200 MHz
    - iii. 100 ± 32 ohms from 201 to 300 MHz
9. Nominal velocity of propagation (NVP):
    - i. Plenum: 72 % @ 10 MHz
    - ii. Riser: 68 % @ 10 MHz
10. Propagation delay (skew), max.: 25 ns/100 m
11. Cat 6 cable termination protection: Subcontractor shall be responsible to provide the terminated cable with guards.

Before a cable is plugged into the camera port, an RJ45 guard shall be used to protect the port against any unauthorized accidental unplugging and to tightly fix the RJ45 to the camera port. This guard shall have the following specification as a minimum:

1. Halogen-free plastic.
2. Can be exchangeable and reusable.
3. These guards shall be fixed at the camera ends.
4. All RJ45 connections shall be protected with a boot of a colour similar to the cable colour.

h. STP Cat-6 Patch Panel

Subcontractor shall furnish, install and terminate multi-port Ethernet STP Cat-6 patch panels in the FEC cabinets as shown on the Contract plans, as may be required in the Particular Specifications and as approved by the Engineer. All Ethernet STP CAT6 cables from the ITS field devices shall be directly terminated at the outdoor STP CAT6 copper patch panel inside the AFS equipment cabinet. Patch panel shall meet ANSI/TIA/EIA568A5 performance requirements for STP category 6. Terminations shall be 568B compliant. Patch panel shall include all required patch cords and patch cables necessary to connect all equipment to the panel. In addition, 25 % additional spare patch cords shall be furnished as part of each patch panel. No separate measurement or payment shall be made for patch cords and any costs incurred by the Subcontractor in so doing shall be considered incidental to the cost per STP Cat-6 patch panel.

STP Cat-6 patch panels shall be in accordance with the following specifications:

1. 8 Ports RJ-45 STP Cat-6
2. Patch panel shall be fitted with metal cable manager for convenience of cable management
3. Highly resistance and inflaming retarding material, Grade UL94-0
4. Module part shall be fitted with shield, protecting inner IDC contact from irregular working in rugged environment
5. Meet or exceed the current T568A and T568B standard
6. Rustproof metal framework
7. Dustproof and weather proof housing, IP-66
8. Enclosed shielded patch panel

9.6.2.10 ITS Electrical and Control Cables

This item provides the electrical supply to the ITS equipment from the field equipment cabinet or other power sources. It shall comply with all electrical conductor requirements as per Article 9.5.2.4 and in accordance with the applicable sections and clauses of Chapter 10, Lighting and Electrical Distribution Works.

Electrical conductor shall be at least 3 core, PVC/PVC, steel wire armoured and shall be installed to maintain a voltage drop of less than 3 %, and sized according to the load of the respective ITS equipment. Cable shall be of outdoor type cross linked polyethylene (XLPE) semi conductor tape insulated, individually copper tape screened, steel wire armoured. Cables shall be sized appropriately to meet the manufacturers requirements, and as detailed in the Specifications and Contract plans.

Cable shall have a bending radius of at least 13 times the overall diameter and shall be able to operate at temperature range of 0^{o} to 80^{o} C.

Unless specified elsewhere in the Specifications, all system cabling shall be compatible with the manufacturer requirements. Wherever possible, the manufacture’s recommended cables shall be preferred.

9.6.2.11 Cabinets and Enclosures

a. Equipment Cabinet(s)

Equipment cabinets (EC) shall be used to house the system equipments and components in the traffic control centre. Dimensions of each cabinet shall be identical, sufficient to house the system equipment, as approved by the Engineer. Cabinet shall be of 14 gauge steel un-welded construction. Cabinet shall have a perforated front door, louvered and perforated side panels, and a louvered and perforated rear door cooling fan units, sized to cool the enclosed equipment and rated at "quiet operation" shall be included in each cabinet. Cabinet shall have lockable front and rear doors. Cabinet(s) shall include provisions for cable and conduit entry through the top and bottom of the cabinet. All cables shall be neatly harnessed and routed within the cabinet using approved cable management techniques. All cables shall be labelled in accordance with ANSI/EIA/TIA 606-A standards.

Each EC shall be corrosion resistant. Each EC shall be completely ventilated. Each EC shall be wired from single phase, 240 V AC, 50 Hz power with a power disconnect switch, from the appropriate power panel. All communications equipment and components in each cabinet shall use this as the primary source of power. Subcontractor shall be requested to submit a calculation for the air follow in each EC in which the number of required fans for ventilation process will be decided as approved by the Engineer.

Separate terminal blocks shall be provided for each power connection within the cabinet and these blocks shall be considered subsidiary obligation to the respective Bill of Quantities items.

Each EC shall include frames for equivalent EIA-310-C standard 48.26 cm rack mounting.

Each EC shall have a unique ID plate and shall include a list of all items installed inside the cabinet.

b. Field Equipment Cabinets

Field equipment cabinet (FEC) shall house the video surveillance field equipment and communications equipment as shown on the Contract plans. FEC shall be provided with fully wired back panels, with all the necessary terminal boards, wiring, harnesses, connectors and attachment hardware for each cabinet location. All terminals and panel facilities shall be placed on the lower portion of the FEC walls below all shelves.

Each FEC shall be provided complete with all internal components, back and side panels, terminal strips, harnesses, and connectors as well as all mounting hardware necessary to provide for installation of equipment as described on the Contract plans and as required by the Particular Specifications.

All FECs shall be identical in size, shape and quality throughout the entire project. In addition, the FECs shall be equipped internally as specified herein.

Details of the FEC design and equipment layout shall be submitted to the Engineer for review and approval prior to fabrication.

Each FEC, as a minimum, shall be supplied with the following:

1. Adjustable shelves, as required
2. Backpanel
3. Surge protection for video connections, power connections, and communications connections
4. Terminal strips
5. Interconnect harnesses with connectors
6. Jack for field telephone
7. On/off light
8. "Door open" connection to backpanel
9. Interior holder for FEC documentation as shown on the Contract plans
10. All necessary installation and mounting hardware

Electrical requirements shall include the following items:

1. Backpanel: This panel shall include the following components:
    i. Single phase isolator –Contractor shall install one isolator unit in each field equipment cabinet to isolate the main power source from the field equipment cabinet when needed. Isolator shall be UL listed. Isolator shall not be affected by ambient temperature, humidity and other environmental conditions prevailing in the Project region.
    ii. Circuit breakers - Circuit breakers shall be approved and listed by Underwriters Laboratories. Operating mechanism shall be enclosed and the switches shall be marked to indicate whether they are in the closed or open position. Contacts shall be silver alloy enclosed in an arc quenching chamber. Each video surveillance field equipment cabinet shall have, as a minimum, a single-pole, 20-amp circuit breaker. Circuit breaker shall be unaffected by ambient temperature range, relative humidity, applied power, and the shock and vibration range specified in Section 2, "Environmental Standards and Test Procedures" of NEMA TS2-1992 or EMEA standard equivalent. Circuit breaker shall have an interrupt capacity of 5,000 amperes and insulation resistance of 100 megohms at 500 V DC.

iii. Power line surge protection - Power line surge protectors shall be provided and installed as described below.

2. Standards:
   i. Housing material PBT (Polybutylene terephthalate)
   ii. Inflammability class acc. to UL 94 V0
   iii. Standards for air and creepage distances: DIN VDE 0110-1
   iv. Standards for air and creepage distances: IEC 60664-1: 1992-10
   v. Standards for air and creepage distances: IEC 61643-1
   vi. Surge voltage category III
   vii. Contamination class 2
   viii. Degree of protection: IP20
   ix. Mounting type DIN rail 35 mm
   x. Design DIN rail module, two-section, divisible
   xi. Number of positions 1
   xii. Ambient temperature (operation) -10 °C to 80 °C
   xiii. Message surge protection faulty Optical, remote indicator contact
   xiv. Direction of action 1L-N/PE
3. Protective circuit:
   a) IEC category I + II
   b) EN type T1 + T2
   c) Lightning protection class III-IV /50 kA (TT, TN-C-S)
   d) Nominal voltage UN 240 V AC (230 V AC. 240 V AC)
   e) Arrester rated voltage Uc (L-N) 350 V AC
   f) Arrester rated voltage Uc (L-PEN) 350 V AC
   g) Rated load current 125 A (TA=55°C)
   h) Nominal discharge surge current In (8/20) μs (L-N) 25 kA
   i) Nominal discharge surge current In (8/20) μs (L-PEN) 25 kA
   j) Lightning test current (10/350) μs, charge 12.5 As
   k) Lightning test current (10/350) μs, specific energy 160.00 kJ/Ω
   l) Lightning test current (10/350) μs, peak value limp 25 kA
   m) Protection level Up (L-N) ≤ 1.5 kV
   n) Protection level Up (L-PEN) ≤ 1.5 kV
   o) Residual voltage (L-N) ≤ 1.3 kV
   p) Residual voltage (L-N) ≤ 1.1 kV (10 kA)
   q) Residual voltage (L-N) ≤ 1 kV (5 kA)
   r) Residual voltage (L-PEN) ≤ 1.3 kV
   s) Residual voltage (L-PEN) ≤ 1.1 kV (10 kA)
   t) Residual voltage (L-PEN) ≤ 1 kV (5 kA)
   u) Residual voltage (L-PEN) ≤ 1 kV (3 kA)
   v) Clamping voltage SVR (L-N) ≤ 0.9 kV
   w) Clamping voltage SVR (L-PEN) ≤ 0.9 kV
   x) Response time (L-N) ≤ 25 ns
   y) Response time (L-N) ≤ 25 ns
   z) Short circuit resistance ICC with max. backup fuse (effective) 25 kA
   aa) Follow current quenching capacity If (L-N) 25 kA (264 V AC)
   bb) Follow current quenching capacity If (L-PE) 25 kA (264 V AC)
   cc) Follow current quenching capacity If (L-N) 3 kA (350 V AC)
   dd) Follow current quenching capacity If (L-PE) 3 kA (350 V AC)
   ee) Power cable input junction terminals - Power distribution blocks suitable for use as a power feed and junction points for two and three wire circuits shall be provided. The line side of each circuit shall be capable of handling two size 1/0 AWG conductors.
   ff) All power sockets shall be PVC type as approved by the Engineer.
   gg) AC neutral and equipment ground wiring shall be electrically isolated from the line wiring by an insulation resistance of at least 10 megohms when

measured at the AC neutral. AC neutral and equipment grounding wiring shall be colour coded white and green respectively.

hh) Backpanel shall be utilized to distribute and properly interconnect all cabinet wiring related to the specific complement of equipment called out on the Contract plans. Each item of equipment including any furnished by the Owner shall have its cable harness properly terminated at terminal boards on the backpanel. All functions available at the equipment connector shall be carried in the connector cable harness to the terminal blocks from the power distribution panel mounted on the left side panel of the cabinet.

4. Wiring: All FEC wiring shall be identified by the use of insulated pre-printed sleeving slipped over the wire before attachment of the lug or making the connection. The wire markers shall carry this legend in plain words with sufficient details so that a translating sheet will not be required. Wiring shall also comply with the following items:
   i. All wires shall be cut to the proper length before assembly. No wires shall be doubled back to take up slack. Harnesses to connectors shall be covered with woven braid finger cuffs. Cables shall be secured with nylon cable clamps.
   ii. Service loops shall be provided to facilitate removal and replacement of assemblies, panels and modules.
   iii. All wiring containing line voltage AC shall be routed and bundled separately and/or shielded from all low voltage, i.e., control circuits. All conductors and live terminals or parts which could be hazardous to maintenance personnel, shall be covered with suitable insulating material.
   iv. All conductors used on the cabinet wiring shall be No. 22 AWG or larger with a minimum of 19 strands. Conductors shall conform to MIL SPEC MIL-W-168780, Type B or D or equivalent EMEA standards. Insulation shall have a minimum thickness of 10 mils. All wiring containing line voltage shall be a minimum size of No. 14 AWG.
5. Terminal strips: Terminal strips located on the backpanel shall be accessible to the extent that it shall not be necessary to remove the electronic equipment from the Video surveillance field equipment cabinet to make an inspection or connection.

Terminal blocks shall be two-position, multiple pole barrier type. Shorting bars shall be provided in each of the positions provided along with an integral marking strip. Terminal blocks shall be so arranged that they shall not upset the entrance, terminating and connection of incoming field conductors. All terminals shall be suitably identified by legends permanently affixed and attached to the terminal blocks. No more than 3 conductors shall be brought to any one terminal screw. No electrically energized components or connectors shall extend beyond the protection afforded by the barriers. All terminal blocks shall be located below the shelves. Terminals used for field connections shall secure conductors by means of a No. 10-32 nickel or cadmium plated brass binder head screw. Terminals used for inter-wiring connections, but not for field connections, shall secure conductors by means of a No. 5-32 nickel plated brass binder head screw.

As a minimum, all connections to and from the electronic equipment shall terminate to an inter-wiring type block. These blocks will act as intermediate connection points for all electronic equipment input/output.

6. Cabinet internal grounding: FEC internal ground shall consist of one or more ground busbars permanently affixed to the video surveillance field equipment cabinet and connected to the grounding electrode. Bare stranded No. 6 AWG copper wire shall be used between busbars and between the busbar and grounding electrode. Each copper ground busbar shall have a minimum of 20 connector points, each capable of securing at least one No. 10 AWG conductor. AC neutral and equipment ground wiring shall return to these busbars.

7. Mechanical Specifications: FEC shall meet the following requirements:

   i. Size and construction: FEC shall be moulded glass reinforced plastic (GRP) for all video surveillance camera equipped locations and shall be free standing and suitable for outdoor installation. FEC shall have suitable ribbing to provide sturdiness. All metallic parts of the cabinet, including but not limited to, bolts, nuts, washers, latches and glanding plate shall be corrosion resistant in the conditions prevailing in the Project region. FEC shall be installed directly on the levelled concrete FEC foundation as indicated on the Contract plans. FEC opening side shall be facing away from the adjacent roadway or as approved by the Engineer. The FECs shall be clean-cut in design and appearance and have the following minimum dimensions:

- 38.1 cm depth, 50.8 cm width, 91.4 cm height.

ii. FECs shall consist of only one compartment and shall have a reinforced lockable door. The compartment shall be protected against dust and water in accordance with the IEC Standard IP-43.

iii. Door shall be pad lockable. Pad locks and master keys shall be supplied. All locks shall be keyed identically. In addition to padlocks, two separate latches shall also be provided within the doors, one (within the right panel) lockable with a key and another (within the left door panel) internally lockable by sliding a bolt. All hinges and appurtenant materials shall be stainless steel. Label indicating "PROPERTY OF OWNERS Name" and a danger sign, both in English and Arabic shall be provided.

iv. GRP wall thickness shall not be less than 4.5 mm and the bottom thickness shall not be less than 6.0 mm. Outside dimensions and internal connections shall be as indicated on the Contract plans and specified herein. A short circuit test certificate shall be submitted with the shop drawings. Doors with gun metal hinges, arranged to give maximum access for cabling and maintenance, shall be provided.

v. Ventilation: FECs shall be provided with vent openings to allow convection cooling of electronic components. Each cabinet shall be provided with a fan rated at a minimum of 2.8 m^3 per minute. Fan or cooling system shall be capable of operating continuously for a minimum of 6000 hours in a 60^o C environment, without the need for after-installation maintenance. Each cabinet shall be provided with a thermostat to control the operation of the fan or cooling system. Thermostat turn-on point shall be manually adjustable from 30° C and 55° C, with a differential of not more than 6° C between automatic turn-on and turn-off.

vi. Serial Number: FECs shall be provided with a unique five-digit serial number. Entire identification code and number shall be either stamped on a metal plate which is riveted to the cabinet, stamped directly on the cabinet, or engraved on a metalized Mylar plate that is epoxied to the cabinet on the upper right hand cabinet side wall.

vii. Shelves: Adjustable shelves shall be provided in each FEC as required to support the equipment as specified on the plans. Shelf adjustment shall be at 50.8 mm intervals in the vertical position.

viii. Shelves shall be removable and capable of supporting the electronic equipment. There shall be a minimum of 25.4 mm between the rear and front edge of the shelf and the back inside wall and door of the FEC, respectively, to allow room for the equipment cables.

8. Protector and cabinet configuration: All ungrounded conductor wires entering or leaving the FEC shall be provided with surge protectors. The conductor leads and the surge protector leads shall be kept as short as possible with all conductor bends formed to the maximum possible radius. Protector units shall be located as near as possible (150 mm) to the entry or exit point, and as far as possible from any electrical equipment. Protector ground lead shall be connected directly to the ground bus.
9. Surge protector utilized for AC power shall not dissipate any energy and shall not provide any series impedance during standby operation. Unit shall return to its non-

shunting mode after the passage of any surge and shall not allow the shunting of AC power.

c. Outdoor Splice Enclosure

Outdoor optical splice enclosure shall be IP-68 and shall be capable of aerial, duct or buried applications. The splice enclosure shall include splice trays.

The splice enclosure shall be suitable for application in the temperature range of -40º to +70ºC. Splice enclosure shall provide space allowing entry of fibre-optic cable without exceeding the minimum bend radius of the cable.

The splice enclosure shall be capable of through, branch or mid-span type splice locations.

Splice enclosures shall be designed to permit selective fibre splicing (looping a backbone cable in and out while only cutting into the desired fibres).

Splice enclosures shall allow splicing of all fibres up to 400 fibres or as specified on the Contract plans.

The splice enclosure shall be completely air tight, waterproof, re-enterable and shall utilize an encapsulant to prevent the ingress of moisture.

The splice enclosure shall be designed to protect the buffer tubes and the splice trays, and shall be re-enterable.

The splice trays shall be capable of accommodating the required number of splices, either fusion or mechanical, including storage and protection of slack fibre.

d. Equipment Enclosure (Pole Mount)

Equipment enclosure (EE) shall be used to house communication system components as required on the Contract plans or the Particular Specifications and when approved by the Engineer. EE shall be pole mounted to be installed on VSS camera poles where fibre communication is required in order to house the required 12 S.M patch-panel. EE shall be of non-metallic, nonconductive construction. EE shall be IP55 compliant. Each enclosure shall include permanent identification markings in sequential numbering as approved by the Engineer. Markings shall be in both English and Arabic.

Each EE shall include provisions for mounting the enclosure as per site design and condition and as approved by the Engineer.

Each EE shall be sized appropriately to house the necessary components as approved by the Engineer with at least 25 % additional spare space.

Each EE shall include a hinged front panel, secured by stainless steel screws, and with a tamperproof lock. All locks shall be keyed alike. Each EE shall be supplied with 240 volt AC, single-phase, 50 Hz from the local power panel and to be grounded service through industry standard plugs.

1. Subcontractor shall submit a complete internal design for the EE for review and approval by the Engineer. Each EE Design shall include the following features, as a minimum:
    - i. Back plate for equipment mounting.
    - ii. Four louvers with each enclosure for air circulation.
    - iii. Sufficient fan model for such applications to be proposed by the contractor and approved by the Engineer.
    - iv. Single-phase isolator to isolate the main power source from the EE1. Subcontractor shall propose a sufficient isolator model to be reviewed and approved by the Engineer.
    - v. Main circuit breaker, Subcontractor shall propose the breaker current values to be reviewed and approved by the Engineer.
    - vi. Electrical sockets shall be of PVC type with on/off buttons or surge suppresser equivalent for such installations.
    - vii. Din rails

viii. PVC trunks for internal cabling management.
ix. Terminal blocks.
x. Grounded plug.

9.6.2.12 Solar Power System

Subcontractor shall furnish a solar power system that is self-cleaning, for low power devices such as video surveillance cameras, road weather information stations, and road vehicle detectors as shown on the Contract plans, as required in the Particular Specifications and as approved by the Engineer.

Solar panels shall be installed on DMS and LCSCS gantries to provide power to low power devices as directed by the Engineer.

Subcontractor shall furnish and install a solar power system for video surveillance cameras, radar vehicle detectors, and road weather information stations, as directed by the Engineer.

Solar cells should be constructed of crystalline silicon either as single or poly-crystalline wafers, or layers of photovoltaic active material placed on a glass superstrate or a metal substrate using vacuum-deposition manufacturing techniques.

a. Technical Requirements

The solar power system shall include the following items:

1. A power storage system comprising a number of batteries in a cabinet mounted on an appropriately sized foundation adjacent to the structure on which the solar panel is attached.
2. Power conversion equipment including an inverter to convert the PV modules' DC output to AC compatible with the ADDC power supply;
3. Appropriate support and mounting hardware, wiring, and safety disconnects

Subcontractor shall submit for review and approval by the Engineer, the design and drawings of the proposed system that show the solar panel attachment to the structure, battery cabinet, cabinet foundations, and associated cabling and civil works. Drawings shall indicate that the solar panel:

- Will receive maximum exposure to the sun;
- Will not be shaded by site obstructions such as nearby buildings or vegetation.

9.6.3 Construction Requirements

9.6.3.1 Testing and Conditional Acceptance

During the execution of this Contract, the Subcontractor shall be required to perform, in the presence of and to the satisfaction of the Engineer, pre-installation and post-installation tests on all of the system components. Purpose of these tests shall be to demonstrate to the satisfaction of the Engineer that all system components function properly and are capable of meeting all the requirements and Specifications of the Contract Documents. Tests shall be performed according to a test plan to be prepared and submitted by the Subcontractor at the beginning of the Contract and to be approved by the Engineer, and under conditions as directed by the Engineer that simulate to the extent practical the environmental and operating conditions that will be encountered during actual field operations after installation. Test plan shall describe test equipment to be used, procedures to be followed, measurements to be taken, and pass-fail criteria to be employed. Engineer shall approve the test plan with revisions and/or additions if he deems necessary. All tests shall be conducted in accordance with the approved test plan.

Subcontractor shall supply complete equipment manuals which will show test point electronic values together with component descriptions and wiring diagrams. These manuals shall be complete printed documents, not a compendium of loose-leaf material.

No equipment or subsystem shall be considered accepted until the Engineer issues a final acceptance certificate as described under Sub-article f of Article 9.6.5 .

a. Pre-installation Testing

All pre-installation tests shall be performed in accordance with the approved test plan.

Each piece of equipment, component, element, appurtenance, and/or subsystem of the ITS and traffic control system shall be individually tested by the Subcontractor in the presence of and to the satisfaction of the Engineer before installation.

Pre-installation tests shall emphasize proper operation and functioning of each unit of equipment, component, element, appurtenance and/or subsystem, whether manufactured and/or assembled by the Subcontractor himself or supplied by a manufacturer other than the Subcontractor.

No pre-installation test shall be considered complete unless the unit being tested meets, in the judgment of the Engineer, all the material, operating and performance criteria established in the Contract Documents.

Any unit that fails to pass any pre-installation test shall be so marked by the Engineer and shall be replaced by the Subcontractor at his own expense until the replacement passes all pre-installation tests to the satisfaction of the Engineer. Repairing a faulty unit shall not be acceptable. If the reason for failure of a unit to pass any pre-installation test is identified by the Engineer as an equipment or system design deficiency, the Subcontractor shall make necessary design modifications to that unit at his own expense, and shall repeat all pre-installation tests on the modified unit to the satisfaction of the Engineer. Engineer has the option of rejecting a modified unit and requesting the Subcontractor to supply at his own expense a unit of different design and/or manufacture.

Once the design of a unit is modified as described above, such design modification shall be incorporated, at the Subcontractor's own expense, into all like units, whether already installed and tested, or to be installed in the future.

Unless otherwise directed by the Engineer, pre-installation tests shall be performed at the testing laboratory in the traffic computer centre building. All costs associated with the pre-installation tests shall be borne by the Subcontractor as an incidental part of his bid price for the unit being tested. No separate payment shall be made for pre-installation tests.

No unit shall be installed in the field unless the Engineer issues a pre-installation test certificate indicating that the unit has passed required tests to his satisfaction.

Engineer has the option of waiving pre-installation testing requirements for a group of like units, after testing a sufficient number of units, randomly selected by him, from such group of like units.

Satisfactory passage of any unit in pre-installation tests shall not relieve the Subcontractor from any of his responsibilities of equipment performance under this Contract.

b. Factory Acceptance Testing

Owner and the Engineer have the right to inspect, with use of their representatives, any or all equipment, components and/or parts of the system during the manufacture, preparation and/or assembly at the Subcontractor’s vendor’s home plant and/or his regional facilities.

For this purpose, the Subcontractor shall notify the Engineer in writing at least four weeks in advance of the commencement of such manufacture, preparation and/or assembly. If the Engineer/Owner uses its right of inspection, no manufactured, prepared and/or assembled equipment, component and/or part shall be shipped to the job site without the inspection approval of the Engineer/Owner’s representative.

Subcontractor shall conduct factory acceptance testing (FAT) for the following major subsystems; traffic signal system, digital video management system, dynamic message sign and lane control speed control signs, and integrated traffic signal, ITS and central computer system software. Each FAT shall have all required systems and software complete and staged at the home plant and include as necessary simulation of interface subsystem to ensure adequate testing.

Subcontractor shall bear all expenses related to the factory acceptance testing. All travel, lodging, living, local transportation and miscellaneous expenses, as requested by the Engineer, for a period up to two weeks each incurred by the representatives (up to four representatives of the Owner and up to two representatives of the Engineer) in connection with such inspection at the Subcontractor vendor's home plant(s) and/or factory (s) shall be paid for by the Subcontractor. Business class travel is required for the Owner and Engineer representatives. At least 1 of the Subcontractor's staff shall be in attendance.

In the event that a factory acceptance test fails requiring a postponement and another trip to the location at a later date, the Subcontractor shall absorb the cost of the revisit, including the costs incurred due to changed travel plans.

c. Independent Testing Supervision and Verification

At the Owner's and Engineer's discretion the Subcontractor shall provide services of an independent entity to act as overseer of all testing activities. This entity shall also certify test results and approve any test procedures and plans. Cost of engaging a separate firm to perform these tasks shall be included in the bid price as a provisional item.

d. Integration Tests

Subcontractor shall submit integrated system test procedures – which will be used to test the compliance with the functional requirements of the systems as a whole. This procedure shall also include detailed functionality testing of any system for which a separate system functionality test was not developed. Full integration test shall demonstrate that all subsystems can be controlled locally (if applicable) from system head-end and from the central system as approved by the Engineer. In addition, any and all functions which require input from multiple subsystems shall be explicitly demonstrated.

e. Post-installation Tests

Following the installation of equipment, components, elements, appurtenances and/or subsystems of the traffic control system and intelligent transportation system, the Subcontractor shall perform post-installation/site acceptance tests in the presence of and to the satisfaction of the Engineer. All post-installation tests shall be performed in accordance with the approved test plan.

Post-installation tests shall emphasize the functional operation and performance of a system as well as the performance of its components.

Post-installation tests shall include, but not limited by, the following, after each system is fully installed and ready for testing:

1. Complete intersection controls including local controller, detectors, signal poles and mast arms, vehicular signals, pedestrian signals, cable and wiring, and all components, parts and appurtenances
2. Complete interconnection (progression) controls along a major artery, including the traffic signal system central computer system, detectors, communications interface, cable and wiring, and all components, parts and appurtenances. This also includes additional system detectors.
3. Automatic Transfer Dual Power Supply Panels, Free Right Turn Signals and Pedestrian Pushbuttons
4. Additional Intersections placed under the Central Computer Control, including all components, parts and appurtenances. This also includes performance checking of all communications cables.
5. Traveller information signs, video surveillance cameras, vehicle detection system, roadway weather information system, over-height vehicle detection system, and communications system.

No post-installation test shall be considered complete unless the system and its components being tested meet, in the judgment of the Engineer, all the material, operating and performance criteria established in the Contract Documents.

Any system or its components that fail to pass any post-installation test shall be replaced by the Subcontractor at his own expense until the replacement passes all post-installation tests to the satisfaction of the Engineer.

If the reason of failure of a system or its components to pass any post-installation test is identified by the Engineer as an equipment or system design deficiency, the Subcontractor shall make necessary design modifications to that system or its components at his own expense, and shall repeat all post-installation tests on the modified system and its components to the satisfaction of the Engineer. Engineer shall have the option of rejecting a modified system and/or its components and requesting the Subcontractor to supply at his own expense a system and/or its components of different design and/or manufacture. Once the design of a system or its components is modified as described above, such design modification shall be incorporated, at the Subcontractor's own expense, into all like systems and components, whether already installed and tested, or to be installed in the future.

Subcontractor shall provide and set up all the test equipment necessary for post-installation tests and shall conduct the tests under the supervision and to the satisfaction of the Engineer.

All costs associated with the post-installation tests shall be borne by the Subcontractor as an incidental part of his bid price for the system being tested. No separate payment shall be made for post-installation tests.

No system shall be started-up unless the Engineer issues a post-installation test certificate indicating that the system has passed required tests to his satisfaction.

Following issuance of the post-installation certificate:

1. The Contractor shall perform a System Start-up and Initial Operation for one month; and
2. The system shall be subjected to a 60-day Reliability Test

Satisfactory passage of any system in post-installation tests shall not relieve the Subcontractor from any of his responsibilities of system performance under this Contract until a final acceptance certificate is issued by the Engineer.

f. Traffic Control System

Post-installation tests shall be performed in the presence of the Employer’s representative on the following systems, after each system is fully installed and ready for testing and commissioning, as per the following items:

1. Complete intersection controls including local controller, detectors, signal poles and mast arms, vehicular signals, pedestrian signals, cable and wiring, and all components, parts and appurtenances.
2. Complete interconnection (progression) controls along a major artery including master controller, detectors, communications interface, cable and wiring, and all components, parts and appurtenances. This also includes additional system detectors.
3. Automatic transfer dual power supply panels, free right turn signals and pedestrian pushbuttons.
4. Additional Intersections placed under central computer control, including all components, parts and appurtenances. This also includes performance checking of all communications cables.
5. Additional loops for traffic violation recording equipment complete.

g. Intelligent Transportation System

The required post-installation test consists of the following components:

1. Production and submission of site acceptance test plans to the Engineer for review and approval.
2. Commissioning of head-end subsystem equipment (verification of function for a particular piece of the ITS Platform equipment)
3. Functional verification for one field installation of each subsystem field equipment type installed. All aspects of the manufacturer-supplied IDDs shall be verified for one complete communications interface of each subsystem field equipment type.
4. End to end testing shall be conducted as a part of the acceptance test.

Subsystem equipment site acceptance testing shall be exhaustive and performed in a manner so as to not disrupt the ongoing work of the traffic management centre.

h. Certification of Results

Subcontractor shall notify the Engineer when the site acceptance tests are to be undertaken.

Subcontractor shall forward to the Engineer duly certified copies of the results when the tests have been successfully completed.

When the Engineer has received these test results, and is satisfied the site has passed the tests, the Engineer and/or the Owner will notify the Subcontractor/Contractor in writing that the site has passed the site acceptance test.

Prior to acceptance and commissioning of the systems, system design document shall be developed; which shall encompass all of the revisions and details pertinent to the actual development and implementation of the systems, including a revised requirements compliance matrix.

If the Engineer/Owner decides the site equipment is not in accordance with the Contract, he may reject the equipment at the site, and he will inform the Subcontractor/Contractor of the reasons in writing.

i. Commissioning of Subsystem Field Equipment

In the case of all subsystem field equipment, following shipment of equipment to the Project location, all head-end subsystem equipment pre-loaded with the relevant software application programs or simulations shall be inspected and tested at the Subcontractor’s facility to verify that equipment is working prior to installation on site.

j. Approval for Commencement of Integration and Reliability Tests

Engineer will notify the Subcontractor in writing of outstanding faults detected during the commissioning of In-station equipment tests and defects detected during or after these tests.

Subcontractor shall prepare proposals for rectifying defects and the additional tests to be conducted after defects are rectified. Proposals shall be submitted to the Engineer for approval.

All defects detected during or subsequent to the commissioning tests shall have been rectified and successfully passed their tests prior to site acceptance for any site.

k. Reliability Test

Upon successful completion of the post-installation test and commissioning, the system components are subjected to a 60-day reliability test. During this test any system failure is considered to have reset the 60-day time-period to zero. Determination of which failures constitute a system failure is at the discretion of the Engineer and the Owner.

Reliability Testing shall be conducted on all components, systems, and functions affected, changed or installed, including but not limited to:

l. System Start-up and Initial Operation

Following the issuance of a post-installation test certificate by the Engineer, the Subcontractor shall start-up the system that passed the post-installation tests, and shall continuously operate the system for an initial operation period of one month.

Engineer and the Owner's personnel shall be present at the start-up and initial operation of all equipment, components and systems.

During the initial operation period the Subcontractor shall continuously observe and monitor the operation of the system and shall make final adjustments and corrections to the system to the satisfaction of the Engineer. If during the initial operation period major system and/or component defects are identified which, in the judgment of the Engineer, require modifications to the system and/or its components, the initial operation period shall restart following the completion of the subject modifications to the satisfaction of the Engineer.

m. Conditional Acceptance

When a system, started-up and initially operated according to the requirements of Sub-article l of Article 9.6.3.1, above, performs to the satisfaction of the Engineer during the initial operation period of one month, the Engineer shall issue a conditional acceptance certificate to indicate that the subject system has been conditionally accepted. Conditional acceptance certificate shall relieve the Subcontractor from his responsibilities concerning the performance of the system except for the Subcontractor's operation and maintenance responsibilities as described in Sub-article c of Article 9.6.5.

9.6.4 Project Handover / Take Over

This section provides general requirements for the handover process of the installed project to the Owner. The Owner has a procedure in place for the handover of traffic control system assets. The Contractor shall follow the detailed instructions provided in that document.

The project handover phase will start when the project implementation is substantially complete, however the steps required for the successful project handover shall start as early as possible, prior to the Taking-Over-Certificate. The goal of the handover process is to ensure that the installed systems and equipment is constructed in accordance to all applicable standards and to the Owners satisfaction, and to ensure that the new equipment can be maintained and operated properly once installed.

Prior to the issuance of the Taking-Over-Certificate the Contractor shall submit to the Engineer all the required documentation including but not limited to:

a. List of all ITS assets
b. Project Documentation
    - Submittals
    - O&M Manuals
    - Training Manuals
    - Test Reports
    - Record Drawings
    - Incident Response Plans etc
c. Developed software with all documentation and licenses
d. Any specialty software used in project development with licenses
e. Inventory of spare parts and maintenance tools
f. Operations and Maintenance Plan
g. Operations and Maintenance Staffing Plan

9.6.5 Operations, Maintenance and Final Acceptance

As part of this Contract, the Subcontractor shall operate and maintain the systems, subsystems, parts and components of the traffic control system for the periods of time specified as follows:

1. Complete intersection controls (including local controller, detectors, signal poles and mast arms, vehicular signals, pedestrian signals, cable and wiring, and all components, parts and appurtenances); Additional loops for traffic violation recording equipment for one year from the date of the conditional acceptance certificate
2. Complete interconnection (progression) controls along a major artery (including master controller, interconnection detectors, communications interface, cable and wiring, and all components, parts and appurtenances); additional system detectors for one year from the date of the conditional acceptance certificate:
3. Automatic transfer dual power supply panels, free right turn signals, and pedestrian pushbuttons (including all components, parts and appurtenances) for one year from the date of the conditional acceptance certificate:
4. Additional intersections placed under the central computer control (including all components, parts and appurtenances, and operation of traffic computer control plans and traffic engineering software); audio and computer communication cables for one year from the date of the conditional acceptance certificate
5. All ITS and electromechanical equipment installed in the contract for three years from the date of the taking-over-certificate.

Subcontractor's system operation responsibilities during the time period specified above shall include, but not by way of limitation, continuous monitoring of system performance and traffic conditions; adjustment and modification of timing patterns and time plans to satisfy requirements of changing traffic and field conditions; malfunction diagnosis and implementation of corrective measures; and other operational activities as specified in the contract Documents and as directed by the Owner and/or the Engineer.

Subcontractor's system maintenance responsibilities during the time periods specified above shall include, but not by way of limitation, periodic cleaning of exposed system components; replacement and/or repair of damaged units; replacement of worn-out parts and burnt-out illumination sources (e.g. bulbs); periodic maintenance of all components that require such periodic maintenance; and other maintenance activities as specified in the Contract Documents and as directed by the Owner and/or the Engineer.

Subcontractor shall also repair or replace as directed by the Owner and/or the Engineer, at the module or subsystem level whichever deemed proper by the Owner and/or the Engineer, any failure whatsoever that occurs during the maintenance periods specified above. Subcontractor shall maintain records of all maintenance and repair calls and equipment failures by type and component (including cost). The records shall indicate the time required to restore operations to full functioning level. These records shall be available for the Owner's and Engineer's inspection and use during the Subcontractor's operation and maintenance period.

Subcontractor shall maintain, in his Project area or regional office, an adequate level of competent and experienced operational and maintenance personnel (including engineers, technicians, mechanics, etc.) capable of performing the above specified operational and maintenance activities to the satisfaction of the Owner and the Engineer. If, at any time during the life of this Contract, the capabilities and/or levels of staff maintained by the Subcontractor in his Project area or regional office are, in the judgment of the Owner and/or the Engineer, insufficient to carry out the Subcontractor's operation and maintenance responsibilities as specified herein, the Subcontractor upon notification by the Owner and/or the Engineer, shall take necessary action to substitute and/or supplement his staff resources to the satisfaction of the Owner and/or the Engineer.

Subcontractor shall initiate a response to maintenance calls and failures in accordance with the requirements of Sub-article c of Article 9.6.5, and shall use replacement equipment to restore the system to its operational level as quickly as practical and to the satisfaction of the Employer and/or the Engineer.

At the end of the Subcontractor's operation and maintenance period, all components of the traffic control system shall be capable of operating in accordance with and to the full satisfaction of all requirements of the Contract Documents. Subcontractor shall demonstrate to the satisfaction of the Owner that the traffic control system is capable of operating in the manner, accuracy and level set forth by these Contract Documents, as directed by the Engineer, and as checked by the post-installation tests and verified.

All costs associated with operations and maintenance activities for the periods specified herein shall be borne by the Contractor as an incidental part of his bid price for the items shown on the Bills of Quantities, operated and maintained by the Subcontractor. No separate payment shall be made for any operations and maintenance prior to Final Acceptance.

a. Maintenance and Repair Shop Facilities

Subcontractor shall use the existing maintenance and repair shop in the Project vicinity traffic control centre building or as directed by the Owner to service all equipment, components and appurtenances of the Traffic control system.

b. Operation and Maintenance Manuals

As part of this Contract, the Subcontractor shall prepare and submit to the Owner operation and service/maintenance manuals.

Subcontractor shall prepare two separate sets of manuals for the traffic control system. First set shall cover in detail the operation and relationship of all equipment, components and systems. Second set shall cover the maintenance and service requirements for all components of the traffic control system together with all data and related information for all equipment, components, materials and appurtenances for the traffic control system. All manuals shall be suitably bound with hard covers, and identified as to the project and content.

All manuals shall be neatly typewritten or mechanically printed with both a table of contents and an alphabetical index in each volume identifying and locating the contents therein. All manuals shall be arranged in a clear, logical and systematic order.

All manuals shall be prepared in English.

Each manual shall contain the name of the Subcontractor, name of the responsible principal or representative in the Project vicinity, his local office telephone number, and his office particulars both locally and at the Subcontractor's headquarters.

All manuals shall be updated as the installation progresses and additional intersection and/or interchanges are added to the system and the system control is expanded. Subcontractor shall be responsible for checking and updating all manuals. Provided manuals shall address the entire traffic control system (TSC) and sub-systems (TSC and ITS) and shall provide detailed information on each component of the system. Operation manuals shall include a sufficient amount of technical information to provide a good understanding of the system appropriate for the system operator. Service and maintenance manuals shall contain all technical information required for the entire system servicing and maintenance. At a minimum, these manuals must incorporate copies of the manufacturer's hardware, software, maintenance information, troubleshooting procedures for the entire system and for each sub-component of the system, preventive maintenance information and corrective maintenance of each component. Document should include a recommended spares listing and identification of every replaceable part of each component, i.e., a complete listing of the lowest replaceable unit (LRU) and the spares recommendation for each for ongoing maintenance.

Subcontractor shall provide comprehensive coverage of each section. Information on each subsection of the system shall be grouped into one section of the manual.

Three copies of each set of manuals shall be submitted to the Owner through the Engineer, as follows:

1. Operation manuals: Operation manuals shall include all particulars and details for the operation of all components of the traffic control system which shall include but not by way of limitation the following:
   i. All written test shall be organized in a consistent format, related to the installation and under separate headings for the different procedures of operations.
   ii. Operation manuals shall identify each intersection and/or interchange and the relationship of each subsystem and control system.
   iii. All instructions shall be organized in a sequence for the various intersections and/or interchanges, and operation of each system.
   iv. Manuals shall include a description of equipment, components, materials and appurtenances. Functions, normal operating characteristics and limiting conditions along with engineering data, test and other pertinent information for the traffic control system shall be included.
   v. Instructions shall clearly describe procedures to be followed in the event of failure of any subsystem or control system.
   vi. Instructions shall be given as to procedure to be followed in the start-up of the subsystem and control systems.
   vii. Instructions shall be given as to procedures to follow to coordinate in the event any portion of the system is altered in any way such as adjusting or resetting of timing or sequencing of any controls.
   viii. Special operating instructions shall be provided as may be required by various systems of control.
   ix. Instructions for the regulation, control, shutdown, start-up and emergency operations of all systems and controls shall be provided.
2. Service and maintenance manuals: Service and maintenance manuals shall include all particulars and details for servicing and maintaining of all components of the traffic control system which shall include but not by way of limitation the following:
   i. Maintenance procedures concerning routine operation of the system with details covering the intervals and sequence of maintaining all equipment, components and appurtenances of the complete system.
   ii. Particulars and details on the adjusting and checking of the complete system.
   iii. A guide to the servicing and "trouble-shooting" of the system.
   iv. All particulars and details for the replacement, disassembly, repair and reassembly of all equipment components and appurtenances.
   v. Instructions regarding the use of lubricants and cleaning materials and the methods to be employed in the use of same. Further, the instructions shall include all precautions to be employed in the use of lubricants and cleaning materials.
   vi. Complete information on all materials including but not by way of limitation the traffic poles, mast arms, signal heads, controllers, detectors and all other materials as specified herein and/or furnished and installed by the Contractor.
   vii. Description of the theory of operation, circuit schematics, logic diagrams and maintenance procedures.
   viii. Where required, the Subcontractor shall furnish separate service manuals for individual items of equipment, components and/or control systems.
3. In addition to other requirements specified herein, the service and maintenance manuals shall contain a listing and description of spare parts and materials required for the Traffic Control System with recommendations as to the quantity to be maintained and the procedure as to the replacement of spare parts and materials.

c. Operations and Maintenance (O&M) Phase

Subcontractor shall respond to maintenance calls and failures 24 hours, 7 days a week, and shall use replacement equipment to restore the system to its operational level as quickly as practical. Subcontractor shall carryout periodic maintenance checkups for specific tasks as directed by the Engineer.

After the subcontractor detects or is notified of an emergency maintenance related system failure, the Contractor's maintenance staffs shall mobilise to attend and resolve the emergency maintenance failure within:

- Ten (I0) minutes following operator verification during the hours of 6:00 am to 7:00 pm, Sunday through Thursday; and
- one (1) hour at all other times outside these hours

On arrival at the site, the Contractor shall analyze the situation and develop an estimate of the time required for repairs and analyze if lane closure(s) are necessary. The Contractor shall determine if the repair should be initiated immediately or if the situation should be monitored through peak traffic hours and repaired during off-peak traffic hours. If the repair time will exceed two hours, the Contractor shall notify the Owner immediately and begin preparation of a contingency plan. A work-around should be considered if it would not negatively impact any part of the Project operations. The Contractor shall notify the Owner when the maintenance actions have been completed and describe any resulting operational restrictions.

At the end of the Contractor's warranty period, the complete system shall be capable of operating in accordance with and to the full satisfaction of all requirements of the Contract Documents. Contractor shall demonstrate to the satisfaction of the Owner that these systems are capable of operating in the manner, accuracy, and level set forth by these Contract Documents, as directed by the Engineer, and as checked by the post installation tests and verified. After this time, the Engineer shall issue the final acceptance certificate.

Upon successful completion of the warranty period of the installed systems, the Engineer shall issue a final acceptance certificate. Final acceptance certificate shall relieve the Contractor from his responsibilities concerning the signal system’s performance.

All costs associated with warranty activities for the periods specified herein shall be borne by the Contractor as an incidental part of his bid price for the items shown on the Bills of Quantities, operated and maintained by the Subcontractor. No separate payment will be made for any operations and maintenance prior to final acceptance.

Upon successful completion of the construction works of this Contract and the issuance of the conditional acceptance certificate, the Subcontractor will be required to provide sufficient staffing to operate the system for a period as specified in the BOQ. Maintenance period shall be renewable at the client discretion for another equal or less period.

Subcontractor shall submit his proposed quality management plan to the Engineer for review and approval.

Subcontractor shall perform all operations and maintenance (O&M) of the system under the direct participation of the Engineer and as directed by the Engineer and/or the Owner. It will be understood that the maintenance of the individual system components shall be the responsibility of the Subcontractor during this period which shall be free to organize it with the individual subsystems’ subcontractors. Subcontractor will be required to assign a minimum level of staffing specialists (traffic engineer, systems engineer, and electromechanical engineer) to be available permanently during this period.

Subcontractor shall maintain an engineering and technical staff with 24-hour / 7-days per week availability to respond promptly to maintenance calls and failures. In addition, the Subcontractor shall perform periodic preventative maintenance operations on the field and central equipment as needed and as directed by the Engineer. Subcontractor’s engineering staff shall update and verify the response plans, ensuring that the plans are current with changing conditions and as directed by the Engineer.

Subcontractor shall provide at least 1 Engineer and 1 technician at site, for each major system, in accordance with Article 9.6.5 of these Specifications, to be permanently located at the control centre and perform the daily operation and maintenance tasks. Subcontractor may combine staff disciplines to operate and maintain multiple system if approved by the Engineer. Subcontractor staff shall be fully qualified with adequate education and at least 3 years experience working with the relevant equipment. Additionally, the staff shall also have manufacturer certifications for installing, operating and troubleshooting the deployed systems.

Mean time to repair (MTTR) shall not exceed four (4) hours, including travel time to the site. Subcontractor shall maintain all the required spares on site with all required maintenance documentation. Spare parts shall be sufficient to meet the system availability requirements.

Subcontractor shall carry out all required preventive and responsive maintenance duties and shall document all activities performed in an electronic data base accessible by the Engineer and the Owner.

System availability shall not be less than 99 % calculated on a quarterly basis. Monthly operation and maintenance fees shall be adjusted in the event the system availability requirement is not met. Amount of adjustment shall be calculated based on 5 % deduction from the following month service fees for every additional one hour of down time.

d. System Performance Parameters

Using the system data, the Subcontractor shall guarantee high level of system reliability and maintainability. System indicators shall be developed for each major subsystem and equipment as directed by the Engineer and as follows:

1. Availability of the central control system
2. Availability of the communication system
3. Availability of the peripheral system
4. System efficiency

Parameters to be developed for this purpose shall include, but not by way of limitation, the following:

1. MTBF (mean time between failures)
2. MTTR (mean time to repair)
3. Availability index equal to [100 – (MTTR / MTBF + MTTR)*100]

e. Spare Parts and Tools

Subcontractor shall maintain at the traffic management centre, all recommended spare parts and tools described in the approved spare parts list. Subcontractor shall maintain the minimum quantities of consumable materials, replacement parts, and tools specified in the approved spare parts list. These items shall be used as needed for the maintenance of the traffic management system and ITS systems and roadway devices and systems for the Contract term, and shall be restocked to the minimum acceptable quantities at the end of each month.

Replacement parts shall be the latest compatible technology, equal to or better in function and quality to meet or exceed the original equipment manufacturers standards for the existing system component or equipment, and by its use, does not cause a required system upgrade. Subcontractor shall maintain inventory control of all replacement parts and equipment.

All equipment and component parts that are furnished shall be new, unused and shall otherwise meet all requirements of the Contract. All parts shall be of high quality workmanship and no part or attachment shall be applied contrary to the manufacturer's recommendations or standard practice.

Subcontractor shall not install spare parts that are deemed damaged or faulty by the Engineer, Owner or the manufacturer. Installation shall be carried out as part of the Contract monthly routine works in accordance with the Contract plans and Specifications and as directed by the Engineer and/or Owner. No separate payment will be allowed for these works unless otherwise specified in the Bills of Quantities.

Spare part inventory shall include all the types and quantities of parts identified as spare parts or lowest replaceable units in the systems and equipment records. On a monthly basis, at a minimum, spare part and consumable inventories shall be checked against the requirements in the systems and equipment records and replacement parts ordered to bring the inventory to the recommended levels. Spare parts and consumable items shall be maintained in a secure location that is staffed as required to meet system availability requirements.

The subcontractor shall provide samples of all equipment, components and parts thereof to the Owner for his review and approval if requested by the Owner and/or the Engineer. The subcontractor shall not start the procurement, manufacturing and/or assembling of any equipment, components and/or parts until after the Owner's approval of the samples. The Owner's approval of such samples shall not relieve the Contractor from his responsibilities of equipment performance under this Contract.

The Owner shall have the right to inspect, through their representatives, any or all equipment, components and/or parts of the spare parts and new materials to be installed under this Contract prior to its installation during preparation and/or assembly at the Contractor's or the Subcontractor's Project vicinity facilities. If the Owner uses its right of inspection, no manufactured, prepared and/or assembled equipment, component and/or spare part shall be shipped to the job site without the inspection approval of the Owner and/or the Engineer.

Contractor assumes all risks for replacing and installing materials and equipment not complying with the above requirements and said materials and equipment may be subject to removal and disposal at the Contractor's expense.

Contractor shall be responsible for all commitments for the supply of replacement materials and equipment so that he can complete the job within the specified time of the Contract. Delays in receipt of replacement materials and equipment will not be considered as a valid reason for a time extension.

Subcontractor shall be responsible for the assembly and testing of the spare parts of the existing Systems to make the systems operational to the satisfaction of the Owner and/or the Engineer.

All equipment, components and parts of the system shall continuously operate in a satisfactory condition on the job site before they will be conditionally accepted by the Owner and/or the Engineer. Owner shall be the sole judge as to whether the equipment has operated in a satisfactory condition.

Subcontractor shall be responsible for the maintenance and repair work on the system and associated equipment during the time period specified within this document.

Subcontractor shall maintain and have readily available an up to date inventory of all consumables, systems equipment, and/or parts. Subcontractor shall be responsible for developing an inventory tracking system for all the spare parts and consumables, maintained in the computerized maintenance management (CMMS) system.

The spare part inventory tracking system shall include at a minimum:

1. Manufacturer;
2. Model number;
3. Descriptive name;
4. Manufacturer serial number;
5. Date of Manufacture;
6. Spare or newly ordered part;
7. Location where installed including stationing, if possible;
8. Date of purchase;
9. Date of repair;
10. Date when scrapped;
11. Calibration status and date;
12. Manufacturer's routine maintenance schedule; and
13. Warranty status if applicable.

f. Final Acceptance

Upon successful completion of the operations and maintenance period of a system as specified in Sub-article c of Article 9.6.5, the Engineer will issue a final acceptance certificate. Final acceptance certificate shall relieve the Subcontractor from his responsibilities concerning the performance of the subject system.

9.6.5.1 New Technology Prices

If at any time during the life of this Contract, the Owner elects the option of authorizing the Subcontractor to implement new technology subsystems, equipment, components and/or software which are developed after the signing of this Contract, the price of such new technology items shall be computed on the basis of the official cost figures audited and certified by the government of the country of origin, unless otherwise agreed upon mutually by the Owner and the Contractor.

9.6.5.2 Training

Subcontractor shall provide full training for all installed systems, software, human machine interfaces (HMI) and equipment. This section provides general requirements for the required training.

Training shall cover all systems, software, HMI and components installed under the Contract. Owner reserves the right to eliminate portions of training, at a corresponding credit, if the Owner's personnel are sufficiently proficient in operation and maintenance of provided equipment. Subcontractor is however required to provide full set of Training documents and materials for all installed equipment and subsystems.

Subcontractor shall provide multiple training courses with the syllabus tailored to the intended audience. Training shall be provided for management, operators, supervisors and maintenance personnel. Description of target audience shall be as follows:

1. Management training: Target audience for this training course shall be management personnel who need an overview of the entire systems and the capabilities thereof. Special emphasis shall be placed on any management features of the central software system.

2. Operator training: Target audience for this training course will be operators of the system. As a result this training shall provide a complete overview of the system including field devices and shall provide complete coverage of all operator features and actions. In addition, this course shall provide operator level troubleshooting instructions.

3. Supervisor training: Target audience for this training course shall be supervisors of the system. This training shall cover all aspects of operator training and shall include any supervisor specific features as well as all configuration features of the central software and of the each subsystem. In addition this course shall provide instructions on supervisor level troubleshooting.

4. Maintenance training: Target audience for this training course shall be maintenance and engineering personnel. In addition to all topics covered under the supervisor training this training shall also cover detailed troubleshooting, preventive and corrective maintenance of all provided equipment.

Training shall not commence without submission and approval of all training documents. At the minimum, the training documentation must contain a lesson plan, instructor manual and student workbook. Lesson plan shall contain the syllabus and the proposed duration of each training session. Instructor's manual shall contain all of the necessary information for the Instructor leading the course. If a power point or other presentation is used, it shall be provided as part of the instructor's manual and the instructions shall be clearly matched to the presentation slides. Student workbook shall contain all required documents, tests, labs and exercises needed by the student during the course. Training shall also not commence until all auxiliary documentation has been submitted and approved (O&M manuals, record drawings).

Instructors shall be proficient in language used for training course delivery (English and/or Arabic if so desired by the Owner). All Instructors must be qualified. Qualification shall be demonstrated through certificates, familiarity with the equipment and equipment manufacturer's approval. CVs of the instructors shall be submitted with the training documentation for approval. No Instructor shall be allowed to teach a course without the approval from the Owner and/or the Engineer.

Training shall be provided in the immediate vicinity of the Project area. Subcontractor shall be fully responsible for the provision of training facilities and any required training equipment. Subcontractor may request to use Owner resources but should be prepared to complete the training if said resources are not available.

All Training shall be provided in multiple sessions. Length of each session should be limited to 4 hours, however if necessary the Subcontractor may request longer sessions. Each session shall include regular breaks including breaks for meals if the training session includes regular meal break times.

Subcontractor shall provide a complete training plan listing the dates for each training session and shall provide all training on time. Final acceptance of the system shall not be given until the training has been successfully completed.

Each training course shall be given in at least two sessions. Subcontractor shall be responsible for determining the time required for training courses and shall submit said estimates as part of the training plan. Owner shall have the option of increasing the training duration based on its own evaluation of proposed training. As a reference, the Owner will not consider the total length of maintenance training course less than 80 hours to be reasonable.

One half of each training course shall include hands-on experience with equipment, operator screens etc. Subcontractor shall be responsible for all hands-on session and shall provide all necessary equipment for said sessions.

All training class time (indoors or outdoors) shall be recorded by the Subcontractor on multimedia compact discs, CDs, or DVDs, for use in standard computer CD/DVD drives. CDs/DVDs shall become the property of the Owner with unlimited duplication and copying rights.

Contractor shall include in his training plan a detailed methodology to provide knowledge transfer of the project skills and capabilities to the Owner. Methodology shall include formal training sessions, seminars, work shadowing, coaching and the provision of templates, tools and techniques as directed by the Engineer. Time span for this methodology shall cover the construction period and the operation and maintenance phases. Subcontractor shall provide valuable insights and recommendations and make suggestions for maintaining an effective knowledge transfer scheme.

Subcontractor shall be responsible for training the Owner designated number of training course attendees. Training facilities shall be able to accommodate up to thirty students.

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Chapter 10: Lighting & Electrical Distribution Works

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10 LIGHTING AND ELECTRICAL DISTRIBUTION WORKS

Specifications for the construction of the Roadway Lighting and Low Voltage Electrical Networks, which consists of all associated el earthworks, supply and installation of all materials, all testing requirements and all subsidiary and related work items, shall be consistent with the requirements of the latest issue of: -

1. PR 402- Abu Dhabi Lighting Manual

All Electrical Distribution requirements shall be as per the requirements of: -

1. Abu Dhabi Water and Electricity Authority (ADWEA)
2. Al Ain Distribution Company (AADC)
3. Abu Dhabi Distribution Company (ADDC)
4. Department of Energy Electricity Wiring Regulations (DOE EWR)

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11 UTILITIES

All the work to be carried out in the Utilities works (Telephone Services, Electrical Services, Sewerage Services, central Cooling, Gas Services, Water Services, and others) which consists of all associated works, furnishing and installation of all materials, all testing and all subsidiary and related work items shall be as indicated on the Drawings, and specified in the relevant Authority's specifications, guidelines and the (Abu Dhabi Emirate Guideline for Infrastructure Services Standards) – latest edition when applicable.

The Contractor should get all the required shop drawings and method statements approved by the Engineer and the relevant authorities. The handing over and commissioning should be as per the Engineer's requirements defined in the contract documents, in compliance with the all relevant Authority's guidelines, and under the supervision of the Authority as appropriate

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CHAPTER 12 – STORMWATER DRAINAGE

DOCUMENT NO: TR-542-1

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12 STORMWATER DRAINAGE

Specifications for construction of the Surface Water Drainage System which consists of all associated earthwork, furnishing and installation of all materials, all testing and all subsidiary and related work items shall be as indicated on the Drawings, and specified in the following standards included in the (Abu Dhabi Emirate Guideline for Infrastructure Services Standards) – latest edition

1. Stormwater and subsoil drainage systems (Volume |)
   Design Manual (WA-726-1)
2. Stormwater and subsoil drainage systems (Volume ||)
   Design Manual (WA-726-2)
3. Stormwater and subsoil drainage systems (Volume |||)
   Operation and Maintenance Management Manual (WA-726-3)
4. Stormwater and subsoil drainage systems Standard Technical Specification
   (Volume 1 , 2 & 3) (WA-726-4)

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CHAPTER 13 – LANDSCAPING AND IRRIGATION

DOCUMENT NO: TR-542-1

SECOND EDITION

SEPTEMBER 2020

13 LANDSCAPING AND IRRIGATION

Specifications for construction of the Irrigation and Landscaping which consists of all associated earthwork, furnishing and installation of all materials, all testing and all subsidiary and related work items shall be as indicated on the Drawings, and specified in the following standards included in the (Abu Dhabi Emirate Guideline for Infrastructure Services Standards) – latest edition

1- Irrigation Manual (Volume I) Design Manual (WA-725-1)
2- Irrigation Manual (Volume II) Operation and Maintenance Manual (WA-725-2)
3- Irrigation Manual (Volume III) Technical Specifications (WA-725-3)
4- Irrigation Manual (Volume IV) Standard Drawings (WA-725-4)

In addition, all the Landscaping manuals and Landscaping standard specs, standard drawings etc. included in the (Abu Dhabi Emirate Guideline for Infrastructure Services Standards) – latest edition.