REPUBLIC OF LEBANON

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

Damaged Roads Clearing and Restoration in South Lebanon for Bint Jbeil Caza

Tender Documents

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GENERAL REQUIREMENTS

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SECTION 1.01 DESCRIPTION OF WORK AND SITE

1.01.01 The Works

1.01.01.01 Background

As Lebanon emerges from the 2023-2024 conflict that affected Lebanon and overlapping multifaceted crises, the proposed emergency Project supports the most urgent repair and reconstruction of damaged critical public infrastructure and public lifeline services and the sustainable management of rubble.

The proposed Lebanon Emergency Assistance Project (LEAP) is a central part of the WBG portfolio in support to Lebanon. The proposed emergency Project will finance activities related to immediate response, recovery, and early reconstruction, such as sustainable rubble management and restoration of critical infrastructure and lifeline services (e.g., water, mobility, energy, health, education) in prioritized geospatial areas. Proposed Project activities will be complemented by activities in other IBRD-financed projects including in the energy, water, agriculture, social protection, and health sectors.

In response to this urgent national priority, this Tender aims to support the restoration of damaged roads within Bint Jbeil Caza.

1.01.01.02 Scope of Works

Based on the observed damage and current conditions, the required restoration works can be categorized as follows:

- Type 1 - Roads totally demolished and closed: require debris removal, reopening, and road restoration.
- Type 2 - Roads demolished and partially closed: require removal of remaining debris and road restoration.
- Type 3 - Roads cleared and reopened: require road restoration only.

The road restoration works mainly consist of the removal of damaged pavement layers and their replacement with subbase and base course layers, followed by a temporary bituminous base course layer.
The required restoration works for each road type are summarized in the following table.

Road Condition Type	Description	Removal of Debris & Clearing	Earth Works	Sub-base & Base Course	Bituminous Base Course	Crossing Drainage Structures	Road Safety Works
Type 1	Roads totally demolished and closed	✓	✓	✓	✓	✓	✓
Type 2	Roads demolished and partially closed	✓	✓	✓	✓	✓	✓
Type 3	Roads cleared and reopened	✕	✓	✓	✓	✓	✓

Notes: ✓ = Work required ✕ = Work not required

SECTION 1.02 QUALITY STANDARDS AND CONTROL

1.02.01 Generally

1.02.01.01 Good Practice

Where and to the extent that materials products and workmanship are not fully specified, the specifications of such material and the workmanship shall be inferred to the contract documents and suits the purposes of the recommended works, and according to good construction practices including the relevant provisions of current standards regulations etc.

1.02.01.02 Setting Out And Record Drawings

A. Setting Out

Before commencing Works on Site the Contractor shall carry out the setting out which includes the works limits, dimensions, ground levels obstructions and other, in conjunction with or as instructed by the Engineer's Representative.

1.02.02 Materials

1.02.02.01 Product List Schedule

The Contractor shall, before placing any purchase order for any materials intended for incorporation in the Works, submit for approval a product list schedule giving a complete description of all such materials, names of the firms from whom he proposes to purchase them and copies of all test reports verifying conformity with the provisions of the Specifications. Materials shall not be ordered without the approval of the Engineer. When directed by the Engineer or otherwise specified, the Contractor shall submit suitable samples for approval.

1.02.02.02 Standards

For products and materials specified to a national standard, such as BS or ASTM, certificates of compliance are to be obtained from manufacturers when requested by the Engineer or the Engineer's Representative.

1.02.02.03 Single Sources

Where a choice of manufacturer or source or supply is allowed for any particular product or material, the whole quantity required to complete the work must be of the same type, manufacture and source. Written evidence of sources of supply are to be provided when requested by the Engineer or the Engineer's Representative and sources are not to be changed without approval.

1.02.02.04 Checking Compliance of Products And Materials

The Contractor shall check all delivery tickets, labels, identification marks and where appropriate, the goods themselves to ensure that all products comply with the Specification. Where different types of any product are specified, he shall ensure that the correct type is being used in each location. In particular, the following shall be checked:

- Sources types, qualities, finishes and colors are correct, and match any approved samples
- Accessories and fixings which should be supplied with the goods have been supplied
- Sizes and dimensions are correct
- Goods are clean, undamaged and in good condition, with intact protective coverings and unbroken seals
- Materials which have a limited shelf life are not out of date.

1.02.02.05 Protection of Products And Materials

The Contractor shall:

- Prevent over-stressing and any other type of physical damage.
- Keep clean and free from contamination and staining.
- Keep dry and in a suitably low humidity atmosphere to prevent premature setting moisture movement and similar defects. Where appropriate allow free air movement around and between stored components.
- Prevent excessively high or low temperatures and rapid changes of temperature in the material.
- Protect adequately from rain, frost, sun and other elements as appropriate.
- Keep different types and grades of materials separately and adequately identified.
- So far as possible, keep materials in their original wrappings, packings or containers, with unbroken seals, until immediately before they are used.

1.02.02.06 Materials Supplied By Employer

The Contractor shall be responsible for all materials furnished by the Employer and shall make good any shortages or deficiencies, from any cause whatsoever, or any damage which may occur, after delivery of such materials.

1.02.02.07 Local Material Sources

When material sources are not designated on the Drawings or in other documents, the Contractor shall be responsible for locating and providing suitable materials from approved sources.

Any information provided in the tender documents about sources of local materials is considered as a guideline only and does not relieve the Contractor of his responsibility in respect of investigation and supply of suitable materials as specified.

Materials, regardless of their source, shall not be incorporated in the Works until approved by the Engineer.

1.02.02.08 Removal From Site

The Contractor shall not remove from the Site any approved plant or equipment without the permission of the Engineer.

1.02.03 Workmanship

1.02.03.01 Work

Work is to be carried out by or under the close supervision of experienced tradesmen skilled in the particular type of work.

1.02.03.02 Manufacturer's Recommendations

Products shall be handled, stored, prepared and used in accordance with manufacturer recommendations. The Contractor shall inform the Engineer's Representative if these conflict with any other specified requirement and submit copies of manufacturer's recommendations to the Engineer's Representative when requested.

1.02.03.03 Suitability Of Previous Work And Conditions

Before starting each new type or section of work the Contractor shall ensure that:

- Previous related work is appropriately complete, in accordance with the project documents, to a suitable standard and in a suitable condition to receive the new work.

1.02.03.04 Defects In Existing Work

The Contractor shall report to the Engineer Representative if any existing work is defective and obtain his instructions before proceeding with new work which may cover up the defective work or which may be adversely affected by the defective work.

1.02.03.05 Rectification Of Defective Work

If any part of the work is known or is suspected to be not in accordance with the Contract, the Contractor shall submit proposals to the Engineer for opening up, inspecting, testing and rectification and carry out the Engineer's instructions in relation thereto, including, where so instructed, removal and reconstruction.

1.02.03.06 Warranties

The Contractor shall:

- Comply with specific requirements for warranties for work, products and installations that are required to be warranted in the specifications,
- Ensure that all warranties shall commence on the date of completion and are transferable to the employer upon completion of the defects liability period, if the specific period of warranty exceeds this date.
- Ensure that the following additional requirements are accommodated in the warranties :
  - a) Related damage and losses when correcting warranted work that has failed, replace other work that has been damaged as a result of such failure or that must be removed and replaced to provide access for correction of warranted work.
  - b) Re-instatement of warranty: when work covered a warranty has failed and been corrected by replacement or rebuilding reinstate warranty by written endorsement the

reinstalled warranty shall be equal to the original warranty with an equitable adjustment for depreciation.

c) Replacement cost: upon determination that the work covered by a warranty has failed, replace or rebuild the work to an acceptable condition complying with the requirements of the Contract Documents. The Contractor shall be responsible for the cost of replacing a rebuilding defective work regardless of whether the Employer has benefited from use of the Work through a portion of its anticipated useful service life.

- Submit written warranties for approval to the Engineer prior to date certified for completion or completion of parts as may be designated.
- At final completion, compile four copies of each required warranty and bind in loose leaf binders in a clear and logical manner.

1.02.03.07 Warranties Employer Recourse

Written warranties made to the Employer are in addition to implied warranties, and shall not limit the duties, obligations, rights and remedies otherwise available under law, nor shall warranty periods be interpreted as limitations on time in which the Employer can enforce other duties, obligations rights, or remedies.

- Rejection of warranties: The Employer reserves the right to reject warranties to limit selections of products with warranties not in conflict with requirements of the contract documents.

1.02.04 Samples And Approvals

1.02.04.1 Samples

Where approval of products or materials is specified, the Contractor shall submit samples or other evidence of suitability. Orders shall not be confirmed or materials used until approval has been obtained. Approved samples are to be retained on the Site for comparison with products and materials used in the Works and removed when no longer required. All materials being used will be subject to inspection, testing, or rejection at any time prior to such incorporation.

Where samples of finished work are specified the Contractor shall obtain approval of stated characteristics before proceeding with the Works and shall retain approved samples on the Site for comparison with the Works Samples which are not part of the finished works shall be removed when no longer required.

1.02.04.2 Source Tests

All sources samples shall be taken by the Contractor in the presence of the Engineer, using approved sampling procedures. All source approval tests shall be performed under the supervision of the Engineer or, when so specified, by an independent laboratory approved by the Engineer and engaged by the Contractor.

After approval of any source of materials, the Contractor shall produce from such source only to the extent that materials produced are of substantially the same quality as the approved samples.

The Engineer will periodically order retesting of previously approved sources to verify that they continue to conform to the Specifications and may order retesting at the same or at different laboratory from the one performing the original approval tests. If retesting indicates that a previously approved source no longer conforms with the Specifications, the Contractor shall forthwith cease production from such source.

1.02.04.3 Approvals

Where and to the extent that products materials or work are specified to be approved, or the Engineer instructs or requires that they are to be approved, the same must be supplied and executed to comply with all other requirements and, in respect of the stated or implied characteristics, either to the express approval of the Engineer, or to match a sample expressly approved by the Engineer as a standard for the purpose.

Inspection or any other action by the Engineer must not be taken as approval of materials, products or work unless the Engineer so confirms in writing in express terms referring to:

- Date of inspection
- Part of the work inspected
- Respects or characteristics which are approved
- Extent and purpose of the approval
- Any associated conditions.

Approval, inspection or any other action by the Engineer shall not in any way relieve the Contractor from his responsibility for the suitability and fitness for purpose of materials, products or work.

Where untested and unaccepted materials have been used, without approval of the Engineer, such use shall be at the Contractor's risk.

SECTION 1.03 TEMPORARY WORKS AND SERVICES

1.03.01 Generally

1.03.01.01 Locations

The Engineer's Representative's approval is to be obtained for the intended Temporary Works and services.

1.03.01.02 Standards And Details

Temporary Works are to be constructed to recognized standards and codes of practice so that they are fit for their purpose. Drawings and details of proposed Temporary Works are to be provided by the Contractor if requested by the Engineer.

1.03.01.03 Temporary Works

Temporary Works and services are to be maintained, altered and adapted and as necessary and cleared away on completion or when no longer required. Work disturbed is to be made good.

1.03.01.04 Traffic Control Plans (TCPs)

The Contractor shall provide all Temporary Works and services and Contractor's Equipment and tools required for the efficient and safe execution of the Works

In addition the Contractor shall submit for approval and prior execution all necessary traffic control plans (TCPs) for each activity.

The temporary safety devices shall include but not limited to:

- Barricade with flashers type k5c.
- Warning Rectangular sign type KCI
- Warning Sign, size greater than or equal to one square meter including posts, supports, foundations and all related works, type K2.
- Plastic Barrier, 145 cm long and 40 cm wide, type K16.
- Cones and flash lights

1.03.02 Temporary Site Facilities

1.03.02.01 Roads

Permanent roads, hard standings and footpaths on the Site may be used provided they are adequately maintained and thoroughly cleaned and made good after use and left in unimpaired condition.

1.03.02.02 Temporary Nameboard

The Contractor shall provide temporary nameboards in both languages English and Arabic at the locations where the works are on going, bearing the Employer's and Engineer's names, the name of the project, the Contractor's name and such other names and information as the Engineer may direct. Design of the name board shall be submitted for the Engineer approval prior to fabrication and erection.

1.03.03 Contractor's Temporary Offices

1.03.03.01 Contractor's Temporary Offices

The Contractor shall provide all necessary temporary sheds, offices, messrooms, sanitary accommodation and other temporary facilities required for his and subcontractors use.

1.03.03.02 Temporary Laboratory

The Contractor shall provide, furnish and equip a laboratory as necessary to carry out all testing of materials on Site required by the Specification, manned by suitably qualified staff.

1.03.04 Temporary Services

1.03.04.01 Water

The Contractor shall provide clean fresh water for the Works and make temporary arrangements for storing and distributing about the Site.

1.03.04.02 Electricity

The Contractor shall provide electric supply and all equipment for lighting and power for the Works and make temporary arrangements for distributing about the Site.

1.03.04.03 Power

The Contractor shall provide electric power for the Works including supplies for commissioning engineering services and plant, at the required voltages.

1.03.04.04 Lighting

The Contractor shall provide lighting for the Site and the Works for safety and security to the Works and to facilitate proper execution of work and to illuminate internal surfaces during

finishing work and inspection. Spaces designed to be artificially lit during daylight hours are to have temporary illumination similar to that provided by the permanent installation.

1.03.04.05 Permanent Electric Supply And Lighting Installation

Permanent electric supply and lighting installation may be used for commissioning and to illuminate the Works subject to the following conditions:

- The employer does not guarantee that it will be available
- The Contractor must take responsibility for the operation maintenance and supervision of the system, indemnify the Employer against all damage and pay all costs and renew all used tubes and lamps
- The Contractor must indemnify the Employer against reduction in manufacturer's guarantee periods for equipment etc., due to its use before completion of the Works.

1.03.05 Temporary Facilities For The Engineer And/Or Employer

1.03.05.01 General

All facilities provided for the Engineer's and/or Employer's staff shall remain available until the end of construction period.

1.03.05.02 Representative's Site Offices

The Contractor shall provide rented space to serve as offices as may be approved by the Engineer for the sole use of the Engineer's Representative and his staff,

1.03.05.03 Telephones

The contractor shall provide one mobile telephone connection. The Contractor shall pay all installation, rental and call charges.

1.03.05.04 Car Ports

Car ports, complete with hardstandings and all necessary adjoining walkways, shall be provided for a minimum of one vehicle. Covered car parking areas shall be adjacent to the offices.

1.03.05.05 Representative's Vehicles

The Contractor shall provide and maintain one new four wheel Drive, air-conditioned vehicles, minimum 2400 CC for the sole use of the Engineer's Representative and his staff and shall supply all fuel and lubricants, repair and maintain the vehicle to keep it in good roadworthy condition at all times, comprehensively insure the vehicle for any driver at all times and replace with identical vehicle any vehicle removed for maintenance or repair or for any other reason.

At the end of the Project Defects Liability Period the above cars shall remain the property of the Contractor.

1.03.05.06 Test Equipment

The Contractor shall make available to the Engineer's Representative all test equipment and testing laboratories required for carrying out tests on materials, Plant or finished work required by the Specification.

1.03.05.07 Inspection Facilities

The Contractor shall provide all ladders, access lighting facilities and assistance etc. required by the Project Manager Representative/Engineer's Representative to inspect any part of the Works.

1.03.05.08 Digital Camera

The Contractor shall provide one digital camera latest model for the sole use of the Engineer's Representative and his staff.

1.03.05.09 Computer

The Contractor shall provide on site for the use of the Engineer's Representative and his staff one latest model computers, portable type (laptop) along with the necessary operating systems, softwares.

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SECTION 2.01 CLEARING, REMOVAL, AND DISPOSAL OF WAR-RELATED DEBRIS

2.01.01 SCOPE

A. This item shall consist of the clearing, removal, demolition where required, loading, transportation, and satisfactory disposal of all war-related debris and obstructions within the limits of the working area, road right-of-way, and other areas designated by the Engineer.

B. War-related debris shall include, but not be limited to, damaged pavement layers, rubble, demolished or partially collapsed structural elements, surface debris, scattered stones and rocks, abandoned materials, and any other obstructions resulting from war damage, except items designated by the Engineer to remain or to be removed under other Sections of the Specifications.

C. The Works shall be executed in a manner that ensures public safety, maintains access to adjacent properties, minimizes disruption to traffic and surrounding areas, and complies with the approved Traffic Management Plan and applicable regulations.

2.01.02 CONSTRUCTION

A. The Contractor shall set out the approved limits of work, and the Engineer shall designate any items to remain within the road right-of-way or adjacent areas. All designated items shall be carefully preserved from damage or disturbance.

B. All war-related debris, including damaged pavement materials, rubble, stones, rocks, surface debris, and other surface and subsurface obstructions not designated to remain shall be removed to ground level or below, as directed by the Engineer.

C. Where breaking up or demolition of damaged pavement layers or structural remnants is required to facilitate proper removal, such demolition shall be carried out in a controlled manner using methods and equipment approved by the Engineer.

D. Holes, depressions, or voids resulting from the removal of debris within the right-of-way shall be backfilled with suitable approved material and compacted in accordance with Section 2.05 – Embankment Construction. Areas outside the right-of-way shall be filled and leveled to match adjacent ground.

E. Clearing and removal operations shall be carried out using suitable equipment and methods approved by the Engineer. The Contractor shall take all necessary precautions to protect existing utilities, adjacent structures, pavements, and road elements that are to remain in place.

F. All materials, rubble, damaged pavement materials, stones, rocks, and debris shall be loaded, hauled, and disposed of at approved dumping areas off the Site, in accordance with environmental regulations and as directed by the Engineer. Written permission from property owners shall be obtained where required.

G. The Contractor shall temporarily divert, protect, and reinstate ditches, drains, and waterways encountered during the Works, in accordance with the Engineer's instructions. Where reinstatement is not possible, the Contractor shall obtain further instructions from the Engineer.

H. The Contractor shall implement all necessary dust control, noise mitigation, traffic control, safety, and environmental protection measures throughout the execution of the Works to ensure the safety of workers, road users, and the public.

2.01.03 MEASUREMENT

A. Where shown as a Pay Item in the Bill of Quantities, clearing, removal, and disposal of war-related debris shall be measured by meter cube (m^3) of area cleared within the limits of the Works, based on the horizontal projection of the cleared area, completed and accepted by the Engineer.

B. The measured quantity shall include all clearing, demolition, loading, transportation, disposal at approved dump sites, backfilling, traffic management, safety measures, and all incidental works necessary to complete the item as specified.

C. Payment shall be made at the Contract unit rate for Clearing, Removal, and Disposal of War-Related Debris, which shall constitute full compensation for all labor, materials, equipment, demolition, transport, disposal at approved dump sites fees, environmental compliance, traffic management, safety measures, and all other works required to complete the item in accordance with the Specifications and to the Engineer's satisfaction.

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Clearing, Removal, And Disposal of War-Related Debris	Cubic meter (m^3)

SECTION 2.02 CLEARING OF EXISTING WATERWAYS, DRAINAGE PIPES, AND BOX CULVERTS

2.02.01 SCOPE

A. This Section covers the clearing of existing waterways, drainage pipes, and box culverts crossing roads within the limits of the Works, provided such structures are found to be in good condition and structurally sound, as determined by the Engineer.

B. The Works shall consist of the removal and satisfactory disposal of silt, sediment, debris, vegetation, and any accumulated materials obstructing the flow of water, in order to restore the hydraulic capacity and ensure proper functioning of the drainage structures.

C. Repair, replacement, or reconstruction of damaged drainage structures shall not be included under this Section and shall be carried out under separate Pay Items, unless otherwise directed by the Engineer.

2.02.02 CONSTRUCTION

A. Prior to commencement, the Contractor shall inspect the existing waterways, pipes, and culverts and notify the Engineer of any defects, damage, or structural deficiencies observed. Clearing works shall proceed only upon confirmation by the Engineer that the structures are suitable for cleaning.

B. Clearing operations shall be carried out using methods and equipment approved by the Engineer, ensuring that the integrity of the existing structures is not damaged during execution.

C. All silt, debris, vegetation, and accumulated materials shall be removed from within the waterways, pipes, and culverts and from their inlets, outlets, headwalls, wing walls, and adjacent channels, as required to ensure free and unobstructed flow of water.

D. Removed materials shall be loaded, transported, and disposed of at approved dumping areas in accordance with environmental regulations and as directed by the Engineer.

E. Upon completion of the clearing works, the drainage structures shall be left in a clean condition, fully functional, and restored to their original hydraulic capacity, to the satisfaction of the Engineer.

F. The Contractor shall take all necessary precautions to prevent pollution, downstream sedimentation, or flooding during the execution of the Works and shall provide temporary flow diversion measures where required.

2.02.03 MEASUREMENT

A. Where included as a Pay Item in the Bill of Quantities, clearing of existing waterways, drainage pipes, and box culverts shall be measured by **cubic meter (m^3)** of silt, debris, vegetation, and accumulated materials removed, measured in place prior to removal or based on approved theoretical volumes, as determined by the Engineer.

B. Measurement shall be limited to materials actually removed from within the waterways, pipes, culverts, inlets, outlets, and associated channels, completed and accepted by the

Engineer.

C. The measured quantity shall include all labor, equipment, temporary works, access arrangements, flow diversion, removal, loading, transportation, disposal of materials, traffic control, safety measures, environmental protection, and all incidental works necessary to complete the item as specified.

2.02.04 PAYMENT

A. Payment shall be made at the Contract unit rate per **cubic meter (m^3)** for *Clearing of Existing Waterways, Drainage Pipes, and Box Culverts*, which rate shall constitute full compensation for all labor, materials, equipment, temporary works, disposal at approved dump sites, environmental protection, traffic management, safety measures, and all other works required to complete the item in accordance with the Specifications and to the Engineer's satisfaction.

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Clearing Of Existing Waterways, Drainage Pipes, And Box Culverts	Cubic meter (m^3)

SECTION 2.03 ROAD EXCAVATION

2.03.01 GENERAL

This Section covers unclassified excavation for the reconstruction of gravel roads on existing roads damaged by war. The Works include all necessary excavation to achieve a stable, uniform, and durable subgrade, suitable for gravel road construction.

2.03.02 WORKS INCLUDED

The Works shall include, but are not limited to:

1. Excavation, loading, hauling, and disposal or stockpiling of all materials, including soil, sand, gravel, and rocks, without classification, from within the working area and road right-of-way.

2. Shaping, leveling, and trimming of the subgrade to the specified line, level, cross-fall, and slope.

3. Removal of unsuitable or soft subgrade materials, as directed by the Engineer.

4. Proof-rolling and quality control to verify subgrade stability, uniformity, and compliance with design requirements.

5. Disposal of unsuitable or excess materials to approved dumping areas in accordance with environmental and regulatory requirements.

6. Protection of existing utilities, structures, and vegetation designated to remain in place.

7. Implementation of safety measures, traffic management, erosion control, dust suppression, and environmental protection throughout the execution of the Works.

2.03.03 COMPLIANCE

All works shall be carried out in strict compliance with:

- The Contract Documents and Drawings.

- Instructions of the Engineer.

- Applicable local laws, regulations, and safety standards.

2.03.04 CONSTRUCTION

1. The Contractor shall notify the Engineer sufficiently in advance of commencing any excavation works for the restoration of road pavement so that the Engineer may, where necessary, inspect, survey, and record the existing ground levels, pavement condition, and cross-sectional profiles of the affected road section. Any excavation, removal of pavement layers, or unsuitable materials carried out before such measurements are taken and approved by the Engineer shall not be measured or paid for.
2. The Contractor shall be solely responsible at all times for the safety and stability of all

excavations within the roadway, including pavement cuts, trenches, and subgrade excavations, whether supported, sloped, or otherwise protected. Approval by the Engineer of any excavation method, support system, or the absence thereof shall not relieve the Contractor of full responsibility for safety.

3. The Contractor shall take all necessary precautions to protect workers and the public, in accordance with applicable safety regulations. The Engineer shall not enter working areas for inspection or approval until such areas are deemed safe.

4. Where excavation works are carried out adjacent to or within public roads, access routes, or pedestrian walkways, the Contractor shall provide and maintain all required traffic control measures, including barricades, cones, barriers, warning signs, temporary diversions, and protected walkways, to minimize risks to road users and pedestrians.

5. Excavation sides for pavement and subgrade restoration works shall be vertical and adequately supported for depths up to 1.5 m unless otherwise directed by the Engineer. Excavations exceeding 1.5 m in depth shall be sloped to a safe angle or supported using approved methods, unless the excavated material is proven to be self-supporting and accepted by the Engineer.

6. All excavated areas shall be kept free of standing water at all times until approved backfilling and gravel pavement layers are placed and compacted. The Contractor shall minimize, to the maximum extent practicable, the duration for which excavations remain open. The Contractor shall be fully responsible for any damage to the excavation, subgrade, or surrounding pavement caused by weather conditions, traffic, construction equipment, or other factors during the period the excavation remains open.

7. In areas adjacent to public roads and walkways, no excavation shall be left exposed for more than three (3) consecutive days unless otherwise approved in writing by the Engineer.

8. The Contractor shall immediately notify the Engineer upon observing any signs of instability, settlement, cracking, or failure within or adjacent to the excavation, pavement edges, or surrounding road structure, and shall promptly take all necessary corrective measures as directed by the Engineer.

2.03.05 METHOD OF MEASUREMENT

A. All material excavated, shaped, and prepared for war-damaged gravel roads shall be measured as “Unclassified Excavation “
B. Measurement shall be by cubic meter (m^3) of material, including:

- Excavation, hauling, disposal to the approved dump sites or stockpiling.
- Shaping, trimming, leveling, compaction, moisture conditioning, proof-rolling.

C. Volumes shall be computed from cross-sections and original ground elevations recorded jointly by the Consultant and Contractor, reflecting war-damaged conditions.

D. Excavation of unsuitable subgrade material shall be measured in cubic meters, including hauling and disposal.
E. Payment shall be made at the Contract unit rate per **cubic meter (m^3)** for **Unclassified Excavation– War-Damaged Roads**.

F. The rate shall constitute full compensation for:

- Labor, equipment, and temporary works for excavation, loading, hauling, and disposal or stockpiling.
- Shaping, leveling, trimming, compaction, moisture conditioning, and proof-rolling.
- Traffic management, safety, dust suppression, erosion control, and environmental protection.
- All incidental works necessary to complete the item to the Engineer's satisfaction.

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Unclassified Excavation	Cubic meter (m^3)

SECTION 2.04 BORROW EXCAVATION

2.04.01 SCOPE

These Works shall consist of excavating suitable material from borrow pits, and designated borrow areas and hauling to stockpiles all as as approved by the Engineer.

The Contractor shall be responsible for the location of suitable borrow pits if and when required and for the suitability and sufficiency of borrow materials to meet the specified embankment and other backfilling requirements.

Borrow pits shall be utilized if there is insufficient suitable excavated material to satisfy the embankment and other backfilling requirements or if the Contractor chooses to excavate suitable material to waste or put it to other uses and replace it by suitable material excavated from borrow pits.

2.04.02 LOCATION OF BORROW PITS

Generally, the borrow pits shall not be located within 50 m from the toe of embankment slope or top of cut or formed slope unless otherwise approved by the Engineer.

In no case shall borrow pit be located within 200 m downstream of a drainage structure without the written approval of the Engineer. Unauthorized borrow pits shall be backfilled and compacted as directed by the Engineer at the Contractor's expense.

In each case where a borrow pit is proposed within privately-owned property the Contractor shall secure the consent of the landowner in writing and if necessary and at his own expense pay for the use of the material and land. The Contractor shall be responsible for any claims for compensation or complaints arising out of borrow pit operations and shall indemnify and keep indemnified the Employer against all such claims.

The Contractor shall be responsible for the stability of the side slopes of borrow pits and channels at all times until the pit or channel is abandoned.

Details of the Contractor's proposed haul routes and traffic arrangements in relation to borrow pit operations shall be submitted for approval before any borrow excavation commences.

Overburden and any unsuitable top layers within each borrow pit shall be completely removed and stockpiled in the vicinity, ready for re-use prior to abandonment of the pit.

Prior to abandonment of any borrow pit or borrow area, the Contractor shall spread and level the original overburden over the exposed surfaces and clean up, grade and contour the pit or area and the adjoining properties occupied during execution of borrow operations, whether Government, or privately-owned, all to the satisfaction of the Engineer.

2.04.03 BORROW MATERIAL

A. Borrow shall be material approved as meeting the requirements for the particular embankment, backfill or other use for which the material is intended.

B. The Contractor shall submit representative samples of materials from each of the proposed borrow pits or borrow areas. A minimum of three sets of tests shall be required from each borrow area for each type of material. Testing shall conform with

the relevant requirements of Part I of specifications Section 4- "Quality Standards and Control" clause No. 4-6-2. Source Tests. No borrow material shall be brought to the site or used in the Works before its approval.

C. The Engineer will periodically require follow-up testing of borrow materials to verify that no change in quality has occurred since the original approval.

2.04.04 MEASUREMENT

A. Borrow Excavation shall be measured by m^3 of suitable material excavated, hauled and used in the proper formation of embankments, including trimming of slopes, preparation and completion of the roadway subgrade and shoulders.

B. The quality of borrow excavation shall be determined by calculating the total quantity of filling after compaction and deducting there from the total quantity of unclassified excavation less an allowance for material condemned by the Engineer as unsuitable for filling.

PAY ITEM	UNIT OF MEASUREMENT
(1) Borrow Excavation	Cubic meter (m^3)

SECTION 2.05 EMBANKMENT CONSTRUCTION

2.05.01 SCOPE

These Works shall consist of constructing road embankments, including preparation of the areas upon which they are to be placed, placing and compacting approved material within areas where unsuitable material has been removed; and placing, and compacting approved embankment material in holes, pits and other depressions within the right-of-way area and within the site limits generally to attain the grading levels, all in accordance with the lines, grades and cross sections shown on the Drawings.

2.05.02 MATERIALS

Material of classes A-l, A-2-4, A-2-5 or A3 "when confined" groups as in AASHTO M145 and complying with Table 2.6.1 shall be used when available, except for rock fill embankments. If material of this character is not available then materials from A-2-6, A-2-7, A-4, A-5 groups may be used provided they comply with Table 2.6.1. However, special attention should be given to the construction.

TABLE 2.6.1: SOIL SUITABLE FOR EMBANKMENT

Maximum dry density	not less than l .7 (AASHTO T-180D)
Organic matter	not more than 5% (AASHTO T-267)
No use of A-6, A-7 soil	(AASHTO M-145)
Maximum size	not more than 1/2 of the layer thickness
Plasticity Index (PI)	less than 20%
4-day soaked C.B.R.	should not be less than 8% (AASHTO T-193) when compacted at 100% maximum dry density in accordance with AASHTO T-180D

The 200 mm depth of embankment subgrade layer immediately below the bottom of sub base shall consist of selected subgrade material having a 4-day soaked CBR of at least 20% when tested in accordance with AASHTO T 193 and with a gradation and P.I. as specified under Section 2.07 - "Subgrade Construction".

The 600 mm depth of embankment immediately below the subgrade layer shall consist of material having a 4-day soaked C.B.R of at least 15% when compacted to 100% maximum dry density in accordance with AASHTO T-180D and tested in accordance with AASHTO T-193 with a P.I. not more than 15%. If rockfill is used for the bottom 400 mm then these requirements shall apply to the top 200 mm below the subgrade layer.

In areas subject to flooding and prolonged inundation of the embankment, such as at bridge and culvert sites, the material used in embankment, unless rock, shall conform to AASHTO M 145, Class A-1-a, A-l-b, A-2-4.

Where embankments are to be constructed using material classified as A3 (AASHTO M 145) or other material subject to side slope erosion or requiring confinement for stabilization purposes, the embankment plating or confining layer shall be constructed using AASHTO M 145 Class A-1-a, A-l-b, or A-2-4 materials or as otherwise approved.

The material used in rockfill embankments shall consist predominantly of rock fragments of such size that the material can be placed in layers of the thickness prescribed conforming to the requirements stated in Table 2.6.2.

Table 2.6.2: ROCK SUITABLE FOR EMBANKMENT

Maximum particle size	1/2 loose layer thickness
Passing 0.42mm (Sieve # 40)	25% maximum
Uniformity coefficient, Cu	5 minimum

where Cu = D60/Dl0
D60 = the particle size at which 60% passes
D10 = the particle size at which 10% passes

Rockfill material shall be obtained from roadway or tunnel excavation and shall be sound, dense, hard and durable rock capable of being spread and compacted as specified. Individual pieces are to be clean and angular. It shall be the contractor's responsibility to excavate material from rock cuts, whether by blasting or other manner, so that all excavated materials are of suitable size.

When suitable materials of widely divergent characteristics are drawn from different sources, such materials may, if approved, be mixed to meet the embankment requirements. Rock and other materials shall be incorporated in such manner as to avoid segregation and an accumulation of boulders, etc. at the toe of embankment slopes.

Logs, trees, stumps, weeds, heavy grass, frozen soil, vegetable matter or other undesirable and noncompatible materials shall not be placed in embankments.

Rocks, broken concrete or other solid materials larger than 100 mm in any dimension shall not be used as fill material in areas where piling works are to be carried out.

2.05.03 CONSTRUCTION

A. General

Prior to placing embankment material on any area, it shall have been cleared and grubbed as specified in Section 2.01 - "Clearing and Grubbing", and the foundation prepared as specified herein.

Equipment used for foundation preparation and for placing, spreading and compacting embankment materials shall be of approved types and furnished in sufficient numbers for the purposes intended. Provision and use of such equipment shall conform with the relevant requirements of Part 1 of specifications, Section 4-4 "Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

Draglines shall not be used to construct embankment unless approval is given and only when special procedures are adopted to keep the layers uniform and the embankment properly graded and well-drained at all times.

Surfaces of embankment layers shall be kept properly shaped and drained at all times. The Contractor shall utilize a sufficient number of motor graders or tractors to level and maintain the surface of each layer of embankment during all placing and compacting operations.

Rockfill shall not be used in the top 20 cm of the embankment below the subgrade. Water must be added as required, and with the approval of the Engineer, to achieve maximum compaction.

Whenever feasible, trucks, scrapers, tractors and other heavy hauling equipment shall be routed over the embankment in such a manner as will contribute effectively to compaction of the fill material.

Where an embankment is to be constructed over an area previously occupied by a building basement, cellar, irrigation canal, well, any previous excavation, or adjacent to structures, and where the proper use of normal compaction equipment is not practicable, the embankment shall be constructed and compacted in accordance with the backfilling requirements of Section 2.09 - "Structural Excavation and Backfill" until the use of normal compaction equipment is practicable. Layers shall not exceed 200 mm thickness (after compaction) and shall be compacted to the degree of compaction specified for the embankment.

Each embankment layer shall be tested and approved prior to placing the following layer in accordance with Subsection 2.06.4 "Testing".

The Engineer may at any time order suspension of delivery of materials to the embankment sites until previously delivered materials have been properly placed and preceding layers are leveled and uniformly compacted to the specified density.

Unacceptable material placed in any embankment shall be removed and disposed of by the Contractor at his own expense.

The Contractor shall be responsible for the stability of all embankments and shall replace all embankment sections which, in the opinion of the Engineer, have been damaged or displaced due to carelessness or neglect on the part of the Contractor, or due to normally occurring natural causes, such as storms, and not attributable to the unavoidable movement of the natural ground upon which the embankment is constructed.

Embankment side slopes shall be neatly finished true to the lines and not steeper than the slope angles as shown on the Drawings. The bottom (toe) of side slopes shall be graded to a well rounded, smooth profile to blend in with the adjacent terrain.

The side slopes of rockfill embankments shall be thoroughly blanketed with A-1, A-2-4 material, and compacted to the satisfaction of the Engineer.

The Engineer may permit the Contractor to utilize suitable surplus material at his own expense to widen embankments or flatten slopes, etc. within the right-of-way. Surplus material using such manner shall be compacted to 90 per cent of maximum density, but this shall not be measured for payment. When widening embankments, the Contractor shall bear the cost of modifying the culverts and any protection work necessary.

Rockfill shall not be used within 5m of a structural element (next to bridge abutments footings, etc.).

Rockfill shall not be used for 60 cm on top and bottom of Box and Pipe Culverts. Subgrade material shall be used in these areas up to width excavated for structures.

B. Trial Embankment Sections

If shown on the drawings, or as required by the Engineer, a trial embankment shall be constructed. The trial section shall be at least 2 lanes wide by 100 m long at approved

locations or adjacent to the Site. Compaction and other equipment used, shall be as specified and listed in the Contractor Equipment Schedule and approved Program of work.

The initial sections of road rock embankment shall serve as the trial sections for rock fill, in order to establish the optimum degrees of consolidation for the different layer thickness. This shall be obtained by compaction trials correlating number of passes of the roller with settlement of the layer, or by different approved methods. The maximum permitted layer thickness shall be related to the unit weight of the vibratory roller and for compaction, as given in Table 2.6.3 and shall not exceed 100 cm loose thickness.

TABLE 2.6.3

Maximum Thickness of Layer (Loose Thickness)	**Minimum Roller Mass* (Kg/m Width)**
40 cm	2300 - 2900
60 cm	2900 - 3600
80 cm	3600 - 4300
100 cm	4300 - 5000

* For multiple rollers, this shall be assumed as the high axle load.

C. Foundation Preparation

If the original surface upon which embankment is to be placed is an existing roadbed, the surface shall be plowed, scarified, or otherwise broken up regardless of the height of the embankment to be placed thereon.

Clearing and grubbing, and removal of tree stumps, shall be undertaken. The degree of compaction for the area to be cleared shall then be determined. The top 150 mm of the surface on which the embankment is to be placed shall be scarified, brought to a uniform moisture content within the specified range, and compacted to the density specified for the embankment. Hard and smooth surfaces are to be roughened before filling is placed.

Where embankment is to be placed and compacted on hillsides or where new embankment is to be compacted against existing embankments or where embankment is built part width at a time, the slopes steeper than 3:1 (H:V) when measured at right angles to the road centerline shall be continuously benched as the embankment is brought up in layers. Benching shall be of sufficient width to permit operation of spreading and compaction equipment, and in any case not less than 2 m wide except where insufficient width is available between existing and new embankments. Each horizontal cut shall begin at the intersection of the original ground and the vertical sides of the previous cuts. The vertical face of each bench shall not be less than 1 m in height and not exceed 2 m. Authorized benching shall be measured as road excavation.

Where embankment is to be placed and compacted on wadi slopes, the entire slope area shall be graded and trimmed to remove any vertical faces and overhangs. The final graded slope shall not be steeper than 1.5:1(H:V). The slope shall then be continuously benched as the embankment is brought up in layers, all as described above for embankment on hillsides.

Rockfill shall not be placed on any slopes steeper than 1:1. All slopes steeper than 1:1 shall therefore be regraded to a slope of 1:1 or shallower and all vertical faces and overhangs removed.

D. Embankment Construction

Roadway embankment consisting of soil or granular material shall be placed in horizontal layers not exceeding 250 mm thickness (before compaction), shall be compacted as specified and shall be approved prior to placing the next layer. The thickness of the first layer over areas of Class A-3 dune sand may exceed 250 mm in order to bridge these areas. Approximately uniform thickness of each layer shall be achieved prior to compaction. As the compaction of each layer progresses, continuous leveling and working of the material shall be carried out to ensure uniform density. The correct moisture content shall be maintained at all times.

Where embankments are to be constructed to a height in excess of 1.5 m above top of original ground level the Engineer may approve layer thickness up to 300 mm (before compaction) if the Contractor's equipment and the nature of the material result in the required density throughout the layer thickness.

When the moisture content of the embankment material does not fall within the required moisture range, (optimum moisture ± 2%) water shall be added and thoroughly mixed into the soil by approved methods or the material shall be aerated, whichever is necessary to adjust the material to the required moisture content.

When water is added to embankment material, the amount added shall be sufficient to provide a moisture content within the required range plus a reasonable additional amount to compensate for evaporation and other unavoidable losses Water added in excess of this amount shall be removed by aeration or other approved means at the Contractor's expense. Satisfactory methods and sufficient equipment shall be used for the furnishing and handling of the water in a manner that will minimize loss due to evaporation or waste.

Embankments that consist of rock-soil material with sufficient soil to make rolling feasible, shall be placed and compacted in an approved manner and to the required degree of compaction. Water shall be added as and when directed to assist in the compaction of such materials.

In the case of embankments which are to be formed of approved rock-soil material containing an appreciable quantity (normally not exceeding 30% greater than 80 mm) of rock fragments and which cannot be placed in layers of the thickness prescribed without crushing, pulverizing, or otherwise breaking down the fragments, the embankment may be constructed in layers not exceeding in thickness twice the average size of the largest rock fragments and in any case not exceeding 600 mm (before compaction).

Rockfill materials shall be placed in such a manner that the larger rocks are well distributed and the voids are filled to the maximum practical extent by smaller particles, each layer shall be bladed into a neat and homogeneous mass prior to compaction. Any rocks found protruding from the leveled surface shall be removed and replaced by smaller particles. Initial breakdown compaction shall be performed with heavy bulldozers. The top level of each layer must be surveyed before and after compaction and approved by the Engineer before the next layer is placed. Oversize rock pieces may be used in high rockfill embankments to a level 3 meters below subgrade.

2.05.04 MEASUREMENT

C. No part of this section is a Pay Item. Original ground cross-sections taken by the Contractor prior to construction of embankment and checked and tested by the Engineer shall form the basis for computing the volume of Embankment required in the measurement of Borrow Excavation if necessary.

D. The volume of Embankment displaced by pipe culverts, box culverts and associated end walls, bridge piers and abutments, shall be deducted from the measured volume of embankment. No deduction shall be made for pipes less than 500 mm in diameter and associated end walls.

E. Surplus materials utilized at the Contractor's option within the right-of-way but beyond the cross sections shown on the Drawings, shall not be measured as part of the embankment.

F. No adjustments or allowances of any kind shall be made in respect of expansion or shrinkage of earthwork volumes, which may occur during excavation and compaction Works.

G. Scarifying old roadbeds, construction of the trial embankment section if it is outside the road and foundation preparation, testing including furnishing and using an approved type electronic compaction meter and grid pattern consolidation surveys, and other ancillary embankment Works shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Pay Items.

SECTION 2.06 SUBGRADE PREPARATION

2.06.01 SCOPE

A. These Works shall consist of furnishing materials, constructing the subgrade layer and preparing the subgrade surface ready to receive the pavement structure and shoulders, all as and where shown on the Drawings.

B. The subgrade layer is the 200 mm minimum depth of selected material immediately below the subgrade surface, or as defined in the drawings or directed by the Engineer

2.06.02 MATERIALS

A. Subgrade material shall consist of selected material having a 4-day soaked CBR of not less than 20 % when tested in accordance with AASHTO T 193 when compacted at 100 % of modified proctor AASHTO (T-180-D) and having a maximum P.I. of 12 %. Subgrade gradation shall be reasonably smooth without gap grading. All material shall pass 75 mm sieve and not more than 18 % shall pass 0.075 mm (No 200) sieve.

B. Minimum tests required on subgrade are listed in Section 2.06 - "Embankment Construction."

2.06.03 CONSTRUCTION

A. Subgrade in Cut

A.1 Where the subgrade is located in rock, the subgrade, unless shown otherwise on the Drawings, shall be undercut to a depth of 200 mm by drilling or blasting as directed. No rock shall project more than 50 mm above the undercut surface elevation. The subgrade layer shall then be constructed using approved subgrade material, as specified for subgrade in embankment.

A.2 Where the subgrade is on in situ soil which is of a quality and CBR value at least equal to those specified for subgrade, the 200 mm depth of such material immediately below top of subgrade shall be scarified and all roots, sod, vegetable and other undesirable matter and stones larger than 75 mm in any dimension shall be removed. The material shall then be brought to a uniform moisture content within the specified range and compacted to 100% AASHTO T 180 (Method D) maximum density.

A.3 Where the subgrade is on in situ soil which is unsuitable for retention as the subgrade layer, the 200 mm depth of such material immediately below the top of subgrade layer shall be subexcavated, hauled away and disposed of unless approved for use as embankment fill. The subgrade layer shall then be constructed using approved subgrade material, as specified for subgrade in embankment. If the material below sub-grade does not satisfy the requirement of top 60 cm, it shall be excavated for further 20 cm and replaced by suitable material to satisfy the requirements of subgrade.

A.4 The underlying natural material shall be scarified, leveled and rolled. The surface of the natural soil shall be approved by the Engineer before placement of suitable material.

B. Subgrade in Embankment

The 200 mm minimum depth of embankment immediately below top of subgrade shall

consist of selected, approved subgrade material. The material shall be spread in one layer over the full width of the top of embankment, brought to a uniform moisture content within the specified range and compacted to 100% AASHTO T 180 (Method D) maximum density.

C. Surface Tolerances

All finished elevations, lines and grades shall be in accordance with the details shown on the Drawings. Each cross section shall be checked at maximum intervals of 25 m, at each change in cross slope and elsewhere as directed.

The tolerances on elevations of finished subgrade, top of embankment under the subgrade layer and subexcavated (undercut) surface shall be as follows:

Finished Subgrade:	
Soil	+ 10 or-30 mm
Rock (if approved)	+ 50 or-50 mm
Top of Embankment or Subexcavated Surface:	
Soil	+ 10 or-30 mm

When the finished subgrade surface is tested with a 4 m long straightedge placed parallel to or at right angles to the centerline the maximum depression of the surface from the testing by straight edge shall be 30 mm.

D. Maintenance of Finished Subgrade

The finished and approved subgrade shall be continuously maintained in a smooth well compacted and properly drained condition until the sub-base (or base) course is constructed. Reapproval of the subgrade will be required if the overlying course is not constructed within 14 days of subgrade completion or if the subgrade layer is damaged by traffic or any other causes prior to the placement of the sub-base layer.

2.06.04 MEASUREMENT

Subgrade preparation shall be measured by square meter (m^2) for the construction of pavement in damaged sections, including trimming, scarifying, moisture conditioning, and compaction as required, to achieve the specified density and the required elevations, lines, and grades, all in accordance with the Contract Specifications and as directed by the Engineer.

PAY ITEM	UNIT OF MEASUREMENT
(1) Subgrade preparation	Square meter (m^2)

SECTION 2.07 NOT APPLICABLE

SECTION 2.08 STRUCTURAL EXCAVATION AND BACKFILL

2.08.01 SCOPE

These Works shall consist of all excavation in any material for bridges, underpasses and overpasses, for buildings and pump houses, retaining walls of all types; and for other major and minor structures, and including all necessary clearing and grubbing; bailing, drainage; pumping; sheeting, temporary shoring and cribbing, construction of temporary cofferdams or cribs; and disposal of all excavated material and backfilling with suitable approved material; all as and where shown on the Drawings. These works shall not include the excavation and filling for drainage, sewage and water pipe trenches.

These Works shall also include the removal of those portions of existing structures below ground which would in any way obstruct or interfere with construction of new structures.

The Contractor will be deemed to have satisfied himself, at the time of tendering, as to the type and nature of soils and rock that will be encountered in structural excavations.

2.08.02 EXCAVATION

A. General

The Contractor shall notify the Engineer a sufficient time in advance of the beginning of any excavation for structures so that the Engineer may, where necessary, survey and record the cross-sectional elevations and measurements of the existing ground and existing structures affected by the proposed structure. Any materials removed or excavated before these measurements have been taken and approved by the Engineer will not be paid for.

The Contractor shall be solely responsible for the safety at all times of all foundation and trench excavations whether supported or otherwise. Approval of the Contractor's support system or omission of a support system for any excavations shall not absolve the Contractor from his sole responsibility in this regard.

The Contractor shall take all necessary precautions, including shoring or otherwise to protect employees in the excavation and on the ground above. The Engineer will not enter excavated areas to approve the foundation and further Works until he deems the areas to be safe.

In areas where the excavation is adjacent to public roads and walkways, the Contractor shall erect all necessary barricades, barriers, enclosed walkways, and warning signs necessary to restrict the exposure of the public to the excavation. All such safety measures shall conform with the requirements of Section 6.10- “Maintenance of Traffic and Detours” and shall be subject to approval.

The sides of all foundation pits and trenches shallower than 1.5m shall be vertical and adequately supported at all times unless otherwise shown on the Drawings. Sides more than 1.5 m in depth shall be sloped at a safe slope or supported in an approved manner unless the material through which the pit or trench is cut is deemed to be sufficiently self supporting and not requiring support.

Pits and trenches shall be kept free from water until footing concrete has been placed or pipes have been installed. The Contractor shall minimize to the maximum extent practicable, the length of time excavated areas are open. The Contractor will be held responsible for damage due to weather, equipment, and other causes during periods when the excavations are left

open.

The Contractor shall schedule the Works so that no excavation is left in an exposed condition for a period greater than 30 days unless otherwise approved.

In areas where the excavation is adjacent to public highways and walkways, no excavation shall be scheduled to be left in an exposed condition for more than 7 days unless otherwise approved.

The Contractor must notify the Engineer of any sign of failure or cracks within or around the excavation immediately when such signs are noticed.

The Contractor shall schedule highway excavation and embankment and drainage works so that they complement each other. If the Contractor's earthwork progress exceeds the progress of the drainage construction to the point where the highway becomes a dam to cross drainage, the Engineer may order the Contractor to open adequate waterways through the highway at the locations where drainage structures are to be installed. Any damage to the highway caused by water passing through these openings shall be repaired at the Contractor's expense.

Exploratory trench excavation 1m deep and 2m wide shall be carried out across structure footings / pile caps either manually or using light equipment under the close supervision of the Engineer to check the existence of archaeological remains, prior to commencement of full scale structure excavation.

B. Temporary Support System

B.1 When a temporary support system is required to protect adjacent property or to protect the public during construction, the Contractor's design for such support system shall be submitted for approval prior to commencing its construction.

B.2 All temporary support systems shall be designed with adequate factors of safety to serve with minimal maintenance, for the duration of its intended use, and shall include adequate safety provisions to protect the public from construction activities.

B.3 Notwithstanding any approval of temporary support systems, the Contractor shall be solely responsible for the adequacy of their design and construction and for maintenance and all necessary safety precautions associated therewith.

C. Excavation for Bridges, Underpasses and Overpasses and Other Major Structures

C.1 The foundations for bridges, underpasses and overpasses, buildings, pump houses and other major structures, shall be excavated in accordance with the dimensions as shown on the Drawings and shall be of sufficient size to permit the placing of the full width and lengths of the footings.

C.2 The excavation shall be carried to the elevations shown on the Drawings or as established by the Engineer. Borings and soil tests, made during design, and actual investigation of the completed foundation excavation shall be utilized by the Engineer to determine final depth. No concrete shall be placed prior to approval of the excavation pit.

C.3 Unless shown otherwise on the Drawings, the bottom of all excavations shall be covered with a 75 mm minimum depth of lean (blinding) concrete class 110/25 to serve as a working platform.

C.4 Foundation pits or trenches shall be of sufficient size and provide minimum sufficient working space to permit construction of structures or structure footings of the full width and length shown on the Drawings.

C.5 Where footings are to be constructed using formwork, the excavations shall generally not extend more than 500 mm beyond the maximum dimension on each side of the proposed footing unless additional working space is clearly required and approved by the Engineer. Any unauthorized overwidth of excavation beyond the lateral limits shown on the drawings or approved by the Engineer shall be backfilled with selected fill or lean concrete as directed by the Engineer.

C.6 Where footings are to be located, in or adjacent to firm, original ground and where formwork is not required or ordered, any unauthorized overdepth excavation below the approved elevation of base of footing shall be backfilled with blinding concrete.

C.7 Where excavation to rock foundation is required, the excavation shall proceed in such a manner as to allow the solid rock to be exposed and prepared in horizontal beds or properly serrated for receiving the concrete. All loose and disintegrated rock and thin strata shall be removed.

C.8 All blasting necessary for any pier or groups of piers or abutment shall be performed prior to placing any concrete. Blasting will not be permitted in the vicinity of concrete which has not cured for at least 14 days.

C.9 When unstable material or other unsuitable material is encountered below foundation elevation, the Contractor shall excavate such material and replace it with suitable backfill material or concrete as directed by the Engineer or shown on the Drawings.

C.10 If temporary works are required for maintaining the excavation dry, the Contractor shall be responsible for the design and execution of the works. The proposed design shall be submitted to the Engineer for approval, however, such approval does not relieve the Contractor for his sole responsibility in this regard.

D. Excavation for box culverts, ducts and miscellaneous structures

D.1 Excavation shall be carried out to the limits required for construction and to the depth required for bedding material or removal of unsuitable material. All trench excavation shall proceed upgrade, commencing at the downstream end.

D.2 Foundation material supporting the bedding or structure shall be AASHTO M 145 Class A-l-a, A-l-b or A-2-4 compacted to 95% AASHTO T 180 maximum density. If the natural material does not meet the classification requirements, it shall be subexcavated to a depth of at least 200 mm and replaced with material meeting the specified requirements. Any rock or hard material within 200 mm of the bottom of the pipes shall be similarly subexcavated and replaced with material meeting the specified requirements.

D.3 If no special bedding material is required, the foundation for precast and prefabricated culverts shall be formed to the shape of the culvert, including all protrusions. The shaping shall extend to 25% of the height of culvert.

D.4 Where rock is encountered in the toe wall excavation for concrete box culverts or concrete, headwalls or endwalls for pipe culverts and the rock is of such quality as will prevent erosion, part of the toe wall may be eliminated in the rock strata as directed and the toe wall shall be keyed into the rock strata in a satisfactory manner.

D.5 When excavation is required for installation of ducts, the Contractor shall notify the Engineer upon completion of the excavation. No duct shall be laid until the depth and cross section of the excavation has been approved.

2.08.03 BACKFILLING

A. General

A.1 The Contractor shall obtain approval for his proposed method and rate of placing of backfill, before backfilling commences.

A.2 Backfill materials shall be uniformly graded granular material, capable of being compacted to required compaction, and having adequate permeability to permit free drainage through it. Backfill material shall also conform to the following:

- Minimum D10 value 1 mm
- Maximum Plasticity Index 10 per cent
- Requirement for bridges, etc. specified in subsequent sections.

A.3 Backfill material shall not be placed against any structure until approval is given. Unless otherwise shown on the Drawings structures shall be backfilled to the same requirements as specified for the adjacent embankment.

A.4 Backfill shall placed in level layers for the full width of the excavated area until the elevation of the original ground or surrounding embankment is reached. Backfill next to walls, between columns or in other confined areas, shall be compacted by approved hand or portable equipment.

A.5 Each successive layer of backfill shall contain only sufficient material to ensure proper compaction and in no case shall any layer be greater than 250 mm thickness (before compaction). The moisture content of the backfill material shall be uniform and within the moisture range designated.

A.6 Jetting of fills or other hydraulic methods involving or likely to involve liquid or semi-liquid pressure, will not be permitted.

A.7 Water shall be drained from the areas to be backfilled wherever practicable. In cases where, in the opinion of the Engineer, it is not practicable to drain the areas to be backfilled, the initial backfill material shall consist of crushed, open graded material conforming to the following gradation:

ASTM **Sieve Size**	**Percentage Passing**
3/8"	100
No. 4	< 85
No. 30	< 45
No. 200	< 5

Such material may be deposited below the standing water level without compaction. Above the water level normal laying and compaction shall be considered.

A.8 Additional water to be added during placement of backfill material to achieve required compaction shall be fresh water or brackish water approved by the Engineer.

A.9 Minimum tests required during backfilling operations to verify material are for each abutment, footing etc.

- One Proctor test

- One Gradation of Materials and at change of material or its source
- One Plasticity Index and field density for all compacted layers.

B. Backfilling for Bridges, Underpasses and Overpasses

B.1 Structures shall not be subject to the pressures of backfilling or to live loads until the 28-day strength of the concrete has been reached, unless a shorter period is approved in special circumstances where the load is sufficiently small as not to constitute a risk of any damage to the structure in the opinion of the Engineer. If approved this period may be extended if subnormal curing conditions exist.

B.2 Backfill placed around culverts, abutments and piers, shall be deposited on both sides to approximately the same elevation at the same time. Special care shall be taken to prevent any wedging action against the structure and slopes bounding the excavation shall be stepped, where necessary, to prevent such wedge action occurring.

B.3 All backfill intended to support falsework loads, including temporary fills and pier backfill, shall be designed for the minimum support required. As a minimum, such material shall be AASHTO M 145, Class A-l-a, A-l-b or A-2-4, compacted to 90% AASHTO T 180 maximum density.

B.4 Backfill material for bridge abutments and approach embankments within 20 m of any part of the substructure shall be AASHTO M 145, Class A-l-a, A-1-b or A-2-4 compacted to 95 % AASHTO T 180 maximum density up to the underside of the subgrade layer. The 200 mm minimum thickness of subgrade layer shall consist of approved subgrade material placed and compacted to 100 % maximum density as specified under Section 2.07 - "Subgrade Construction". The backfill shall be completed to the level of the original ground or to the top elevation of any adjacent embankment.

B.5 Backfill around retaining walls shall be completed to the level of the original ground line and to such heights above original ground line or to the levels as shown on the Drawings. Care shall be exercised to prevent forward movement of the wall.

B.6 Unless shown otherwise on the Drawings, when special permeable backfill (sheathing) is to be placed against the back faces of abutments, retaining walls or wing walls, it shall consist of a continuous covering of approved type proprietary filter cloth protected by a continuous wall of 200 mm minimum thickness precast porous(no-fines) concrete blocks laid in stretcher bond with dry joints. Prior to construction of the block wall, a Type 1 or Type 3 underdrain of at least 150 mm diameter shall be laid along the base of the wall under the sheathing in accordance with the relevant requirements of Section 6.04 - "Pipe Underdrains", where the materials for Type 1 and 3 underdrains are given.

C. Backfilling for Box Culverts, and Miscellaneous Structures

C.1 Backfill material for box culverts and miscellaneous structures within 300 mm of any part of the structure shall be Class A-l-a, A-l-b or A-2-4. Backfilling and construction of the subgrade layer shall be as specified for bridges, underpasses and overpasses.

C.2 Backfill around and over pipe culverts shall not commence until headwalls and wingwalls have been constructed and attained the specified 28-day strength.

C.3 Water used for compaction of backfill around metal pipes shall be from an approved source and shall not contain more than 0.5% combined chlorides and sulphates nor contain other potentially harmful minerals.

C.4 When pipes or other structures temporarily extend above the grade of the partially constructed embankment, the Contractor shall construct the fill over the structure of sufficient depth to protect the structure from any damage resulting from construction or other traffic.

C.5 In no case shall surplus material be dumped in stream channels.

C.6 The Contractor shall complete the backfill around box culverts to the level of the original ground line and to the full width of excavation area. If the top of culvert extends above the original ground line the Contractor shall continue the backfill to the top of culvert and for a width of 3 m on each side of the culvert for the full width of highway embankment. If the embankment is in place at the time of backfilling, the Contractor shall backfill around the culvert to the top of embankment.

C.7 Backfill around pipe culverts and storm drains shall be completed to the level of original ground line and to the full width of excavation area. If the top of the culvert extends above the original ground line the Contractor shall continue the backfill to the top of culvert for a width of 1.5 times the maximum external width of the culvert on each side of the culvert centerline to the full width of the highway embankment. If the embankment is in place at the time of backfilling, the Contractor shall backfill around the culvert to the top of culvert or as shown on the Drawings.

C.8 Any existing highway pavement cut through, damaged or removed during excavation for pipe culvert installation shall be reinstated, after pipe installation and trench backfilling, using approved base and surfacing course materials at least equivalent to those in the original pavement. Materials and construction shall conform with the relevant requirements of Section 4.10 - "Pavement Repairs and Trench Reinstatement Works".

C.9 Miscellaneous structures other than pipe culverts and storm drains shall be backfilled in accordance with the methods specified. Compaction of backfill when structures are outside the highway right-of-way or in approach roads, minor roads or similar areas, shall be to 90% AASHTO T 180 maximum density.

D. Permeable Drainage Layer to Abutment, Retaining Walls and Under Bases of Structures

D.1 The drainage layer shall consist of clean single size no lines gravel having a minimum size of 20mm and minimum thickness of 30mm.

2.08.04 MEASUREMENT

A. Structural backfilling shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Structural Excavation.

B. All structural excavation, of whatever type, shall be measured as "unclassified" which shall be deemed to include all materials encountered of any nature, including silts, clays, sand, gravel and granular materials and fractured, jointed and solid rock.

C. Structural Excavation for box culverts less than one sq.m in external cross section and structural excavation for pipe culverts, underdrains (subsoil drains), pits, catchbasins, manholes, inlets, energy dissipators, slope protection Works, fence posts, guardrail

posts, lighting columns, sign posts, signal supports and all other minor structures, shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Pay Items.

D. Structural Excavation shall be measured by cubic meter of material excavated for the major structures hauled away and disposed of as directed, or stockpiled on or in the vicinity of the Works, and the excavated areas backfilled, completed and accepted.

E. Measurement of structural excavation shall be of original ground elevations, or ground elevations after removal of all unclassified road excavation. Limits shall not be greater than vertical planes 500 mm from the maximum dimension, on each side of the footing or other controlling portion of the structure. Where structures are to be constructed against natural ground or rock, excavation limits shall be the dimensions of the structure as shown on the Drawings. Bottom limits shall be the ordered foundation elevations. Only material excavated from its original position shall be measured for payment. No measurements shall be made of structural excavation in embankments previously constructed by the Contractor.

F. Additional excavation in unstable material or other unsuitable material encountered below foundation level shall be measured as part of the unclassified structural excavation.

G. Unauthorized overdepth and overwidth excavation and the backfill material including blinding concrete required in such cases, shall not be measured for direct payment, but shall be considered as Subsidiary Works the costs of which will be deemed to be included in the Concrete Prices for Pay items.

H. Temporary cofferdams, temporary support system, bailing, drainage, pumping, sheeting, and all other Temporary Works shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Pay Items.

I. Permeable drainage layer (permeable backing) shall be measured by the cubic meter successfully placed and accepted.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Unclassified Structural Excavation	Cubic meter (m^3)
(2) Permeable Backing (specify thickness)	Cubic meter (m^3)
(3) Previous Backfill	Cubic meter (m^3)

SECTION 2.09 EXCAVATION AND FILLING FOR PIPE TRENCHES

2.09.01 EXCAVATION FOR PIPE TRENCHES

A. Excavating

Commencement: do not begin excavation of any section of work until a full supply of pipes and fittings is available for that section.

Trench width: (up to 300 mm above crown of pipe) is not to exceed the following:

- For pipes not exceeding 65 mm diameter: 300 mm
- For pipes over 65 mm and not exceeding 600 mm diameter: nominal diameter + 600 mm
- For pipes over 600 mm diameter: nominal diameter + 1000 mm.

Excessive trench width: bear the cost of increased pipe strength or additional pipe protection where required by the Engineer due to excavations being taken wider than specified.

Excessive trench depth: bear the cost of and backfill any excavations deeper than required with concrete, blinding grade unless otherwise instructed.

Battered sides: excavation with battered sides will not be permitted within 4m of any building or other structure.

Excavation in fill: embankments and other areas of fill are to be filled and compacted as specified to a height of at least 600 mm above top of pipe prior to trench excavation.

Excavation in existing pavements: to be executed carefully and to minimum widths. Use methods which will give a straight and vertical face and maintain pavement at original level and condition.

Combined trenches: where one pipe is at a lower level than an adjacent pipe in a common trench:

- The whole trench is to have a depth related to the lower pipe, with increased thickness of bedding to upper pipe as necessary.
- Lower pipe is to be backfilled with thoroughly compacted granular material up to a level of 0.30 meters above the higher pipe.

Formation for beds generally:

- Excavate immediately before laying beds or pipes
- Remove unstable material, rock projections, boulders and hard spots and replace with approved filling material that will be compacted as instructed.
- Harden local soft spots by tamping in bedding material.

Formation in rock: excavate to 150 mm below bed level and replace with granular material or concrete, blinding grade as directed.

Subsoil for filling: stockpile excavated subsoil required for backfilling in temporary spoil heaps along sides of excavations or elsewhere on the Site as instructed.

2.09.02 BACKFILLING FOR PIPE TRENCHES

A. Filling materials

A.1 Initial backfill: selected fill, sand or other approved material conforming to the following:

Standard Sieve Size (mm)	Percent by weight passing for UPVC for A/C and other pipe	Percent by weight passing for UPVC pipes
19.00	100	-
4.76	25-100	100
1.19	10-75	25-75
0.354	5-30	10-30
0.177	3-10	3-10
0.074	0-5	0-5

For GRP pipes graded crushed stone 2.83-8 mm shall be used for initial backfilling.

B. Workmanship: Backfilling

B.1 Initial backfill: where pipe surround does not extend up to a level 300 mm above top of pipe, backfill to that level with initial backfill laid and hand compacted in 150 mm layers.

B.2 Main backfill: material excavated from the trench, unless specified otherwise is to be with a maximum size of 75 mm, laid and well compacted in layers not exceeding 300 mm thick. Do not use heavy compactors until there is 600 mm cover over pipes.

B.3 Concrete: when backfilling to pipes with concrete beds and surrounds, do not start backfilling within 24 hours of placing concrete. Do not use heavy compactors and prevent traffic loads within 72 hours of placing concrete.

B.4 Temporary crossing are to be provided over trenches to prevent construction traffic damaging pipes after backfilling.

C. Restoration of surfaces

C.1 General: restoration of asphalt, concrete and gravel pavements and the likes are to be some materials and thickness to match the existing pavement. Materials and workmanship are to be in accordance with local authority requirements and as directed by the Engineer.

C.2 Restoration of pavement: repave according to the existing pavement quality and level and ensure that new pavement is matching to provide a uniform surface with the existing profile.

C.3 Restoration of grassed areas: after backfilling, spread approved fertile soil over affected area and seed, fertilize and water until grass is restored to its former condition.

C.4 Restoration of unsurfaced areas: after backfilling, grade surface and any adjoining areas disturbed to provide a level, smooth surface.

C.5 Proceed with restoration of surfaces as soon after completion of other work as is

practicable, but in no case more than 10 days after backfilling of trenches and other excavated areas and complete within a further 20 days.

2.09.03 MEASUREMENT

A.1 Unclassified trench excavation for gravity pipe networks (excluding pipe culvert crossings under roadways) shall be paid for per meter cube measured in horizontal layers for the different depth categories shown in the Bill of Quantities. Trench length shall be measured between outer surfaces of manholes. Trench width shall be as shown on Drawings. Depth of excavation shall be the depth of every horizontal layer.

A.2 Unclassified trench excavation for pressure pipes shall be paid for per meter cube measured in depth categories as shown in the Bill of Quantities. Trench width and depth as shown on Drawings.

A.3 Soil support system for pipe trenches shall be paid for by square meter of supported trench edges, measured from top of the trench, after deducting the highway excavation till bottom of excavation- Type of support and location shall be determined and approved by the Engineer.

A.4 Notwithstanding any approval of temporary support Systems, the Contractor shall be solely responsible for the adequacy of their design, construction, maintenance and all necessary safety precautions associated therewith.

A.5 Removal of pavement layers above pipe trenches shall be paid for under highway excavation as detailed in Section 2.03.

A.6 Rates for unclassified trench excavation shall include for:

Excavation in any material encountered,

Blasting, barring, wedging or other quarrying methods for rock excavation,

Excavation at any level and to any depth,

Excavating curved on plan,

Allowance for working space,

Increase in bulk for excavating,

Excavating below water table and dewatering as necessary,

Keeping excavations free from water,

Leveling, ramming, trimming and grading bottoms and trimming sides and bottoms of excavation,

Planking and strutting and supporting the sides of excavation, except where included as a separate pay item in BOQ,

Returning, filling and ramming selected excavated material around foundations, multiple handling of excavated material and excavation from borrows and transporting about the site,

Segregation of the various classes of excavated spoil and stock piling as may be directed by the engineer,

Disposal of unsuitable material or surplus excavated material including depositing and consolidating where directed on site or removing from site and depositing at a tip to be provided and paid for by the contractor.

Pipe bedding and surround (primary backfill) and final backfill,

Filling over-excavation,

Consolidation of surround (initial backfill) material using water or hand tamping,

Compaction of secondary backfill (main backfill) material,

Reinstatement of road surfaces. Width of surfaces reinstatement shall be the trench width plus one (1.0) meter.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Trench Excavation for Pipes	Cubic meter (m^3)

SECTION 2.10 NOT APPLICABLE

SECTION 2.11 NOT APPLICABLE

DIVISION 3

SUB-BASE AND BASE COURSES

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SECTION 3.01 MATERIALS FOR SUB-BASE AND BASE COURSES

3.01.01 SCOPE

A. Materials specified for use in the construction of the sub-base and base courses for flexible and rigid pavements, may include any or all of the following :

- Granular screened material, or partially crushed of approved classes, consisting of well graded gravel including sand and silt, or crushed stone or crushed gravel for sub-base course construction.
- Crushed stone, of approved classes, for base course construction.
- Stabilizing materials including Portland cement, bitumen and lime, used where specified in sub-base and base courses (and in subgrades).

B. All material sources and the quality of materials proposed for use in the Works shall be approved prior to procuring or processing material from such sources. Inspection, sampling, testing and retesting as necessary, shall be at the Contractor's expense as prescribed in Part 1- Section 4-6 “Samples and Approvals” of the specifications, and as specified hereunder for specific materials.

C. Storage and handling of all materials shall conform with the relevant requirements of part 1 of specifications, Section 4-6 “Samples and Approvals”. Materials shall be stored on hard, clean surfaces or as directed by the Engineer.

3.01.02 GENERAL

A. Sources and Production

A.1 Locating sources and manufacturers of materials in accordance with the requirements of the Specifications are the responsibility of the Contractor who shall produce the required granular materials and aggregates at the rates and in the quantities necessary to complete the Works on time.

A.2 The Contractor shall have satisfied himself as to the location, suitability and quantity of materials available; extent of work necessary to obtain the material available; the work required to open the quarry and to crush, screen and wash the materials, and the length of haul to the Site.

A.3 Prior to starting quarry or borrow pit operations, the Contractor shall obtain written permission from the Authorities or Owners concerned.

A.4 Screening plants or crushing and screening plants shall not be put into operation prior to their approval. If, after any plant is put into operation, it fails to perform as intended, the Contractor shall either rectify the defects in the existing plant to the satisfaction of the Engineer, or shall provide alternative approved plant.

A.5 Approval of the crushing and screening plants and other equipment shall in no way relieve the Contractor of his responsibilities in respect of producing granular materials and aggregates which conform to the Specifications and in the quantities required for the completion of the Works on time.

B. Stockpiling

B.1 Stockpile areas shall be surveyed prior to stockpiling to establish control points and to obtain a record of existing cross sections for future use in determining stockpile quantities. The areas shall be adequately drained at all times.

B.2 Stockpiling procedures shall not result in noticeable degradation or segregation of the stockpiled material, or introduction of foreign materials into the stockpile, or coning. Heights of granular material and aggregate stockpiles shall not exceed 3m berms.

C. Sampling and Testing

C.1 Sampling and testing procedures shall conform with the relevant requirements of Part 1- Section 4-6 “Samples and Approvals” of the specifications, and with the following requirements.

C.2 The Contractor shall submit to the Engineer, 10 days prior to the scheduled beginning of crushing and screening operations, a statement of origin and composition of all stone and/or gravel aggregates and granular materials proposed for use in the Works.

C.3 In order to ascertain the properties of granular and aggregate materials, the Contractor shall submit for testing and approval, representative samples of all materials intended for incorporation in the Works, prior to starting quarry or borrow pit operations. The representative samples shall be taken by the Contractor in the presence of the Engineer.

C.4 Tests performed by the Contractor shall be ulilized in assessing the locations, extent of deposits and quantities of materials which will conform to the specifications when properly processed, and shall in no way obviate the need for further testing by the Engineer. Approval of specific sources of materials shall not be construed as final approval and acceptance of materials from such sources.

C.5 The Contractor shall conduct necessary tests in the Field Laboratory in the presence of the Engineer and the Contractor's Materials Engineer.

C.6 Processed materials shall be tested and approved before being stockpiled on Site or incorporated in the Works and may be inspected and tested at any time during their preparation, storage and use. Questionable materials, awaiting testing and approval, shall not be unloaded and mixed with materials previously approved. If the grading and quality of any materials delivered to the Site do not conform to the grading and quality of the established control samples, the Engineer will reject such materials.

C.7 Samples shall satisfy all specified test requirements. The Contractor shall permit the Engineer to inspect any and all materials used or to be used, at any time during or after their preparation, or while being used during progress of the Works. Unsatisfactory materials, whether in place or not, shall be removed promptly from the Site. The Contractor shall furnish all necessary labor, transport, tools and equipment required by the Engineer for such inspections.

3.01.03 GRANULAR MATERIAL FOR SUB-BASE

A. Granular material for use in sub-base courses, shall be a naturally occurring gravel, blended as necessary with fine or coarse material and screened to produce the specified gradation. Crushing of natural granular material shall not normally be required, unless for the purpose of meeting the gradation requirements, or when shown on the Drawings

(to produce a higher quality sub-base with improved mechanical stability).

B. Gravel shall consist of hard, durable and sound stones, free from dirt, organic matter, shale or other deleterious substances.

C. Granular materials delivered to the road site shall meet the requirement of class A or B as shown in table 3.1.1, when tested in accordance with AASHTO T-27 after dry mixing and just before spreading and compacting. The Class of granular material to be used shall be as shown on the Drawings or otherwise as selected by the Engineer. The actual gradation shall, in all cases, be continuous and smooth within the specified limits for each Class.

Table 3.1.1: Gradation of Granular Material by Class

Sieve Designation (square openings)	**Percent by weight passing**	
	Class A	**Class B**
50 mm (2 in .)	100	100
25 mm (1 in.)	-	75 - 95
9.5 mm (3/8 in.)	30 - 65	40 - 75
4.75 mm (No. 4)	25 - 55	30 - 60
2.00 mm (No. 10)	15 - 40	20 - 45
0.425 mm (No. 40)	8 - 20	15 - 30
0.075 mm (No . 200)	2 - 8	5 - 20

D. The material shall contain a maximum of 5% clay content at any stage of construction when tested in the Hydrometer Test in accordance with AASHTO T88.

E. The loss in weight of granular material shall not exceed 50% after 500 revolutions, when tested in accordance with AASHTO T 96 (Los Angeles Abrasion Test).

F. The granular material shall have a 4-day soaked CBR of not less than 30 when compacted at 100% of modified proctor AASHTO (T 180-D) and tested in accordance with AASHTO T 193.

G. When tested for soundness in accordance with AASHTO T 104, the material shall not show signs of disintegration and the percentage loss in weight after 5 cycles shall not exceed 12 % in the case of the sodium sulfate test and 18% in the case of the magnesium sulfate test.

H. The portion of granular material, including any blended material, passing the 0.425 mm (No. 40) mesh sieve shall have a liquid limit (L.L.) of not more than 25 and a plasticity index (P.I.) not greater than 6 when tested in accordance with AASHTO T 89 and T 90.

I. If additional fine material is required to correct the gradation the granular material, or for adjusting the L.L. or P.I. of the fraction passing 0.425 mm (No 40) sieve, it shall be uniformly blended and mixed with the granular material. Additional fine material for these purposes shall be obtained from the crushing of stone, gravel, or slag, if naturally occurring fine material is not available.

3.01.04 AGGREGATE FOR BASE COURSES

A. Aggregate for use in base course construction shall be either crushed stone or crushed gravel. The time aggregate shall consist of screenings obtained from crushed stone, gravel, or sand. Aggregate may be washed, if directed, to remove excessive quantities

of clay, silty clay or salts.

B. Crushed stone shall consist of hard, durable particles or fragments of stone, free from dirt or other objectionable matter and shall contain not more than 8% of flat elongated, soft, or disintegrated pieces.

C. Crushed gravel shall consist of hard durable stones, rocks, and boulders crushed to specified sizes and shall be free from excess fault, elongated, soft or disintegrated pieces, dirt, or other objectionable matter.

D. The method used in production of crushed gravel shall be such that the finished product shall be as uniform as practicable. The crushing of the gravel shall result in a product, which shall have at least 90% by weight of particles with at least one fractured face. All stones, rocks, and boulders of inferior quality occurring in the pit shall be wasted.

E. Any material passing 4.75 mm (No. 4) sieve and produced in the crushing process shall be incorporated in the base material up to the gradation limits required for the base course aggregate.

F. Crushed aggregate for base course delivered to road site shall meet the requirements of Class A or Class B gradations as shown in Table 3.1.2 when tested in accordance with AASHTO T 27 after mixing with water and just before spreading and prior to compacting. The Class of aggregate to be used shall be as shown on the Drawings or otherwise as selected by the Engineer. The actual gradation shall, in all cases, be continuous and smooth within the specified limits for each Class. Gap graded aggregate will not be accepted. If gradation is tested after compaction a tolerance of 3% is allowed in upper limit for percentage of material passing sieve 200.

Table 3.1.2: Gradation of Base Course Aggregate by Class

Sieve Designation (square openings)	**Percent by weight passing**	
	Class A	**Class B**
50 mm (2 in .)	100	-
25 mm (1 in.)	75 - 95	100
9.5 mm (3/8 in.)	40 - 75	50 - 85
4.75 mm (No. 4)	30 - 60	35 - 65
2.00 mm (No. 10)	20 - 45	25 - 50
0.425 mm (No. 40)	15 - 30	15 - 30
0.075 mm (No . 200)	5 - 20	5 -15

G. The amount of the fraction of material passing the No 200 mesh sieve shall not exceed one half the fraction passing the No. 40 mesh sieve.

H. The loss in weight shall not exceed 30% after 500 revolutions and the Sand Equivalence shall exceed 50, when respectively tested in accordance with AASHTO T 96 (Los Angeles Abrasion Test) and T176 (Sand Equivalence).

I. The crushed aggregate base course material shall have a 4-day soaked CBR of not less than 80 when compacted at 100% of modified proctor AASHTO (T 180-D) and tested in accordance with AASHTO T 193.

J. When tested for soundness in accordance with AASHTO T 104, the material shall not show signs of disintegration and the loss by weight shall not exceed 12% in the case of the sodium sulfate test and 18% in the case of the magnesium sulfate test.

K. The portion of aggregate, including any blended material, passing the 0.425 mm (No. 40) mesh sieve shall have a liquid limit (L.L.) of not more than 25 and plasticity index (P.I) of not more than 6 when tested in accordance with AASHTO T 89 and T 90.

L. If additional fine material is required to correct the aggregate gradation, or for adjusting the L.L. or P.I. of the fraction passing the 0.425 mm (No. 40) sieve, it shall be uniformly blended and mixed with the aggregate material plant at the crusing plant or by an approved plant. Reworking of the material in situ to obtain the specified gradation will not be permitted. Additional fine material for these purposes shall be obtained from the crushing of stone, gravel, or natural material.

3.01.05 STABILIZING AGENTS

A. Cement as Stabilizing Agent

Cement shall be Portland cement conforming to AASHTO M 85 Type 11, or sulfate resistant Portland cement conforming to AASHTO M 85, Type V.

B. Bitumen as Stabilizing Agent

B.1 Bitumen may include straight run (penetration grade) bitumen; RC cutback bitumen, MC cutback bitumen, or cationic emulsified bitumen. Penetration grade, cutback bitumen and emulsified bitumen shall conform with all relevant requirements herein.

B.2 The selection of a suitable bitumen will depend on the properties of the material to be stabilized and shall be subject to laboratory and field trials by the Contractor, under the supervision of the Engineer.

B.3 When the material moisture content is high and material must be dried, the use of penetration grade bitumen or viscous cutback bitumen and plant mixing of materials are appropriate.

B.4 When the natural moisture content of the material is low, cutback bituminous or emulsified bitumen are appropriate.

C. Lime as Stabilizing Agent

C.1 Hydrated lime (calcium hydroxide) and quicklime (calcium oxide) shall conform to AASHTO M 216 Mixing of different brands of lime or use of lime from different mills will not be permitted.

C.2 Lime slurry shall be a homogeneous pumpable mixture of lime and water. Slurry shall be a premixed material in which the lime solids content shall be not less than 30 % by weight.

3.01.06 MEASUREMENT

Granular, aggregate and stabilized materials for Sub-base and Base Courses shall be measured as prescribed in the appropriate Sections of these Specifications.

SECTION 3.02 GRANULAR SUB-BASE COURSE

3.02.01 SCOPE

These Works shall consist of furnishing granular sub-base material of the required Class, mixing, spreading on prepared subgrade, compacting and finishing, all as and where shown on the Drawings

3.02.02 MATERIALS

All materials shall conform with the relevant requirements of Section 3.01 - "Materials for Sub-base and Base Courses", in respect of granular material for sub-base construction.

3.02.03 SUBGRADE SURFACE PREPARATION

A. The subgrade shall have previously been constructed in accordance with the requirements of Section 2.06 - "Subgrade Construction" and properly maintained and kept well drained thereafter.

B. At all special grade control points, such as at bridge structures, existing pavements, etc. the subgrade shall be lowered to a depth sufficient to permit construction of the sub-base course to the specified elevations and thickness. Transitions shall be of sufficient length to avoid abrupt changes of grade and shall be within plus or minus 3 % of the final design grade unless otherwise directed. Surplus material shall be removed and disposed of.

C. The subgrade shall be inspected and approved immediately prior to commencement of sub-base construction. Any soft, yielding material shall be removed and replaced by approved topping material. Holes, depressions and other irregularities shall be made good as directed and the subgrade recompacted as necessary and finished ready to receive the sub-base course.

3.02.04 EQUIPMENT

Equipment used to handle, place, spread, water, compact and finish sub-base shall conform with the requirements of Part 1 of specifications - Section 4-4 "Contractor’s Plant and Equipment" and with the Contractor's approved Work Program.

3.02.05 CONSTRUCTION OF TRIAL SECTIONS

A. If directed by the Engineer, before commencement of sub-base construction, the Contractor may be required to lay and compact trial sections of varying thickness of sub-base. Each trial section shall be 2 lanes wide by 50 m long, at approved locations on or close to the Site. Each trial section shall be laid using the same materials, mix proportions, mixing, spreading and compaction equipment, and construction procedures, proposed for use in the Works.

B. The objectives of these trials shall be to determine the adequacy of the Contractor's equipment, the loose depth measurements that will 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 sub-base material.

3.02.06 CONSTRUCTION

A. Stockpiling of Granular Material

A.1 Stockpiling procedures shall conform with the relevant requirements of Section 3.01 - "Materials for Sub-base and Base Courses".

A.2 Methods used for stockpiling granular material and removing it from stockpiles shall not result in significant degradation or segregation nor the introduction of significant amounts of foreign materials or extraneous matter.

A.3 Granular material adversely affected in the opinion of the Engineer by stockpiling or handling procedures, shall not be incorporated in the Works regardless of previous approval of such material, until the deficiencies have been rectified in an acceptable manner.

B. Mixing and Spreading

B.1 All components of sub-base course material shall be mixed thoroughly and uniformly with water in situ. The amount of water added, as approved by the Engineer, shall be such that the material will be uniform and within the specified moisture content range at the time of compaction. Wetting of granular material in stockpiles or in trucks before or during delivery to the Site will not be permitted. However, water shall be added to the material, if necessary, during placing and compaction of sub-base material.

B.2 The sub-base material shall be placed on the subgrade in a uniform layer or layers not exceeding 200 mm thickness (after compaction). Where the required uncompacted thickness is greater than 250 mm but less than 500 mm the material shall be placed in layers of equal thickness.

B.3 If approved heavy duty vibratory compaction equipment is used the maximum layer thickness may be increased up to 300 mm (after compaction) provided compaction tests with appropriate testing equipment indicate that the specified compaction standard will be attained and uniform through the thickness.

B.4 The sub-base material shall be placed to the required width using a self-propelled spreader or a motor grader equipped with blade extensions. Water shall be applied by approved spraying equipment and thoroughly mixed with the sub-base material.

B.5 The material shall not be handled in such a way as to cause segregation. If the spreading equipment causes segregation in the material or leaves ridges or other objectionable marks on the surface which cannot be readily eliminated or prevented by adjustment of the equipment the use of such equipment shall forthwith be discontinued and it shall be replaced by a spreader or grader capable of spreading the material in a proper manner.

B.6 All segregated material shall be removed and replaced with well-graded material. "Skin" patching will not be permitted. Only minor surface manipulation and watering to achieve the required surface tolerances will be permitted during the compaction process.

B.7 Neither hauling nor placement of material will be permitted when, in the judgment of the Engineer the weather or surface conditions are such that hauling operations will cause cutting or rutting of the subgrade or cause contamination of the sub-base material.

C. Compaction

C.1 The Contractor shall plan the sequence of 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 material to the extent that additional water is required to prevent raveling or excessive drying the application of such water shall be carried out as directed and at the Contractor's expense.

C.2 The sub-base material shall be compacted by means of approved compaction equipment, progressing gradually from the outside towards the center, with each succeeding pass uniformly overlapping the previous pass.

C.3 Rolling shall continue until the entire thickness of each sub-base layer is thoroughly and uniformly compacted to 100 % AASHTO T 180 (Method D) maximum density. Final rolling of the completed course shall be by means of an approved self-propelled roller. Rolling shall be accompanied by sufficient blading, to insure a smooth surface, free from ruts or ridges and having the proper shape. When additional water is required, it shall be applied in an approved manner.

C.4 Any areas inaccessible to normal compaction equipment shall be compacted by use of portable mechanical tampers until the required standard of compaction is achieved.

C.5 Each layer shall be completely compacted and approved prior to delivery of materials for the subsequent layer.

C.6 Prior to placing a subsequent layer, the existing surface shall be made sufficiently moist as directed, to ensure proper bond between the layers.

C.7 The edges and edge slopes of the sub-base course shall be bladed or otherwise dressed to conform to the lines and dimensions shown on the Drawings and to present straight, neat lines and slopes as free of loose material as practicable.

C.8 Material which has dried out prior to final compaction, or which has dried and decompacted subsequent to final compaction, shall be watered and recompacted using approved equipment and procedures. If the Contractor is unable to return the material to its original or specified condition with respect to compaction, thickness and surface tolerances, the Contractor shall remove the material and reconstruct the sub-base course on a reapproved subgrade.

D. Tolerances

D.1 The fully compacted and completed sub-base course shall conform to the lines, grades and cross sections as shown on the Drawings.

D.2 The elevations of the finished sub-course shall be checked by the Contractor in the presence of the Engineer at maximum intervals of 10 m and at intermediate points as directed.

D.3 The tolerances on elevations of finished surface shall be plus 10 mm to minus 20 mm, minus tolerance shall be compensate by the proceeding layer.

D.4 When the finished surface is tested with a 3 m long straightedge, placed parallel to, or at right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 10 mm.

D.5 All areas which exceed the specified tolerances shall be corrected by removing the defective sections of sub-base and reconstructing them or, if approved, by adding new material mixing and recompacting and finishing to the specified standard.

E. Maintenance of Completed Sub-base

Following completion and acceptance of the sub-base course, it shall be maintained by the Contractor at his own expense. The sub-base shall be bladed, broomed and otherwise maintained, keeping it free from raveling and other defects until such time as the base course is placed. Water shall be applied at such times and in such quantities as directed by the Engineer.

3.02.07 TESTING

A. Every 500 lin.m of sub-base material or whenever there is a change in the material source shall be subject to a full set of tests after mixing in situ and, if found satisfactory, shall be approved for compaction. This approval shall not be deemed to constitute acceptance of the sub-base course.

B. Sampling and testing shall conform with the relevant requirements of part 1 of specifications Section 4-6 “Samples and Approvals”.

C. Compaction shall be tested in accordance with AASHTO T 191 or AASHTO T 205. If there is a delay between the construction of any layer and the following layer, if necessary and required by the Engineer the compaction of the lower layer may be reverified to ensure that it has not loosened due to traffic, passage of construction equipment, adverse weather conditions or otherwise.

3.02.08 MEASUREMENT

A. Granular Sub-base Course shall be measured by cu. m of granular material furnished, screened, crushed if so specified, mixed with water, placed, spread, compacted and finished, completed, and accepted. Measurements shall be of volumes computed from the cross sections shown on the Drawings and of the. field measurements of area and compacted depth of each Trial Section.

B. No measurement shall be made for direct payment of overdepth construction, regardless of the Engineer's permission for it to remain in place.

PAY ITEM	UNIT OF MEASUREMENT
(1) Granular Sub-base Course	Cubic meter (m^3)

SECTION 3.03 AGGREGATE BASE COURSE

3.03.01 SCOPE

These Works shall consist of furnishing crushed aggregate base course material of the required Class, mixing, spreading on prepared sub-base course, compacting and finishing, all as and where shown on the Drawings.

3.03.02 MATERIALS

All materials shall conform with the relevant requirements of Section 3.01 - "Materials for Sub-base and Base Courses", in respect of crushed aggregate for base course construction.

3.03.03 SURFACE PREPARATION

A. Where a sub-base course is present, it shall have previously been constructed in accordance with the requirements of Section 3.02 - "Granular Sub-base Course" and properly maintained and kept well drained thereafter.

B. The sub-base surface shall be inspected and approved prior to commencement of base construction. Holes, depressions and other irregularities shall be made good as directed and the sub-base recompacted as necessary and finished ready to receive the base course.

C. Where sub-base course is omitted in the contract drawing and the aggregate base course is placed directly on completed sub-grade, preparation of the sub-grade surface shall be as specified in Section 3.02 - "Granular Sub-base Course".

3.03.04 EQUIPMENT

Equipment used to handle, place, spread, water, compact and finish base course shall conform with the requirements of specifications Part 1 - Section 4-4 - "Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

3.03.05 CONSTRUCTION OF TRIAL SECTIONS

A. If the Engineer deems it necessary the Contractor shall lay and compact trial sections of varying thickness of base. Each trial section shall be 2 lanes wide by 50 m long, at approved locations on or close to the Site. Each trial section shall be laid using the same materials, mix proportions, mixing, spreading and compaction equipment, and construction procedures, proposed for use in the Works.

B. The objectives of these trials shall be to determine the adequacy of the Contractor's equipment, the loose depth measurements that will result in the specified compacted layer depths, the field moisture content for compaction, and the relationship between the number of compaction passes and the resulting density of the base course material.

3.03.06 CONSTRUCTION

A. Stockpiling of Aggregate Materials

A.1 Stockpiling procedures shall conform with the relevant requirements of Section 3.01 - "Materials for Sub-base and Base Courses".

A.2 Methods used for stockpiling aggregate materials and removing them from stockpiles shall not result in significant degradation nor the introduction of significant amounts of foreign materials or extraneous matter.

A.3 Aggregate materials adversely affected, in the opinion of the Engineer, by stockpiling or handling procedures, shall not be incorporated in the Works regardless of previous approval of such material, until the deficiencies have been rectified in an acceptable manner.

B. Mixing and Spreading

B.1 All components of base course material may be premixed with water, in a pugmill mixing plant or on site. The amount of water added, as determined, shall be such that the material will be uniform and within the specified moisture content range at the time of compaction. The Engineer may allow other methods of mixing provided such method(s) do not reduce the standard of work. The Contractor will be required to demonstrate, in the presence of the Engineer, his ability to attain the requirement given in this Specification.

B.2 The premixed material shall be placed on the sub-base in a uniform layer or layers not exceeding 250 mm in thickness (before compaction). Where the required uncompacted thickness is greater than 250 mm but less than 500 mm, the material shall be placed in layers of equal thickness.

B.3 If approved, heavy duty vibratory compaction equipment is used, the maximum layer thickness may be increased up to 350 mm(after compaction) provided compaction tests indicate that the specified compaction standard will be attained.

B.4 The base course material shall be placed to the required width using a self-propelled spreader or motor grader, and shall be delivered such that it is ready for compaction without further shaping.

B.5 The material shall not be handled in such a way as to cause segregation. If the spreader causes segregation in the material, or leaves ridges or other objectionable marks on the surface which cannot be readily eliminated or prevented by adjustment of the spreader operation, the use of such spreader shall forthwith be discontinued and it shall be replaced by a spreader capable of spreading the material in a proper manner.

B.6 All segregated material shall be removed and replaced with well-graded material. "Skin" patching will not be permitted. Only minor surface manipulation and watering to achieve the required surface tolerances will be permitted during the compaction process.

B.7 Hauling; or placement of material will not be permitted when, in the judgment of the Engineer, the weather or surface conditions are such that hauling operations will cause cutting or rutting of the sub-base or sub-grade or cause contamination of the base course material.

C. Compaction

C.1 The Contractor shall plan the sequence of 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 material to the extent that additional water is required to prevent raveling or excessive drying, the application of such water shall be carried out in an approved manner and at the Contractor's expense.

C.2 The base course material shall be compacted by means of approved compaction equipment, progressing gradually from the outside towards the center, with each succeeding pass uniformly overlapping the previous pass.

C.3 Rolling shall continue until the entire thickness of each base layer is thoroughly and uniformly compacted to 100% AASHTO T 180 (Method D) maximum density. Final rolling of the completed course shall be by means of an approved self-propelled roller. Rolling shall be accompanied by sufficient blading, to ensure a smooth surface, free from ruts or ridges and having the proper shape. When additional water is required, it shall be applied in an approved manner.

C.4 Any areas inaccessible to normal compaction equipment shall be compacted by use of portable mechanical tampers until the required standard of compaction is achieved, or to the satisfaction of the Engineer.

C.5 Each layer shall be completely compacted and approved prior to delivery of materials for the following layer.

C.6 Prior to placing a following layer, the surface shall be made sufficiently moist as directed, to ensure proper bond between the layers.

C.7 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 Drawings and to present straight, neat lines and slopes as free of loose material as practicable.

C.8 Material which has dried out prior to final compaction, or which has dried and decompacted subsequent to final compaction, shall be watered and recompacted using approved equipment and procedures. If the Contractor is unable to return the material to its original or specified condition with respect to compaction, thickness and surface tolerances, for the final layer only the Contractor shall scarify the material and reconstruct the base course on a re-approved sub-base surface or to the satisfaction of the Engineer.

D. Tolerances

D.1 The fully compacted and completed base course shall conform to the lines, grades and cross sections as shown on the Drawings.

D.2 The elevations of the finished base course shall be checked by the Contractor in the presence of the Engineer at intervals of 20m on straight lines and of 10 m on curves and at intermediate points as directed.

D.3 The tolerances (for final layer only) on elevations of finished surface shall not exceed + 10 mm or -15 mm.

D.4 When the finished surface is tested with a 4 m long straightedge, placed parallel to, or right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 12 mm.

D.5 All areas which exceed the specified tolerances shall be corrected by removing c defective sections of base course and reconstructing them or, by scarifying and adding new material and recompacting and finishing to the specified standard.

E. Maintenance of Completed Base

Following completion and acceptance of the base course it shall be maintained by the Contractor at his own expense. The surface shall be broomed rolled and otherwise maintained keeping it free from raveling and other defects until such time as the following course is placed. Water shall be applied at such times and in such quantities as directed.

3.03.07 TESTING

A. Sub-Base and Base course material shall be tested in accordance with Table 3.3.1 after mixing with water at the mixing plant or in-situ compaction and if satisfactory shall be approved for use. This approval shall not be deemed to constitute acceptance of the base course for full payment purposes.

B. Sampling and testing shall conform with the relevant requirements of specifications Part 1 - Section 4-6 Samples and Approvals.

C. Compaction shall be tested in accordance with AASHTO T 191, AASHTO T 205 or any acceptable method. If there is a significant delay between the construction of any layer and the following layer, the Engineer may require the compaction of the lower layer to be reverified to ensure that it has not loosened due to traffic, passage of construction equipment, adverse weather conditions or otherwise.

Table 3.3.1: Required Tests and Minimum Repetition for Base course Material

Source of Materials		Control on Site (The Road)	
Required Tests (A)	**Repetition Required for all Tests in (A)**	**Required Tests (B)**	**Repetition Required for all Tests in (B)**
1. Gradation of Materials	• Test for each source	1. Proctor	• Test for every 500 LM for each layer
2. Plasticity Index	• For every 2000 m3	2. Gradation of Materials	• When Materials changed
1. Abrasion	• When Materials changed	3. Plasticity Index	
2. C.B.R.		4. C.B.R	
3. Sand equivalent		5. Abrasion	
4. Percentage of fractured Grains/Base course		6. Sand equivalent	
		7. Clay lumps & friable particles	
		8. Field Density	
		9. Thickness	• Test for every 2000 m^2 and for every layer

3.03.08 MEASUREMENT

A. Aggregate Base Course shall be measured by m^3 of aggregate materials furnished, crushed and screened, mixed with water, placed, spread, compacted and finished, completed, and accepted. Measurements shall be of volumes computed from the cross sections shown on the Drawings and of the field measurements of area and compacted depth of each Trial Section. Aggregate Base Course for temporary Diversions shall not be measured for direct payment, but shall be considered as Subsidiary Works the cost of which will be deemed to be included in the Contract prices for the Pay Items.

B. No measurement shall be made for direct payment of overdepth construction, regardless of the Engineer's permission for it to remain in place.

PAY ITEM	UNIT OF MEASUREMENT
(1) Aggregate Base Course	Cubic meter (m^3)

DIVISION 4

BITUMINOUS CONSTRUCTION

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REFERENCE STANDARDS AND SPECIFICATIONS

AASHTO M17	……	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
AASHTO M20	……	Standard Specification for Penetration-Graded Asphalt Cement
AASHTO M81	……	Standard Specification for Cutback Asphalt (Rapid-Curing Type)
AASHTO M82	……	Standard Specification for Cutback Asphalt (Medium-Curing Type)
AASHTO M85	……	Standard Specification for Portland Cement
AASHTO M140	……	Standard Specification for Emulsified Asphalt
AASHTO M156	……	Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
AASHTO M208	……	Standard Specification for Cationic Emulsified Asphalt
AASHTO M316	……	Standard Specification for Polymer-Modified Emulsified Asphalt
AASHTO M320	……	Standard Specification for Performance-Graded Asphalt Binder
AASHTO M332	……	Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
AASHTO MP2	……	Standard Specification for Superpave Volumetric Mix Design
AASHTO R28	……	Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
AASHTO T11	……	Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
AASHTO T27	……	Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates
AASHTO T30	……	Standard Method of Test for Mechanical Analysis of Extracted Aggregate
AASHTO T40	……	Standard Method of Test for Sampling Bituminous Materials
AASHTO T44	……	Standard Method of Test for Solubility of Bituminous Materials
AASHTO T48	……	Standard Method of Test for Flash Point of Asphalt Binder by Cleveland Open Cup
AASHTO T96	……	Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
AASHTO T104	……	Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
AASHTO T112	……	Standard Method of Test for Clay Lumps and Friable Particles in Aggregate
AASHTO T113	……	Standard Method of Test for Lightweight Pieces in Aggregate

AASHTO T164	……	Standard Method of Test for Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
AASHTO T166	……	Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
AASHTO T182	……	Standard Method of Test for Coating and Stripping of Bitumen-Aggregate Mixtures
AASHTO T194	……	Standard Method of Test for Determination of Organic Matter in Soils by Wet Combustion
AASHTO T240	……	Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
AASHTO T245	……	Standard Method of Test for Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
AASHTO T278	……	Standard Method of Test for Surface Frictional Properties Using the British Pendulum Tester
AASHTO T279	……	Standard Method of Test for Accelerated Polishing of Aggregates Using the British Wheel
AASHTO T302	……	Standard Method of Test for Polymer Content of PolymerModified Emulsified Asphalt Residue and Asphalt Binders
AASHTO T304	……	Standard Method of Test for Uncompacted Void Content of Fine Aggregate
AASHTO T313	……	Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
AASHTO T314	……	Standard Method of Test for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
AASHTO T315	……	Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
AASHTO T316	……	Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer
ASTM C88	……	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate
ASTM C127	……	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
ASTM C128	……	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C131	……	Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	……	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C183	……	Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement
ASTM C207	……	Standard Specification for Hydrated Lime for Masonry Purposes
ASTM D5	……	Standard Test Method for Penetration of Bituminous Materials

ASTM D36	……	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)
ASTM D75	……	Standard Practice for Sampling Aggregates
ASTM D92	……	Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D113	……	Standard Test Method for Ductility of Bituminous Materials
ASTM D140	……	Standard Practice for Sampling Bituminous Materials
ASTM D242	……	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
ASTM D402	……	Standard Test Method for Distillation of Cutback Asphaltic (Bituminous) Products
ASTM D423	……	Method of Test for Liquid Limit of Soils
ASTM D424	……	Standard Method of Test for Plastic Limit
ASTN D692	……	Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures
ASTM D946	……	Standard Specification for Penetration Graded Asphalt Cement for Use in Pavement Construction
ASTM D1075	……	Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures
ASTM D2026	……	Standard Specification for Cutback Asphalt (Slow-Curing Type)
ASTM D2042	……	Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene
ASTM D2170	……	Standard Test Method for Kinematic Viscosity of Asphalts
ASTM D2171	……	Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer
ASTM D2172	……	Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM D2399	……	Standard Practice for Selection of Cutback Asphalts
ASTM D2419	……	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate
ASTM D3143	……	Standard Test Method for Flash Point of Cutback Asphalt with Tag Open-Cup Apparatus
ASTM D3625	……	Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water
ASTM D4318	……	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4402	……	Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
ASTM D4791	……	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ASTM D5821	……	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
ASTM D6926	……	Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus
ASTM D6927	……	Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures

SECTION 4.01 MATERIALS FOR BITUMINOUS CONSTRUCTION

4.01.01 SCOPE

A. Materials specified for use in the construction of the various bituminous pavement courses include the following:

- Coarse and fine mineral aggregates and filler.
- Bitumen products including penetration or performance graded bitumens, cutback bitumens, emulsified bitumens and modified bitumens for use in bituminous courses and surface treatments.

B. All material sources proposed for use in the Works shall be approved prior to procuring or processing material from such sources. Materials used in the Works shall be tested and approved before use. Inspection, sampling, testing and retesting as necessary, shall be at the Contractor's expense as specified hereunder for specific materials.

C. Storage and handling of all materials shall conform to the relevant requirements of Part 1 of Specification Section 4.3: Materials. Materials shall be stored on hard, clean surfaces.

4.01.02 AGGREGATE MATERIALS GENERAL

A. Sources and Production

A.1 The Contractor shall demonstrate recognition of the location, suitability and quantity of materials available; extent of work necessary to obtain the material available; the work required to open the quarry and to crush, screen and wash (if necessary) the materials; and the length of haul to the Site prior to the start of the Works.

A.2 Prior to starting quarry operations, the Contractor shall obtain written permission for extraction from the Authorities and/or owners concerned.

A.3 Crushing and screening plant shall not be put into operation prior to the Engineer's written approval. If after being put into operation any plant fails to perform as intended, the Contractor shall either rectify the defects in the existing plant to the satisfaction of the Engineer or shall provide alternative approved plant.

A.4 Approval of the crushing and screening plant and other equipment shall not relieve the Contractor of his responsibilities in respect of producing aggregates which conform to the Specifications and in the quantities required for the timely completion of the Works.

B. Stockpiling

B.1 Stockpile areas shall be surveyed prior to stockpiling to establish control points and to obtain a record of existing cross sections for future use in determining stockpile quantities. The stockpile areas shall be adequately drained at all times.

B.2 Stockpiling procedures shall not result in degradation or segregation of the stockpiled material or the introduction of foreign materials into the stockpile. Heights of aggregate stockpiles shall not exceed 5 metres.

B.3 Topsoil shall be stripped from the stockpile areas prior to use and stored on site in heaps no higher than 1.5 metres and reinstated on completion of the works.

C. Sampling and Testing

C.1 Sampling and testing procedures shall conform to the relevant requirements of Part 1 – Section 4.6: Samples and Approvals and to the following requirements:

C.2 The Contractor shall submit to the Engineer for approval at least 30 days prior to the scheduled beginning of crushing and screening operations, a statement of origin and composition of all aggregates proposed for use in the Works.

C.3 In order to ascertain the properties of aggregate materials, the Contractor shall submit for testing and approval, representative samples of all materials intended for incorporation into the Works, prior to starting quarry operations. The representative samples shall be taken by the Contractor in the presence of the Engineer.

C.4 Tests performed by the Contractor shall be utilized in assessing the location, extent of deposits and quantities of materials conforming to the Specifications when properly processed. Any special tests that may be required by the Engineer shall be carried out by the Contractor either in his own laboratory or in a third-party laboratory approved by the Engineer. All testing as carried out by the Contractor shall not obviate the need for further testing by the Engineer. Approval of specific sources of materials shall not be construed as final approval and acceptance of materials from such sources.

C.5 Processed materials shall be tested and approved before being stockpiled on Site or incorporated in the Works and shall be inspected and tested at any time by the Engineer during preparation, storage and use. Questionable materials awaiting testing and approval shall not be unloaded and mixed with materials previously approved. If the grading and quality of any materials delivered to the Site do not conform to the grading and quality of the established control samples, the Engineer shall reject such materials.

C.6 Samples shall satisfy all specified test requirements. The Contractor shall allow the Engineer to inspect any and all materials used or to be used at any time during or after preparation or while being used during construction of the Works. Unsatisfactory materials, whether in place or not, shall be removed promptly from the Site. The Contractor shall furnish all necessary materials, labour, tools, equipment and transport required by the Engineer for such inspections.

4.01.03 AGGREGATES FOR BITUMINOUS PAVING MIXES

A. General

A.1 Aggregates for use in bituminous base course shall consist of crushed rock or crushed gravel.

A.2 Aggregates shall not contain more than 1% gypsum.

B. Coarse Aggregates

B.1 Coarse aggregate shall be the fraction of crushed aggregate material retained on the 4.75 mm (No. 4) sieve.

B.2 Crushing shall result in a product such that 100% by weight shall have at least one fractured face, and at least 90% by weight shall have 2 or more fractured faces.

B.3 Aggregates shall not contain more than 5% chert by weight.

B.4 Aggregate particles shall be clean, and reasonably free of deleterious substances such as: clay lumps, alkali, salt, and organic materials. The maximum permissible amounts of these harmful substances are listed below:

SUBSTANCE	STANDARD	MAXIMUM ALLOWED % by weight
Coal and lignite	AASTHO T113	1.0
Clay lumps, friable particles, and deleterious material	AASHTO T112	1.0
Organic materials	AASHTO T194	0.03

B.5 Aggregate particles shall be clean, hard, durable and sound. The physical characteristics of the coarse aggregate shall comply with ASTM D692.

B.6 Aggregates shall be washed to remove any clay lumps, organic matter, adherent dust, clay film or other extraneous or deleterious matter that may prevent or detract from proper adhesion of bitumen to the aggregate particles.

B.7 Aggregates shall comply with the following Standards and limits:

TEST	STANDARD	LIMIT		
		Limestone	Basalt	Other
Fractured particle in coarse aggregate One face – (%)	ASTM D5821	For Marshall Mixes: 90% minimum For Superpave Mixes: Refer to Section 4.03.03		
Soundness Using Sodium Sulphate (5 cycles)	ASTM C88	12% maximum 9% maximum on sites over 1000m above sea level	6% maximum	12% maximum 9% maximum on sites over 1000m above sea level
Soundness Using Magnesium Sulphate (5 cycles)	ASTM C88	18% maximum, 14% maximum on sites over 1000m above sea level	9% maximum	18% maximum, 14% maximum on sites over 1000m above sea level
Degradation (Loss by abrasion)	ASTM C131	30% maximum	20% maximum	20% maximum
Water Absorption	ASTM C127	2% maximum	2% maximum	2% maximum
Resistance to Stipping	ASTM D3625/3625M	95% minimum	95% minimum	95% minimum

TEST	STANDARD	LIMIT		
		Limestone	Basalt	Other
Flakiness and Elongation (5:1 aspect ratio)	ASTM D4791	10% maximum	10% maximum	10% maximum
OR Flakiness Index	BS EN933-3	25% maximum	25% maximum	25% maximum
Polish Stone Value	AASHTO T278 & T279	40 minimum	45 minimum	45 minimum

C. Fine Aggregates

C.1 Fine aggregates shall be the fraction of crushed aggregate material passing the 4.75 mm (No. 4) sieve. Fine aggregate shall consist of natural sand or manufactured fine aggregate such as crushed stone and crushed gravel.

C.2 The percentage by weight of friable particles, clay lumps, and other deleterious material shall not exceed 0.3% as determined by AASHTO T112.

C.3 Fine aggregates shall be washed to remove any clay lumps, organic matter, adherent dust, clay film or other extraneous or deleterious matter that may prevent or detract from proper adhesion of bitumen to the aggregate particles.

C.4 The physical characteristics of fine aggregates shall comply with the following Standards and limits:

TEST	STANDARD	LIMIT
Liquid Limit	ASTM D4318	25% maximum
Plasticity Index	ASTM D4318	Non-plastic
Sand Equivalent	ASTM D2419	For Marshall Mixes: 40% minimum For Superpave Mixes: Refer to Section 4.03.03
Water Absorption	ASTM C128	1.0% maximum
Angularity	AASHTO T304 Method A	40% minimum

D. Mineral Fillers

D.1 Mineral filler shall be added when the combined grading of coarse and fine aggregates is deficient in material passing a 0.075 mm (No. 200) sieve.

D.2 Mineral filler shall consist of finely divided mineral matter such as limestone dust, hydrated lime, other non-plastic mineral filler free from clay and organic impurities and Portland cement, conforming to AASHTO M 17.

4.01.04 AGGREGATES FOR SEAL COATS

A. Cover aggregates for bituminous seal coats shall consist of screenings of crushed stone. Aggregate for slurry seals shall consist of crushed stone fines or natural sand blended with not less than 50% crushed stone fines. For heavy duty applications slurry aggregate shall consist of

100% crushed fines. The suitability of sources of crushed stone fines for use in slurry seal shall be demonstrated to the Engineer for approval prior to use.

B. Aggregates shall not contain more than 1% crystalline or amorphous gypsum (expressed as SO_3) and shall not contain more than 5% chert.

C. Aggregate particles shall be clean hard durable and sound. For particles retained on 4.75 mm (No. 4) sieve at least 90% by weight shall have 2 or more fractured faces and 100% by weight shall have one or more fractured faces.

D. Flakiness and Elongation Indices shall be tested in accordance with BS EN 933-3:1997 and shall not exceed 25 %. The percentage by weight of clay lumps and friable particles as determined by AASHTO T 112 shall not exceed 3%. Lightweight aggregate of specific gravity of 2 or less shall not exceed 3 % as determined by AASHTO T113.

E. Aggregates shall be washed or processed by an approved method to remove any clay lumps, organic matter, adherent dust or clay films or other extraneous or deleterious matter that may prevent or detract from proper adhesion of bitumen to the aggregate particles.

F. Cover aggregates and aggregate for slurry seals shall be tested in accordance with AASHTO T 27 and T11 and shall conform to the gradations given in Table 4.1.2.

Table 4.1.2: Gradation of Aggregates for Seal Coats

Sieve Designation (Square openings)	1st Application Grading B	2nd Application Grading C	Slurry Aggregate
25.0 mm (1 in)	100		
19.0 mm (3/4 in)	90 - 100		
12.5 mm (1/2 in)	20 - 55	100	
9.50 mm (3/8 in)	0 -15	58 - 100	100
4.75 mm (No. 4)	0 - 5	10 -30	90 - 100
2.36 mm (No. 8)	-	0 -10	65 -90
1.18 mm (No. 16)	-	0 -5	45 -70
0.60 mm (No. 30)	-	-	30 - 50
0.30 mm (No. 50)	-	-	18 -30
0.15 mm (No. 100)	-	-	10 -20
0.07 mm (No. 200)	0 - 0.5	0 - 0.5	5 -15

G. The loss in weight of aggregate after 500 revolutions, when tested in accordance with AASHTO T 96 (Los Angeles Test), shall not exceed 30 %.

H. When tested for soundness in accordance with AASHTO T 104, the aggregates shall not show signs of disintegration and the loss by weight shall not exceed 10% in the case of the sodium sulphate test or 12% in the case of the magnesium sulphate test.

I. When tested for resistance to stripping in accordance with AASHTO T 182, at least 95% of the aggregate surface area shall remain coated with a bitumen film.

4.01.05 BITUMEN

A. Type Certification and Grade

A.1 The Contractor shall furnish the vendor's certified test reports for each load of bitumen delivered to the site. Each report shall be delivered to and approved by the Engineer before the material in the load may be used. The furnishing of the vendor's certified test report for the bituminous material shall be the basis for final acceptance.

A.2 The grade of bitumen may be changed by the Engineer by one grade either side of the specified grade at no extra cost to the Employer. When more than one type or grade is specified under any item, the Engineer shall select the type and grade to be used in the Works.

B. Transporting Bitumen

B.1 All transporting of bitumen shall be by conveyances that are free from contamination. Tank cars or tank trucks used for transporting bitumen shall be carefully inspected, drained and cleaned before loading to prevent contamination of the bitumen from residues of previous loads. Bitumen may also be delivered and transported in metal drums.

B.2 Tank trucks or trailers used to transport bitumen shall be equipped with a suitable sampling device which shall be built into the tank, recirculating or discharge line so that a sample can be drawn during circulation or discharge in accordance with ASTM D140 or a comparable device acceptable to the Engineer.

C. Storage of Bitumen

C.1 The Contractor shall provide an adequate storage facility for bitumen at the site of the mixing plant. This facility shall be clean, stable and provided with cover and shelter from excessive temperatures.

C.2 No open fires or smoking shall be permitted in or around the storage facility.

C.3 The storage capacity shall be sufficient to maintain a uniform operation while allowing for delayed shipments and time for testing. Different batches of bitumen shall be separated to allow for easy identification.

C.4 If the bitumen is delivered to the site in metal drums they shall be inspected on arrival at Site for perforations, rusting, melting and other defects that would directly cause pollution or chemical changes to the bitumen. Any drums showing any of these defects shall be rejected by the Engineer.

C.5 The stored bitumen products should be protected from temperatures that exceed the range of -5°C to +60°C.

D. Heating of Bitumen

D.1 Heating equipment shall be of a type approved by the Engineer. Any method of agitation or heating that introduces free steam or moisture into the bitumen shall not be approved. During the process of manufacture, conveyance, storage and construction, all bitumen shall not be heated to temperatures more than 10°C above the maximum application temperature specified nor above 170°C, whichever is the lower. Materials heated in excess of these temperatures shall be rejected by the Engineer and not be used in the Works.

D.2 Tanks for heating and storage of bitumen shall be capable of heating the material, under effective and positive control at all times to the specified temperature. The system shall provide uniform heating for the entire contents of the tank. The circulation system shall be of adequate size to ensure proper and continuous circulation of the bitumen during the entire operating period. Steam, oil jacketing or other insulation shall be provided for maintaining the required temperature of bitumen, weigh buckets, spray bars and other containers.

D.3 Thermometers of approved types and adequate range (calibrated in 1ºC increments) for accurately measuring the temperature of the bitumen while heating shall be located so as to be readily visible and shall be kept clean and in proper working order at all times.

D.4 Where storage tanks are required, their capacity shall be sufficient for at least one day's production.

D.5 Bitumen materials wasted through careless handling or rendered unsuitable for use by overheating shall not be used in the Works.

E. Sampling and Testing

E.1 Procedures for sampling of bituminous materials shall conform to AASHTO T 40.

E.2 General requirements and procedures for sampling and testing of the various types of bitumen shall conform to Part 1–Section 4.6: Samples and Approvals.

4.01.06 BITUMEN PRODUCTS

A. Penetration Graded Bitumen

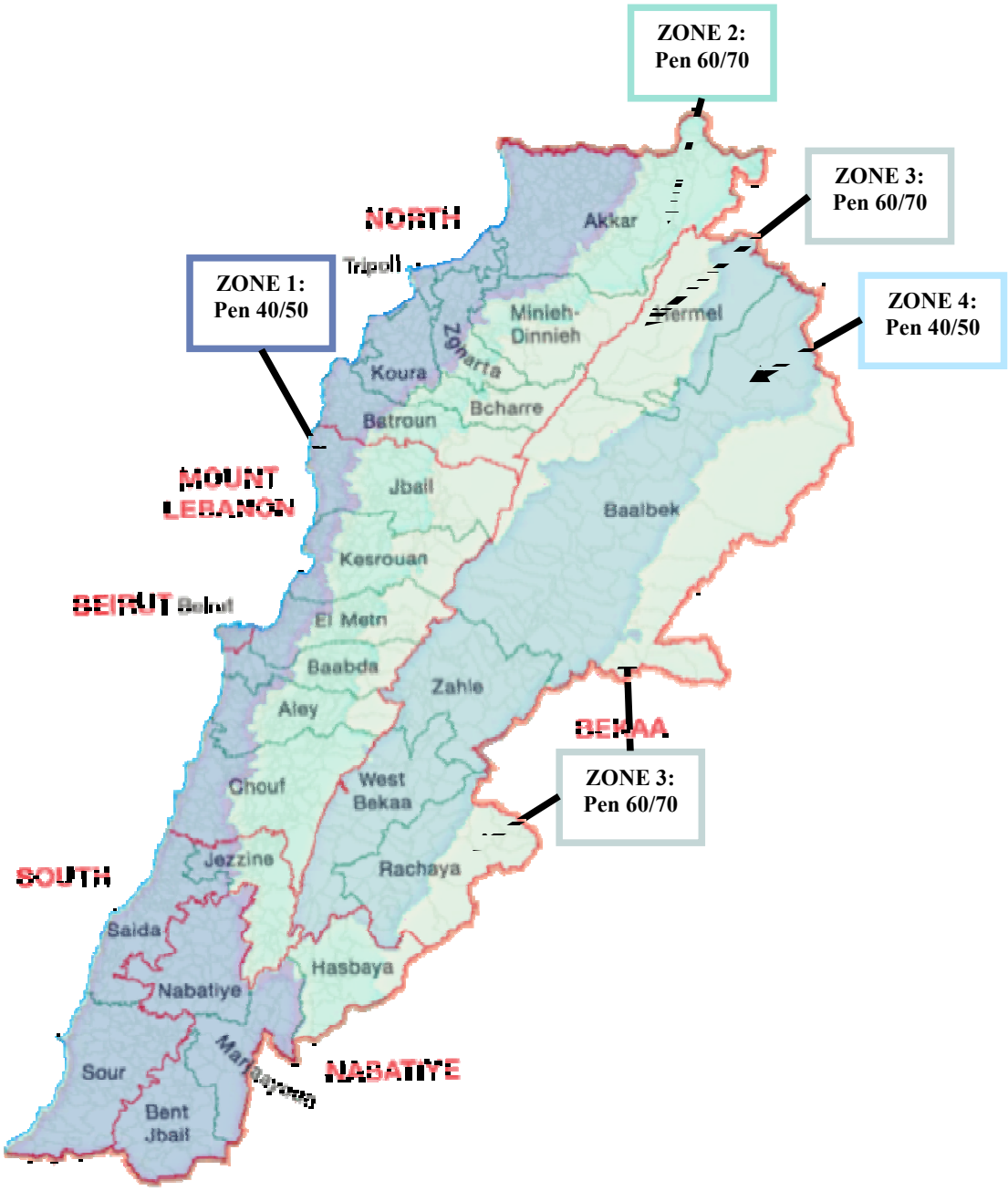
A.1 The binder type shall be classified according to ASTM D946/D946M, as shown in Table 4.1.3.

TABLE 4.1.3: PROPERTIES OF PENETRATION GRADE BITUMEN

		Penetration Grade					
		40 -50		60 - 70		85 - 100	
Test	**Standard**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Original Binder							
Ductility at 25°C (cm)	ASTM D113	100	-	100	-	100	-
Penetration at 25°C (0.1 mm)	ASTM D5	40	50	60	70	85	100
Softening Point (° C)	ASTM D36	52	-	49	-	45	-
Solubility in Trichloroethylene (% wt)	ASTM D2042	99	-	99	-	99	-
Flashpoint (Cleveland Open Cup.) (°C)	ASTM D92	230	-	230	-	230	-
Thin Film Oven Residue							
Penetration of residue (% of original)	ASTM D5	55	-	52	-	47	-
Ductility at 25°C - 5cm/min (cm)	ASTM D113	-	-	50	-	75	-

A.2 Sampling and testing shall be in accordance with the AASHTO standard method listed in AASHTO M 20-70. The penetration and softening point tests shall be tested once every 75 tons of asphalt concrete per layer. The remaining tests shall be performed once every 450 tons of asphalt concrete per layer.

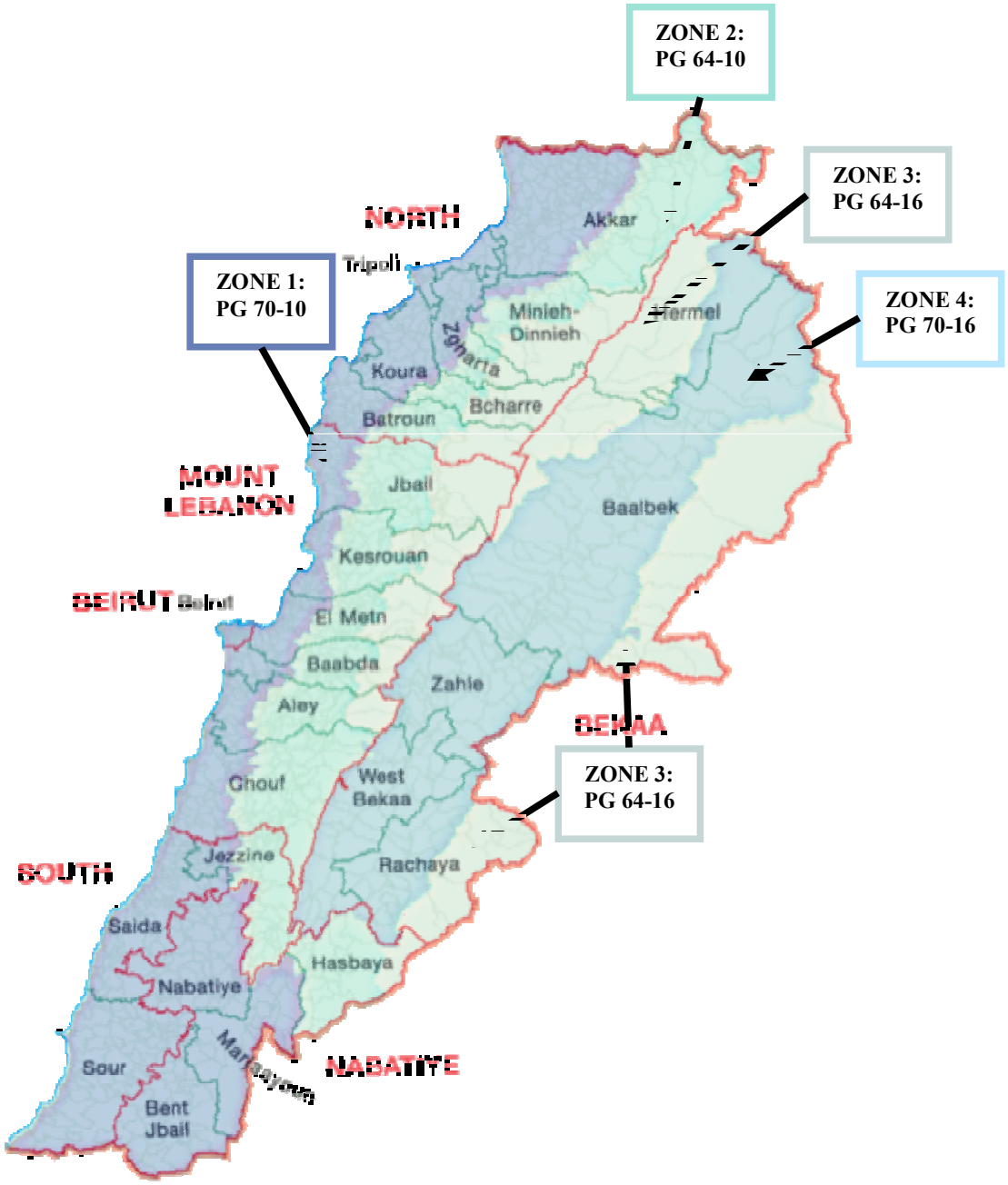
A.3 The binder penetration grade shall conform to the following grading map of Lebanon:


ZONE 2:
Pen 60/70
ZONE 3:
Pen 60/70
ZONE 1:
Pen 40/50
ZONE 4:
Pen 40/50
ZONE 3:
Pen 60/70
NORTH
Tripoli
Akkar
Minieh-
Dinnieh
Hermel
Zgharta
Koura
Bcharre
Batroun
MOUNT
LEBANON
Jbail
Baalbek
Kesrouan
BEIRUT
Beirut
El Metn
Baabda
Zahle
Aley
BEKAA
Chouf
West
Bekaa
Jezzine
Rachaya
SOUTH
Saida
Hasbaya
Nabatiye
Marjayoun
NABATIYE
Sour
Bent
Jbail

B. Performance Graded Bitumen

B.1 The PG grade selection is dependant of the climate and traffic as described in Asphalt Institute MS-26 and shall meet the requirements of AASHTO M320 and M332.

B.2 The base binder PG grade shall conform to the following PG grading map of Lebanon:



B.3 A one-grade increase, equivalent to 6˚C, shall be applied to the base high-temperature PG grade in cases of slow traffic (between 20 km/h and 70 km/h) or standing traffic (<20 km/h). Over and above, a one-grade increase shall be applied to the base high-temperature where traffic volume exceeds 10 million ESALs as specified in Table 4.1.4.

TABLE 4.1.4: ADJUSTMENTS FOR HIGH TEMPERATURE GRADE FOR TRAFFIC CONSIDERATIONS

EXISTING CONDITION	HIGH-TEMPERATURE GRADE ADJUSTMENT
Slow/Standing Traffic	+ 1 Grade (6˚C)
Traffic Volume Exceeds 10 Million ESALs	+ 1 Grade (6˚C)

B.4 PG Binders shall be tested in accordance with the latest version of AASHTO M 320 and the material shall conform to the following requirements:

Test	Standard	Specification Range
Original Binder		
Solubility in Trichloroethylene (%)	AASHTO T44	Min 99%
Flash Point (°C)	AASHTO T48	Min 230°C (450°F)
Viscosity (Brookfield) at 135° C, max °C	AASHTO T316	Max 3 Pa.s
Dynamic shear (G*/sinφ) at 10 rad/s	AASHTO T315	Min 1 KPa
Phase Angle (φ)	AASHTO T315	Max 75°
Rolling Thin Film Oven Residue (AASHTO T 240)		
Mass change (%)	AASHTO T240	Max 1%
Dynamic shear (G*/sinφ) at 10 rad/s	AASHTO T315	Min 2.2 Pa.s
Pressurized Aging Vessel Residue (AASHTO R28)		
Dynamic Shear (G*sinφ) at 10 rad/s	AASTHO T315	Max 5000 KPa
Creep at 60 seconds: -Stiffness, S -*m* Value	AASHTO T313	 -Max 300 MPa -Min 0.3
Direct Tension at 1 mm/min failure strain	AASHTO T314	Min 1%

B.5 If the creep stiffness is below 300 MPa, the direct tension test can be skipped. If the creep stiffness is between 300 and 600 MPa, the direct tension can replace the creep stiffness.

B.6 For unmodified binder, the mixing and compaction temperature ranges shall be those corresponding to viscosity ranges of 0.17+/- 0.02 Pa-s and 0.28+/- 0.03 Pa-s, respectively, as determined from viscosity vs. temperature curves (ASTM D4402).

B.7 Sampling and testing shall be in accordance with ASTM D6373. The binder grading tests shall be tested once every 75 tons of asphalt concrete per layer. The remaining tests shall be performed once every 450 tons of asphalt concrete per layer.

C. Polymer Modified Bitumen (PMB)

C.1 A high-temperature PG Grade of 76 or greater will require addition of modifier such as SBS (Styrene Butediene Styrene) or similar. The Contractor shall submit a Method Statement for the preparation of PMB blending including the type of polymer intended for use to the Engineer's

approval, and shall demonstrate through testing that the modified asphalt meets all the specification requirements and AASHTO M320 specifications.

C.2 The modified bitumen shall be tested for compatibility with the polymer modifier to ASTM D7173 for both Softening Point and DSR. The difference in °C between the softening points of the respective top and bottom portions of the tube sample shall not exceed 4°C. The separation ratio based on G* shall have an average G* value [(Top + Bottom)/2] within 0.8 to 1.2 of the initial G* value.

C.3 The mixing and compaction temperatures shall be established in the laboratory by determining the Brookfield viscosity of the approved Polymer Modified Bitumen at three different temperatures 135° C, 165° C and 195° C. The established mixing and compaction temperatures shall then be evaluated and finalized based upon successful site trials. The mixing temperature shall not exceed 180° C.

C.4 The optimal polymer content in asphalt binder shall be determined based on laboratory trial blends according to AASHTO T302 and shall satisfy the range of 2 to 5% by mass of binder.

C.5 The mixing and preparation of modified bitumen shall be carried out in accordance with the manufacturers' instructions, and with the approval of the Engineer. The modifier shall be pre-blended into the conventional bitumen before mixing with the aggregate in the hot mix plant. Blending temperature shall not exceed that set by the manufacturer.

C.6 The production of the modified bitumen shall require a high shear blending system to ensure complete and controlled dispersion and chemical reaction of the modifiers with the conventional bitumen. The Contractor shall ensure proper circulation and agitation during storage to avoid separation of the modifier from the base bitumen.

D. Rapid-Curing (RC) Cutback Bitumen

D.1 RC cutback bitumen shall conform to the requirements of AASHTO M 81, grades RC-70, RC-250, RC-800, and RC-3000 with properties as listed in Table 4.1.5.

D.2 Sampling and testing shall be in accordance with the AASHTO standard methods listed in AASHTO M 81.

D.3 RC cutback bitumen spraying temperature ranges shall be as follows:

RC Cutback Bitumen Grade	Spraying Temp °C
RC - 70	40 - 75
RC - 250	65 - 105
RC - 800	90 - 115
RC - 3000	105 – 135

E. Medium-Curing (MC) Cutback Bitumen

E.1 MC cutback bitumen shall conform to the requirements of AASHTO M 82, grades MC-30, MC-70, MC-250, MC-800 and MC-3000 with properties as listed in Table 4.1.6.

E.2 Sampling and testing shall be in accordance with the AASHTO standard methods listed in AASHTO M 82.

E.3 MC cutback bitumen spraying temperature ranges shall be as follows:

MC Cutback Bitumen Grade	**Spraying Temp ^{o}C**
MC - 30	21 - 63
MC - 70	45 - 80
MC - 250	70 - 110
MC - 800	95 - 125
MC - 3000	110 – 145

F. Slow-Curing (SC) Cutback Bitumen

F.1 SC cutback bitumen shall conform to the requirements of ASTM D 2026 grades SC-70, SC-250, SC-800, and SC-3000 with properties as listed in Table 4.1.7.

F.2 Sampling and testing shall be in accordance with the appropriate ASTM standard methods.

F.3 SC cutback bitumen spraying temperature ranges shall be as follows:

SC Cutback Bitumen Grade	Spraying Temp ^{o}C
SC – 70	45 - 80
SC -250	70 - 110
SC - 800	95 - 125
SC - 3000	110 – 145

TABLE 4.1.5: PROPERTIES OF R.C. CUTBACK BITUMEN

	RC-70		RC-250		RC-800		RC-3000	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Kinematic Viscosity at 60°C centistokes ASTM D2170	70	140	250	500	800	1600	3000	6000
Flash Point (Tag, open-cup) °C ASTM D3143	-	-	27	-	27	-	27	-
Water, %	-	0.2	-	0.2	-	0.2	-	0.2
Distillation Test: ASTM D402								
Distillate, % by volume of total distillate to 360°C								
- to 190°C	10	-	-	-	-	-	-	-
- to 225°C	50		35	-	15	-	-	-
- to 260°C	70		60	-	45	-	25	-
- to 315°C	85		80	-	75	-	70	-
Residue from distillation to 360°C volume percentage of sample by difference, ASTM D402	55	-	65	-	75	-	80	-
Volume percentage of sample by difference	600	2400	600	2400	600	2400	600	2400
Tests on residue from distillation								
Absolute viscosity at 60°C poises, ASTM D2171	100	-	100	-	100	-	100	-
Ductility, 5 cm/min. at 25 °C cm, ASTM D113	99	-	99	-	99	-	99	-
Solubility in Trichloroethylene, %, ASTM D2042	99	-	99	-	99	-	99	-
Spot Test with:								
Standard naphtha	Negative for all grades							
Naphtha-xylene solvent, - % xylene	Negative for all grades							
Heptane-xylene solvent, - % xylene	Negative for all grades							

TABLE 4.1.6: PROPERTIES OF M.C. CUTBACK BITUMEN

	MC-30		MC-70		MC-250		MC-800		MC-3000	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Kinematic Viscosity at 60°C centistokes, ASTM D2170	30	60	70	140	250	500	800	1600	3000	6000
Flash Point (Tag, open- cup) °C, ASTM D3143	38	-	38	-	66	-	66	-	66	-
Water, %	-	0.2	-	0.2	-	0.2	-	0.2	-	0.2
Distillation Test:										
Distillate, % by volume of total distillate to 360°C, ASTM D402										
- to 225°C	-	25	0	20	0	10	-	-	-	-
- to 260°C	40	70	20	60	15	55	0	35	0	15
- to 315°C	75	93	65	90	60	87	45	80	15	75
Residue from distillation to 360°C volume percentage of sample by difference, ASTM D402	50	-	55	-	67	-	75	-	80	-
Tests on residue:										
Tests on residue from distillation Absolute viscosity at 60°C poises, ASTM D2171	300	1200	300	1200	300	1200	300	1200	300	1200
Ductility, 5 cm/min. at 25 °C cm, ASTM D113	100	-	100	-	100	-	100	-	100	-
Solubility in Trichloroethylene, %, ASTM D2042	99	-	99	-	99	-	99	-	99	-
Spot Test with:										
Standard naphtha	Negative for all grades									
Naphtha-xylene solvent, - % xylene	Negative for all grades									
Heptane-xylene solvent, - % xylene	Negative for all grades									

TABLE 4.1.7: PROPERTIES OF S.C. CUTBACK BITUMEN

	SC - 70		SC - 250		SC - 800		SC - 3000	
	Min	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Kinematic Viscosity at 60 °C centistokes, ASTM D2170	70	140	250	500	800	1600	3000	6000
Flash Point (Cleveland open-cup) °C, ASTM D92-IP 36	66	-	79	-	93	-	107	-
Distillation test:								
Total distillate to 360°C, volume %, ASTM D402	10	30	4	20	2	12	-	5
Solubility in trichloroethylene %, ASTM D2042	99	-	99	-	99	-	99	-
Kinematic viscosity on distillation residue at 60°C, St, ASTM D2170	4	70	8	100	70	160	40	350
Asphalt residue:								
Residue of 100 penetration %	50	-	60	-	70	-	80	-
Ductility of 100 penetration	100	-	100	-	100	-	100	-
Residue at 25°C, cm Water, %	-	0.5	-	0.5	-	0.5	-	0.5

G. Emulsified Bitumens

G.1 Selection and use of emulsified bitumens shall generally be in accordance with the recommendations in AASHTO M140 or M208 or M 316 for the designated types and grades, subject to the following requirements.

G.2 Emulsified bitumens which have been subjected to freezing temperature while in storage shall be retested and acceptance or rejection of the material shall be based on the results of the retest.

G.3 The manufacturer shall furnish samples of the base bitumen used in the emulsion.

G.4 When samples of undiluted emulsion are not readily available for test purposes, tests shall be made on the diluted emulsion and the respective specifications modified to reflect the changes in properties resulting from dilution of the bitumen.

G.5 All emulsified bitumens shall adhere firmly to the surface of the mineral aggregate or the highway surface as appropriate. Failure of the emulsified bitumen to perform satisfactorily on the job shall be deemed cause for its rejection regardless of satisfactory laboratory test results.

H. Anionic Emulsified Bitumen

H.1 Anionic emulsified bitumens shall, prior to dilution, conform to the requirements of AASHTO M 140, for Types SS-1 and SS-1h and as listed in Table 4.1.8.

H.2 Sampling and testing shall be in accordance with AASHTO T 59.

H.3 Emulsified bitumen spraying temperature ranges shall be determined to ensure that appropriate viscosities for each application are achieved. If the viscosity curves are not available values shall be 25-65°C, except for Grade RS-2 where the range shall be 50-75°C. The temperature range for pugmill mixing for medium and slow setting types shall be 15-65°C.

I. Cationic Emulsified Bitumen

I.1 Cationic emulsified bitumens shall, prior to dilution, conform to the requirements of AASHTO M 208 or M 316, for Types CSS-1 and as listed in Table 4.1.9.

I.2 Sampling and testing shall be in accordance with AASHTO T 59.

I.3 The emulsified bitumen spraying temperature range shall be so that appropriate viscosity for each application is achieved. If viscosity curves are not available these values, generally considered as guidance shall be in the range of 25-65 ºC (except for Grade CRS-2 where the range shall be 50-75 ºC). The temperature range for pugmill mixing for medium and slow setting types shall be 15-65 ºC.

TABLE 4.1.8: PROPERTIES OF ANIONIC EMULSIFIED BITUMEN (SLOW SETTING)

	SS-1		SS-1h	
	Min.	**Max.**	**Min.**	**Max.**
Test on emulsions:				
Viscosity, Saybolt Furol at 25° C,s	20	100	20	100
Viscosity, Saybolt Furol at 50° C,s	-	-	-	-
Storage stability test, 24-h, %	-	1	-	1
Cement mixing test, %	-	2.0	-	2.0
Sieve test, %	-	0.1	-	0.1
Residue by distillation, %	57	-	57	-
Tests on residue from distillation test:				
Penetration, 25°C, 100g, 5 s	100	200	40	90
Ductibility, 25°C 5 cm/min. cm	40	-	40	-
Solubility in trichloroethylene %	97.5	-	97.5	-

TABLE 4.1.9: PROTECTION OF CATIONIC EMULSIFIED BITUMEN

	Slow-Setting CSS-1		
	Min.		**Max.**
Tests on emulsions:			
Viscosity, Saybolt Furol at 25°C, s	20		100
Storage stability test, 24-h, %	1		
Particle charge test		Positive	
Sieve test, %			0.15
Cement mixing test, %			0.10
Distillation:			2.0
Residue, %	57		
Tests on residue from distillation test:			
Penetration, 25°C, 100 g, 5 s	100		250
Ductibility, 25°C, 5 cm/min, cm	40		
Solubility in trichloroethylene %	97.5		

4.01.07 MEASUREMENT

Items listed in this Section shall be measured as prescribed in the appropriate sections of these Specifications.

SECTION 4.02 BITUMINOUS PRIME AND TACK COATS

4.02.01 SCOPE

The work covered in this section consists of furnishing and applying MC cutback bitumen prime coat to a previously constructed subgrade, aggregate base course, or concrete pavement; and furnishing and applying RC cutback bitumen or emulsified bitumen as a tack coat to a previously constructed bituminous base surface to provide a bond for a superimposed bituminous course as and where shown on the Drawings.

4.02.02 MATERIALS

A. Medium-Curing Cutback Bitumen

MC cutback bitumen (for prime coats) shall be as recommended by ASTM D2399-83. MC 70 shall be used unless otherwise specified.

B. Rapid-Curing Cutback Bitumen

RC cutback bitumen (for tack coats) shall be Grades RC-70 or RC-250 as appropriate and as specified in Section 4.01 - Materials for Bituminous Construction or as specified in the Drawings.

C. Slow-Curing Emulsified Bitumen

Slow-setting cationic/anionic emulsified bitumen (for tack coats) shall be slow-setting Grades SS-1, SS-1h, CSS-1, or CSS-1h, as appropriate and as specified in Section 4.01 - Materials for Bituminous Construction or as specified in the Drawings.

4.02.03 EQUIPMENT

Equipment used for diluting emulsified bitumen, heating cutback bitumen, spraying cutback and emulsified bitumen and for the application of blotting material to prime coats shall conform to the requirements of Part 1 of Specification Section 4-4 - Contractor's Plant and Equipment.

4.02.04 CONSTRUCTION OF TRIAL SECTIONS

A. The Engineer shall, if necessary, instruct trial sections to be constructed prior to the commencement of on-Site prime or tack coat applications. The Contractor shall construct trial sections using varying application rates of bitumen as selected by the Engineer. Each trial section shall be 2 lanes wide by 50 metres long, at approved locations on or close to the Site.

B. Each trial section shall be constructed using the same materials, mixing and spraying equipment and construction procedures proposed for use in the Works.

C. The objectives of these trials shall be to determine the adequacy of the Contractor's equipment and the most suitable application rates for cutback bitumen prime and tack coats.

D. The Contractor shall not proceed with any site coat applications until the methods and procedures established in the trials have been approved by the Engineer.

4.02.05 APPLICATION PROCEDURES

A. General

A.1 All equipment used for surface cleaning, heating bitumen and application of prime and tack coats shall be suitable for the purposes intended and shall be approved by the Engineer before use.

A.2 All surfaces to receive prime or tack coats shall conform to the specified tolerances and compaction requirements and shall be properly cleaned using power brooms or power blowers. Surfaces shall be approved before applying any bitumen material.

A.3 Prime coats and tack coats shall be applied only when the surface to be treated is sufficiently dry for tack coats and sufficiently moist for prime coats and when the ambient temperature is above 15°C. Prime and tack coats shall not be applied during fog, rain, strong winds, generally dusty conditions or dust storms.

A.4 The surfaces of all structures, kerbs, gutters and other highway appurtenances shall be protected to prevent them from being splattered or stained with bitumen or damaged during equipment operation. The Contractor shall be responsible for making good any such staining or damage to the satisfaction of the Engineer.

A.5 Traffic shall not be permitted on surfaces after they have been cleaned and prepared for prime or tack coat application.

A.6 If there are undue delays in applying prime or tack coats or subsequent paving thereafter, the surface tolerances and compaction of the granular course shall be reverified, deficient areas corrected and or replaced and prime or tack coats reapplied in accordance with the Engineer’s instructions and at the Contractor's expense.

A.7 The Contractor shall maintain prime coats and tack coats intact until they are covered by the subsequent pavement course. Any area where the coats have been damaged shall be cleaned of all loose material, surface defects repaired and the coat re-applied at the Contractor's expense. Traffic control measures shall conform to the relevant requirements of Section 6.07 - Maintenance of Traffic and Detours.

B. Prime Coat Application

B.1 If required by the Engineer, when the surface is an untreated subgrade or a granular surface, the cleaned surface shall be given a light application of water and allowed to dry to the condition deemed appropriate by the Engineer before the bituminous material is applied.

B.2 Heating of MC cutback bitumen and its temperature at the time of application shall conform to the relevant requirements of Section 4.01 - Materials for Bituminous Construction.

B.3 Areas to be primed shall be as shown on the Drawings and shall include 200 mm widths outside the edges of the pavement line, the top of embankment slopes to the pavement lines and between kerbs or gutter edges at bridges and viaducts.

B.4 Application rates for prime coat shall be determined by the Engineer from the trial sections and shall be generally within the following ranges:

Range of Application Rates for Prime Coat

Type of Surface	Litres/ m^2
Untreated subgrade surfaces, shoulders base course:	0.75 - 2.0
Other surfaces:	As determined from field tests or trials

B.5 The Engineer may order additional trial sections and/or alter the previously established rates of application during progress of the Works.

B.6 Prime coat shall be applied using pressure distributors operated by skilled workmen. The spray nozzles and spray bar shall be adjusted and frequently checked so that a uniform distribution is ensured. Spraying shall cease immediately if any nozzle ceases to spray and corrective measures taken before spraying is resumed.

B.7 Hand spraying shall be used only for priming small patches or inaccessible areas that cannot be primed by the normal operation of the pressure distributor.

B.8 Application of prime between separate areas of priming shall not be excessive. Any excess prime coat shall be removed from the surface and any skipped areas or recognized deficiencies shall be corrected using hand sprays.

B.9 When required by the Engineer, a light covering of blotting material shall be applied to the prime coat 48 hours after spraying and when it has not dried sufficiently to withstand damage by traffic. The blotting material shall be a smooth fine sand or other material approved by the Engineer.

B.10 Prime coats shall be cured for 3 days before traffic is allowed on it or before the succeeding pavement layer is placed, or as directed by the Engineer.

C. Tack Coat Application

C.1 Tack coat application shall be as shown on the Drawings and on clean dry surfaces and the application rate shall be as instructed by the Engineer. Emulsified bitumen shall be diluted and thoroughly mixed with an equal amount of water before application.

C.2 Heating of RC cutback bitumen and its temperature at the time of application shall conform to the relevant requirements of Section 4.03: Bituminous Courses. Where slow-curing emulsified bitumen (SS or CSS Type) is used for tack coat, it shall not require heating except in temperatures below 20°C.

C.3 The rate of application shall be approved by the Engineer between 0.3 and 0.6 kg. /sq m. depending on whether RC cutback or emulsified bitumen is used and on the surface condition of the bituminous course on which the tack coat is to be sprayed. The Engineer shall alter the previously established rates of application during progress of the Works, if he deems it necessary.

C.4 The tack coat shall be allowed to dry only until it is in a suitable tacky condition to receive the superimposed bituminous course. Tack coat applications shall not proceed so far in advance of the following course that it dries out completely.

C.5 Spraying procedures shall be as specified for prime coat application.

C.6 Blotting material shall not be applied to tack coats.

4.02.06 MEASUREMENT

A. Bituminous Prime Coat shall be measured by the square metre of the areas primed at the appropriate rate specified by the Engineer.

B. Bituminous Prime Coat for Temporary Diversions shall be measured separately as shown in the Bill of Quantities.

C. Bituminous Tack Coat shall be measured by the square metre of the areas applied at the appropriate rate specified by the Engineer.

D. Surface preparation, protective measures to avoid staining or damage to appurtenances, blotting of prime coats when required and cleaning stains and repairing damage caused by equipment, etc shall not be measured for direct payment, but shall be considered as subsidiary work; the costs of which shall be deemed to be included in the Contract prices for the Pay Items.

PAY ITEM	UNIT OF MEASUREMENT
(4.2.1) Bituminous Prime Coat	Square Meter (m^2)
(4.2.2) Bituminous Tack Coat	Square Meter (m^2)
(4.2.3) Bituminous Prime Coat in temporary diversions	Square Meter (m^2)

SECTION 4.03 BITUMINOUS COURSES

4.03.01 SCOPE

A. The work covered in this Section consists of the general requirements for furnishing materials, mixing at a central mixing plant, spreading and compacting the bituminous base course all as and where shown on the Drawings.

4.03.02 MATERIALS

A. Bituminous mixes shall comprise of coarse and fine mineral aggregate, mineral or cement filler and bitumen with mix additives if specified.

B. All materials shall conform to the relevant requirements of Section 4.01 - Materials for Bituminous Construction.

4.03.03 MIX DESIGN

A. General

A.1 Bituminous concrete mix design shall be conducted based on the Marshall Method of Mix Design (Asphalt Institute Manual Series MS-2) or the Superpave Volumetric Mix Design Method (Asphalt Institute Manual Series SP-2 or AASHTO MP 2).

A.2 Bituminous concrete mix designs shall be performed by the Contractor and verified by the Engineer.

A.3 The bituminous layers of the surface course shall consist of 4 to 7cm thick layers (NMAS 12.5 or 19mm), and those of the bituminous base course shall consist of 7 to 10cm thick layers (NMAS 19 or 25mm). The maximum nominal maximum aggregate size (NMAS) used in the asphalt mix shall depend on the layer thickness as follows:

ASPHALT LAYER THICKNESS (CM)	Maximum NMAS (MM)
4 - 5	12.5
6 - 7	19.0
8 - 10	25.0

B. Marshall Method of Mix Design

B.1 The Marshall design method shall conform to the requirements of the Asphalt Institute Manual Series MS-2.

B.2 The aggregate gradation when tested in accordance with ASTM C126 shall conform to the gradation shown below. Combined gradations which approach maximum limits on some sieves and minimum limits on other sieves shall be avoided.

AGGREGATE GRADATION FOR BITUMINOUS MIXES

SIEVE SIZE (MM)	% PASSING		
	12.5mm NMAS	19.0mm NMAS	25.0mmNMAS
37.5	100	100	100
25.0	100	100	90-100
19.0	100	90-100	68-90
12.5	90-100	69-90	57-78
9.5	68-90	58-78	49-69
4.75	48-68	40-60	34-56
2.36	33-53	25-45	22-42
1.18	20-40	15-30	13-29
0.600	14-30	10-22	8-21
0.300	9-21	6-15	6-14
0.150	6-10	5-10	4-10
0.075	2-10	2-8	1-7

B.3 The Marshall test procedure requires preparing the mixture in accordance to ASTM D6926. Marshall stability and flow shall comply with ASTM D6927 and AASHTO T245. The Marshall testing machine shall conform with ASTM D6927. The performed rate of loading shall be 2 inch/minute.

B.4 The Marshall mix design criteria are listed in the table below:

MARSHALL DESIGN CRITERIA FOR BITUMINOUS MIXES

Properties	**Bituminous Base Course**		
Traffic Volume*	**Low (< 1M ESAL)**	**Medium (1-5M ESAL)**	**High (>5M ESAL)**
No. of compaction blows each end of specimen by freely held Marshall hammer	75	75	75
Stability (kg), minimum	800	900	1000
Marshall Flow (mm)	2 – 3.5	2 – 3.5	2 – 3.5
Stiffness (kg/mm), minimum	400	400	500
% Air Voids	4 – 6	4 – 7	4 – 7
% Voids in Mineral Aggregate (VMA)	Minimum 12 (25 mm NMAS) Minimum 13 (19mm NMAS)		
% Voids Filled with Asphalt (VFA)	60 – 75	55 – 70	50 – 65
Loss of Marshall Stability by 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), ASTM D1075	30	30	30
% Air Voids at Refusal, minimum	2	2	2
Filler to bitumen ratio	0.8-1.4		

C. Superpave Volumetric Mix Design Method

C.1 The Superpave volumetric mix design method shall conform to the requirements of the Superpave Volumetric Design Method (Asphalt Institute Manual Series SP-2 or AASHTO MP 2).

C.2 The bitumen mix shall conform to the mix design requirements shown below:

Design ESALs Million	Gyratory compaction level and % theoretical maximum specific gravity, Gmm			Minimum voids in the mineral aggregate (VMA %) Nominal Maximum Aggregate Size			Voids	Dust to Binder Ratio
	$N_{initial}$	N_{design}	N_{max}	25.0	19.0	12.5		
<0.3	6 ≤ 91.5%	50 ≤ 96.0%	75 ≤ 98.0%	12.0	13.0	14.0	70-80	0.8 – 1.6
0.3 to <3	7 ≤ 90.5%	75 ≤ 96.0%	115 ≤ 98.0%				65-78	
3 to <10	8 ≤ 89.0%	100 ≤ 96.0%	160 ≤ 98.0%				65-75	
10 to <30	8 ≤ 89.0%	100 ≤ 96.0%	160 ≤ 98.0%				65-75	
>30	9 ≤ 89.0%	125 ≤ 96.0%	205 ≤ 98.0%				65-75	

C.3 The consensus aggregate properties are based on the traffic level and the position within the pavement structure. The coarse and fine aggregate properties shall comply with AASTHO M323 requirements:

Design ESALs (Million)	Fractured Face Coarse Aggregate (1 face % min/ 2 face % min) Depth from Surface (mm)		Uncompacted Void Content of Fine Aggregate (% min) Depth from Surface (mm)		Sand Equivalent (% min)	Flat & Elongated (% max)
	≤ 100	> 100	≤ 100	> 100		
<0.3	55/--	--/--	-	-	40	-
0.3 to <3	75/--	50/--	40	40	40	10
3 to <10	85/80	60/--	45	40	45	10
10 to <30	95/90	80/75	45	40	45	10
>30	100/100	100/100	45	45	50	10

C.4 The aggregate gradation shall satisfy the Superpave control points as given in AASHTO MP-2:

SIEVE SIZE (MM)	12.5mm NMAS		19.0mm NMAS		25.0mm NMAS	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
37.5	-	-	-	-	-	100
25.0	-	-	-	100	90	100
19.0		100	90	100	-	90
12.5	90	100	-	90	-	-
9.5	-	90	-	-	-	-
4.75	-	-	-	-	-	-
2.36	28	58	23	49	19	45
1.18	-	-	-	-	-	-
0.600	-	-	-	-	-	-
0.300	-	-	-	-	-	
0.150	-	-	-	-	-	-
0.075	2	10	2	8	1	7

4.03.04 JOB MIXES AND PROJECT MIXES

A. The Contractor shall submit for the Engineer's approval the proposed Job Mix Formula at least 30 days prior to the date of mix production at the mixing plant and after receiving approval of the aggregates and delivery to the Site of the bitumen specified.

B. The Job Mix Formula shall stipulate a single combined grading of all aggregate and filler materials showing the specific ranges in percentage by weight passing each sieve size and of each material to be used in the total mix.

C. The Job Mix Formula shall be established by the Contractor, under the supervision of the Engineer, in the field laboratory. Mix design procedures shall conform to the Marshall or Superpave method of mix design and relevant procedures. All trial mixes shall be prepared and tested by the Contractor in the presence of the Engineer.

D. The Job Mix Formula shall specify a combination of mineral aggregates including filler and bitumen, plus bitumen modifier if required, in such proportions to produce a Job Mix which is within the limits of the specified grading and bitumen content ranges and which meets the Marshall or Superpave test requirements, as prescribed for each particular type of bitumen course. It shall also stipulate the mixing temperature at discharge from the mixer which, unless otherwise agreed by the Engineer, shall be 170ºC.

E. For Marshall mixes, the Marshall Test procedure shall be used to determine the percentage of bitumen to be incorporated in the mix. The Job Mix Formula shall take into consideration the absorption of bitumen into the aggregates. Air voids shall be calculated in accordance with the procedure given in the Asphalt Institute Manual, MS-2. For Superpave mixes, volumetrics shall be calculated in accordance with the procedure give in the Asphalt Institute Manual, SP-2 or AASHTO MP-2.

F. When compacting specimens in accordance with the Marshall Test procedure, the number of blows applied with the compaction hammer shall be 75 on each side, unless otherwise specified

on the Drawings or instructed by the Engineer. Superpave gyratory compactor shall be used to compact Superpave specimens based on the compaction levels specified in Section 4.03.03(C).

G. In order to meet the moisture susceptibility requirements, an approved additive such as hydrated lime or liquid antistripping agent, may be used in the Job Mix. Portland cement shall meet the requirements of AASHTO M 85. Hydrated lime shall meet the requirements of ASTM C 207, Type N. Cement or hydrated lime will normally be required in the approximate range of 1-2% by weight of the aggregates and shall be added at the cold feed in dry or slurry form as directed. Liquid antistripping agent shall be provided in the range of 0.6-1.0% by weight of the bitumen, or according to the manufacturer's specifications.

H. Upon receipt of approval of the Job Mix Formula, the Contractor shall adjust the mixing plant to supply the individual aggregates, mineral filler and bitumen in the correct proportion to produce a final project mix conforming to the job mix limits given in Table 4.3.1.

TABLE 4.3.1: MAXIMUM VARIATIONS OF PROJECT MIX FROM APPROVED JOB MIX

Aggregates passing No. 4 (4.75mm) and larger	± 4%
Aggregates passing No. 8 (2.36 mm)	± 3%
Aggregates passing No. 16 (1.18 mm)	± 3%
Aggregates passing No. 30 (0.6 mm)	± 3%
Aggregates passing No. 50 (0.3 mm)	± 3%
Aggregates passing No. 100 (0.15mm)	± 1%
Aggregates passing No. 200 (0.075mm)	± 1%
Bitumen content	± 0.2%
Temperature of mixing and placement	± 10˚C
Air void content	± 1%

I. Any deviation from the limits in Table 4.3.1 shall be made only with the approval of the Engineer.

J. Conformance to gradation requirements shall be determined on the extracted aggregate in accordance with AASHTO T 30. The bitumen content shall be determined in accordance with AASHTO T 164.

K. The Engineer shall test the project mix at least twice daily during plant operation and, if necessary, direct the Contractor to readjust the plant to conform to the Job Mix Formula. If, due to differing cold feed or hot bin gradations, the Contractor cannot consistently produce a project mix meeting the Job Mix requirements, production shall cease, the Job Mix shall be redesigned and re-approved by the Engineer and the plant readjusted to produce a new Job Mix.

L. The participation of the Engineer in the preparation of the Job Mix Formula shall not relieve the Contractor of his responsibility for producing project mixes meeting the specified requirements.

4.03.05 EQUIPMENT

A. General

Plant and equipment for mixing, transporting, spreading and compacting bituminous mixes shall conform with the requirements set in Volume 1 and to the Contractor's approved Work Programme.

B. Mixing Plant

B.1 Bituminous mixes shall be produced in a batch mixing plant of adequate size with a minimum capacity of not less than 80 tons/hr and a mixer capacity of not less than a 750 kg batch. The plant shall conform to the relevant requirements of AASHTO M 156.

B.2 A mechanical batch counter shall be installed as part of the timing device and shall be designed to register only completely mixed batches.

B.3 The mixing plant shall be fully equipped to control the gradation of hot dry aggregates and of cold damp aggregates. A suitable dust collection system shall be installed, capable of returning all dust to the mixture whenever required. Suitable filters shall be incorporated whenever the mixing plant is in the vicinity of inhabited areas, or whenever they are required by law.

B.4 The cold feed system shall be a continuous belt feed type or other system approved by the Engineer. It shall be easily modified to allow hydrated lime slurry to be added to the mix prior to heating and dry powdered lime to be added after heating.

B.5 An approved type automatic weighing, cycling and monitoring system shall be installed as part of the batching equipment. Facilities for easy sampling of the aggregates from the hot bins whilst the plant is in operation shall also be provided.

B.6 The use of a continuous mixing plant shall only be considered in special circumstances. If the Contractor proposes to use a continuous mixing plant for all or part of the bituminous mixing, full details of the plant including its in-service record and the manufacturer's specifications shall be submitted for approval by the Engineer before proceeding with the purchase or delivery to Site of such plant.

B.7 The Contractor shall systematically inspect and verify in the presence of the Engineer the following key operational aspects of the mixing plant on a weekly basis or whenever suspect:

- The state of repair of the screens and their frame mountings
- Proper working of cold and hot bin gates
- The accuracy of batching scales for filler, aggregates and bitumen.
- Proper working of the nozzles of the mixer bitumen sprayer
- The state of repair of the paddle tips and liners of the mixer

B.8 The Contractor shall furnish for reference and retention by the Engineer one complete set of the manufacturer's instruction and operating manuals for the mixing plant intended for use.

B.9 At the commencement of the Contract, 2 copies each of the latest editions of the Asphalt Institute Specification SS-1 and Manuals MS-2, MS-3, MS-8, MS-22, SP-1, and SP-2 shall be furnished by the Contractor for use by the Engineer's supervisory staff and one copy of each shall be issued to each of the Contractor's senior staff involved in bituminous works. At the end of the Contract all the copies shall become the property of the Employer.

C. Spreading and Finishing Equipment

C.1 Bituminous courses shall be spread and finished using self-contained, power-propelled pavers of sufficient capacity to be capable of laying up to 80 ton/hr. Pavers shall be provided with electronically controlled vibratory screed or strike-off assemblies with devices for heating the screed and shall be capable of spreading and finishing the various courses of bituminous plant

mix to the correct thickness and lane and shoulder widths applicable to the typical cross sections shown on the Drawings and in incremental widths down to 2.4 metres minimum and up to 8 metres maximum.

C.2 Pavers shall employ mechanical devices such as equalizing runners, straightedge runners, evener arms or other compensating devices to maintain the correct grade and confine the edges of the mix to the specified edge lines without the use of stationary side forms. Joint leveling devices shall be provided for smoothing and adjusting longitudinal joints between lanes.

C.3 Pavers shall be equipped with receiving hoppers having sufficient capacity for a uniform spreading operation. Hoppers shall be equipped with a distribution system to place the mix uniformly in front of the full length of the screed.

C.4 The screed or strike-off assemblies and extensions shall effectively produce a finished surface of the required evenness and texture without tearing, shoving or gouging the mix.

C.5 The paver shall be capable of being operated at forward speeds consistent with satisfactory laying of the mix. The speed shall be fully adjustable between 3 and 6 metres/minute.

C.6 Automatic controls shall consist of automatic linkage arrangements such that, through the process of adjusting the screed thickness control, the mix can be placed and finished to a predetermined grade and a uniform crown or cross section. Articulated averaging beams shall be at least 9 metres in length.

C.7 If during construction, the spreading and finishing equipment in operation leaves in tracks or indented areas or other irregularities in the pavement surface 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.8 The Contractor shall make available for reference by the Engineer the manufacturer's instruction and operating manuals for each paver intended for use.

4.03.06 CONSTRUCTION OF TRIAL SECTIONS

A. Immediately prior to finalization of the Job Mix Formula, the Contractor shall lay trial sections of the various bituminous mixes intended for use in the Works. Each trial section shall be 2 lanes wide by 50 metres long at approved locations close to the Site. Each trial section shall be laid using the same materials, Job Mix, mixing, spreading and compaction plant and spreading and compaction procedures proposed for use in the Works.

B. Each trial section shall serve as a field verification of the Job Mix design. The mix density achievable and the air voids at that density shall be determined and, if less than required, the Job Mix Formula shall be adjusted accordingly.

C. Each trial section shall also demonstrate the adequacy of hauling, spreading and compaction equipment and the suitability of the construction method and organization proposed.

D. If the trial section meets the required specification, the Job Mix Formula shall be approved by the Engineer.

E. The trial section shall be carried out at the Contractor's expense and shall be removed from Site, if so required by the Engineer.

4.03.07 MIXING PROCEDURES

A. Each aggregate ingredient shall be heated and dried such that the temperature recorded in the hot fines bin after screening shall not exceed 170 ºC. If any aggregates contain excess moisture that may cause foaming in the mixture or their temperature is in excess of 170 ºC, they shall be removed from the bins and disposed of as directed by the Engineer.

B. Immediately after heating, the aggregates shall be screened into at least 3 sizes and conveyed to separate bins ready for batching and mixing with the bitumen. When the aggregates furnished are of such size and grading that separating into 3 bins is impractical, the number of required separations may, if approved by the Engineer, be reduced to 2 only. Screening operations shall produce, at plant operating capacity, gradations in each of the sizes of heated and dried aggregates that are reasonably uniform and will result in the production of a mix conforming to the Job Mix requirements.

C. The dried and heated aggregate and (cold) mineral filler shall be combined in the plant in the proportionate amounts as determined by the Job Mix. Immediately prior to bitumen entering the mixer, bitumen modifier or antistripping additive, if required, shall be thoroughly mixed with the bitumen which shall then be introduced into the pugmill mixer in the proportionate amounts determined by the Job Mix.

D. The temperature of the bitumen upon entering the pugmill shall be within 15°C of the aggregate temperature. Unless otherwise directed, the bitumen temperature shall be as given in Table 4.3.2.

TABLE 4.3.2: BITUMEN PROPERTIES

Penetration Grade of Bitumen	PG Grade of Bitumen	Viscosity (Centistokes)	Max. Temperature °C Immediately after discharge from Pugmill
85 - 100 pen.	PG 58-xx	170 ± 20	160
60 - 70 pen.	PG 64-xx	170 ± 20	165
40 - 50 pen.	PG 70-xx	170 ± 20	170
-	PG 76-xx	170 ± 20	175

E. Any mix subjected to higher temperatures than those shown in Table 4.3.2 shall be rejected.

F. The mixing time required in order to obtain a homogeneous mix and adequate coating of the aggregates with bitumen shall be determined by the Contractor in the presence of the Engineer. This time shall be redetermined whenever the source of aggregate for the mix changes.

G. In batch plants, mixing time shall begin upon entry of bitumen into the pugmill.

H. Mixing time for continuous mixing plants shall be determined by the following formula or other approved method agreed with the Engineer:

Mixing time (sec) = Pugmill dead capacity (kg) divided by pugmill output (kg/sec)

4.03.08 SURFACE PREPARATION

A. When the bituminous mix is to be placed on a prepared subgrade, sub-base or base, the surface shall be prepared to meet the appropriate specified compaction and surface tolerance requirements. The surface shall then be primed as specified in Section 4.02 - Bituminous Prime and Tack Coats. No bituminous mix shall be laid on a prime coat until it has been inspected and approved by the Engineer.

B. When the bituminous mix is to be placed on an existing bituminous surface, the surface shall be cleaned of all foreign material and broomed free of dust. Any loose, broken or shattered bituminous material along the edges of the existing surface shall be removed and the exposed subgrade, and a sufficient width of the shoulder adjacent to the edge of the existing surface, shall be shaped, bladed, compacted and broomed to provide a uniform firm subgrade for the new surface course.

C. Broken, soft or unstable areas of existing bituminous surface, base or subgrade shall be removed and replaced. The areas shall be excavated to a depth as directed by the Engineer and refilled with the specified bituminous mix.

D. Prior to placing of the bituminous mix on an existing bituminous surface a tack coat as specified in Section 4.02 - Bituminous Prime and Tack Coats shall be applied to the existing surface at the rate determined by the Engineer. No mixture shall be laid on a tack coat until it has been inspected and approved by the Engineer.

4.03.09 DELIVERY, SPREADING AND FINISHING

A. Delivery of Mix to Site

A.1 A sufficient number of haul vehicles shall be provided so that adequate supplies of mix are delivered to ensure paving is a continuous operation.

A.2 Hauling equipment for aggregates and bituminous mixes shall consist of trucks having dump bodies suitable for tipping materials in a windrow or in spreader boxes. The bodies shall be constructed so that volume measurements can be accurately determined. They shall be constructed and maintained such that loss of materials during hauling operations will not occur. Dump controls shall be capable of operation from the driver's seat.

A.3 Hauling equipment for hot bituminous mixes shall have tight, clean, smooth metal surfaces which are periodically thinly coated with a lime solution or other approved material to prevent adherence of the mix. All hauling units shall be equipped with a canvas or other approved type cover which shall be used to cover the hot material upon loading at the mixing plant and shall not be removed until the mix is discharged into the paver. Hot mix material may be transported without such cover only when permitted by the Engineer and in special circumstances.

A.4 The dispatching of the hauling vehicles to the Site shall be scheduled so that all material delivered is placed at least 90 minutes before sunset to allow sufficient time for compaction, unless the use of artificial light has been approved by the Engineer. Delivery of material shall be at a uniform rate and in an amount well within the capacity of the paving and compacting equipment.

A.5 The mix at delivery to the paver shall be not more than 10°C below the discharge temperature at the mixing plant. The minimum temperature for the commencement of compaction is 130°C. Mix loads with temperatures less than 130°C shall not be accepted, and the load shall be

disposed of and another load used. If there is a consistent failure to meet the temperature requirement the Engineer shall order paving operations to stop until suitable measures are taken by the Contractor to ensure that temperature requirements are met.

A.6 Each haul vehicle shall be weighed after each loading at the mixing plant and accurate records shall be kept of the gross and net weight, date and time of loading for each load.

B. Setting Out and Reference Lines

B.1 The Contractor shall survey the centreline profile and crown of the existing surface or base and determine a reference grade line which shall be submitted to the Engineer for approval. A reference line of wire or suitable cord shall be installed at a uniform grade parallel to the approved reference grade line such that conformance with the required geometrics, surface tolerance and minimum thickness requirements shall be ensured. The reference line shall be supported at 8 metre maximum spacing unless there is noticeable sag in the line or the pavement surface, in which case the maximum spacing shall be 4 metres.

B.2 The reference line shall be maintained taut and free from sags at all times during spreading and initial compacting operations.

B.3 Except where the paver is matching a previously placed layer, a wire or cord reference line shall be installed on both sides of the paver for the initial bituminous course being laid. Thereafter only one reference line shall be required if the paver is equipped with adequate automatic superelevation control.

C. Spreading and Finishing

C.1 Bituminous mixes shall only be laid when the air temperature is at least 5 ^{o}C or above and the surface temperature of the underlying course is at least that specified in Table 4.3.3, when the existing surface is free from moisture and when the weather is not foggy, rainy, dusty or excessively windy. The temperature requirements shall only be waived when so directed by the Engineer.

TABLE 4.3.3: MINIMUM SURFACE TEMPERATURES FOR ASPHALT CONSTRUCTION

Asphalt Course Thickness	Minimum Surface Temperature ^{O}C
100 mm or greater	5
Greater than 50mm but less than 100mm	8
50mm or less	10

C.2 After completion of surface preparation the bituminous mix shall be spread and finished true to crown and grade by approved automatically controlled bituminous pavers. The mix shall only be spread and finished by approved hand methods when Engineer determines that machine methods are impracticable. Hand methods shall include heated hand tampers of at least 10 kg weight and mechanical (vibratory) tampers of types approved by the Engineer.

C.3 The paver shall spread the bituminous mix without tearing the surface and shall strike a finish that is smooth, true to cross section, uniform in density and texture and free from hollows, transverse corrugations and other irregularities.

C.4 The paver shall be operated at a speed which gives the best results for the type of paver being used and which coordinates satisfactorily with the rate of delivery of the mix to the paver. A uniform rate of placement shall be achieved without repeated intermittent operation of the paver.

C.5 The mix shall be delivered to the paver in time to permit completion of spreading, finishing and compaction of the mix during daylight hours.

C.6 If during laying the paver is repeatedly delayed because of lack of supply or if the paver stands at one location for an extended period resulting in the (unrolled) mat under and adjacent to the rear of the spreader falling below the minimum temperature for breakdown rolling, the affected portion of mat shall be cut out and discarded and a transverse joint constructed. Paving shall not recommence until the Engineer is satisfied that paving can proceed without interruption.

C.7 Contact surfaces of kerbing, gutters, manholes and similar structures shall be painted with a thin, uniform coating of tack coat material. The bituminous mixture shall be placed uniformly high near the contact surfaces so that after compaction it will be 10 mm above the edge of such structure.

C.8 If during the paving operations the spreading and finishing equipment in operation leaves surface tracks or indented areas or other objectionable irregularities in the pavement that are not satisfactorily corrected by the scheduled operations, the use of the equipment shall be discontinued, until faults are corrected to the approval of the Engineer. If this is not possible, other satisfactory spreading and finishing equipment shall be provided by the Contractor.

C.9 Where successive bituminous layers are to be placed, the surface of each existing layer shall be swept clean with a power broom, or by other approved means and a tack coat applied at the rate designated by the Engineer and in accordance with the relevant requirements of Section 4.02 - Bituminous Prime and Tack Coats.

C.10 Transverse joints in succeeding layers shall be offset by at least 2 metres. Longitudinal joints shall be offset at least 150 mm.

C.11 The bituminous mix shall be spread in one or more layers in order that after rolling the nominal thickness of each layer of the compacted bituminous material does not exceed 3 times the maximum size of aggregate. This maximum thickness may be increased slightly when such an increase is more appropriate to total pavement thickness and provided the Engineer determines that such an increased thickness will not be detrimental to the quality of the finished bituminous course and the Contractor can show that the required density is attained throughout the layer thickness.

C.12 Transitions and structure approaches shall meet the design criteria for geometry and surface tolerance specifications and shall not be visually discontinuous or abrupt in appearance.

C.13 Side roads, entrances and lay-bys shall be paved in accordance with the details shown on the Drawings.

D. Joints and Edges

D.1 All joints between old and new pavements or between successive days' work shall provide thorough and continuous bonds between the old and new material.

D.2 Before placing a fresh mix against previously laid or against old pavement, the contact surface shall be cut back to a near vertical face and shall sprayed or painted with a thin uniform coat of tack coat material unless otherwise directed by the Engineer. Longitudinal joints shall be made by overlapping the paver screed on the previously laid material (cut back as necessary) and depositing a sufficient amount of fresh mix so that the joint formed is smooth and tight.

D.3 The Contractor shall schedule paving operations to minimize exposure of longitudinal joints prior to the completion and compaction of joints. The leading lane shall not be laid in advance of the adjacent trailing lane by more than one half day of paving and the leading lane shall not be laid more than 0.5 km ahead of the trailing lane without the Engineer's approval. In the event of failure to conform to these requirements, the Engineer shall suspend paving on the leading lane.

D.4 Unsupported edges of bituminous layers shall be rolled immediately following the rolling of the longitudinal joint. The material along the unsupported edge may, with the Engineer's approval, be raised slightly by hand methods to ensure that the full weight of the roller will bear fully on the edge material.

D.5 On completion the longitudinal edges of bituminous pavement shall be true to the width and alignment as shown on the Drawings. The edges shall be cut back if necessary prior to rolling, additional mix placed manually in a longitudinal strip adjoining each pavement edge and the edge rolled down to a neat 3:1 (H:V) slope or as shown on the Drawings.

D.6 Transverse joints shall be carefully constructed and thoroughly compacted to provide a smooth riding surface. Joints shall be straight-edged and string-lined to assure smoothness and a true alignment. If the joint is formed with a bulkhead, such as a board, to provide a straight line and vertical face, it shall be checked with a straight edge before fresh material is placed against it to complete the joint. If a bulkhead is not used to form the joint and the roller carries over the end of the new material, the line shall be cut back a sufficient distance to provide a true surface and cross-section. If the joint has been distorted by traffic or by other means, it shall be trimmed to line. In either case, the joint face shall be painted with a thin coating of bitumen before the fresh material is placed against it.

E. Compaction

E.1 Rollers shall be operated by competent and experienced operators in accordance with the manufacturer's instructions, copies of which shall be submitted to the Engineer. Rollers shall be kept in operation continuously during paving operations so that all parts of the pavement receive substantially equal compaction at the time desired.

E.2 After spreading and strike-off and as soon as the mix conditions permit the rolling to be performed without excessive shoving or tearing, the mixture shall be thoroughly and uniformly compacted using approved types, sizes and numbers of rollers. Rolling shall not be prolonged to the point where cracks appear or shoving or displacement occurs.

E.3 All rollers shall be self-propelled vibratory steel wheel, 2-axle tandem steel-tired and pneumatic-tired types in proper operating condition, capable of reversing without backlash or tearing of the surface and shall be operated at speeds slow enough to avoid displacement of the bituminous mix. The minimum numbers of rollers required is 3, of which one shall be a pneumatic type. The Contractor shall select a suitable method and pattern of rolling that will achieve the required compaction, to the Engineers approval.

E.4 Prior to use on site of pneumatic-tired rollers, the Contractor shall furnish, for reference and retention by the Engineer, manufacturers' charts or tabulations showing the contact areas and contact pressures for the full range of tyre inflation pressures and for the full range of tire loadings for each type and size of compactor tire to be used. The Contractor shall ensure that tyre pressures are maintained at all times in conformity with such charts or tabulations. The maximum allowable tolerances shall be plus or minus 35 kN/m^2.

E.5 Rollers shall move at a slow but uniform speed with the drive roll or wheels nearest the paver. Recommended speeds are shown in Table 4.3.4.

TABLE 4.3.4 RECOMMENDED SPEEDS OF ROLLERS (Km/Hr)

	Breakdown	Intermediate	Finish
Steel Tired Static Weight Rollers	3	5	5
Pneumatic Tired Rollers	5	5	9
Vibratory Rollers	4.5	4.5	-

E.6 If vibratory rollers are used the vibration mechanism shall be turned off before changing direction before the roller has stopped and turned on again on completion of the manoeuvre.

E.7 Rolling shall begin as soon as the mixture will bear the roller weight without undue displacement. The minimum temperature of the mat at which rolling shall be allowed to start is 120°C.

E.8 Breakdown rolling shall consist of 3 complete coverages unless otherwise directed. Rolling shall be longitudinal, beginning at the low side of the spread of material and proceeding towards the high side, overlapping on successive trips by at least one half the width of the rear wheels. Alternate passes of the rollers shall be of slightly differing lengths.

E.9 The speed of the rollers, rolling pattern and, in the case of vibratory rollers, the frequency and amplitude of vibration shall be approved by the Engineer. To prevent adhesion of the mix to the rollers, the wheels shall be kept properly and lightly moistened with water. An excessive use of water shall not be permitted.

E.10 The rolling pattern, type and number of rollers shall be established by a site trial to achieve the required compaction. The established rolling pattern shall be follows.

E.11 The initial or breakdown rolling shall be followed by intermediate rolling involving passes with pneumatic-tired rollers unless otherwise specified. Tyre contact pressure shall be as approved by the Engineer.

E.12 Finishing rolling shall be carried out by means of tandem power steel rollers unless otherwise agreed by the Engineer. If the specified density is not achieved, changes shall be made in size and number of rollers being used to ensure the compaction requirements are met.

E.13 The compacted density for all bituminous courses shall be 97.5% of the average bulk specific gravity determined in the lab for each day's production unless otherwise directed by the Engineer.

E.14 Any mix that becomes loose, broken, mixed with foreign material or which is defective in finish or density or which does not conform in all other respects with the specified requirements shall be removed and replaced with suitable material and properly finished.

4.03.10 SAMPLING AND TESTING

A. Sampling and testing shall conform to the relevant requirements of Part 1 of the Specifications, Section 4-6 "Samples and Approvals", and Table 4.3.5.

TABLE 4.3.5: TESTS FOR BITUMINOUS PAVEMENTS: MINIMUM REQUIREMENTS

Work Item	Test at Source of Material	Frequency	Test at Road Site	Frequency
4-1 Materials used in Asphalt Mix (at Batching plant)	1- Specific gravity and water absorption 2- Abrasion test 3- Chert content 4- Clay lumps and friable particles 5- Flaky and elongated particles 6- Soundness	For each source **and** When material quality changes **and** When requested by the Engineer		
4-2 Materials used in Asphalt mix (from hot bins)	1- Gradation 2- Specific gravity and water absorption 3- Plasticity index 4- Sand equivalent 5- Stripping with asphalt	For each source **and** When material quality changes **and** When requested by the Engineer		
4-3 Asphalt Mix Design (each layer) (At Batching Plant)	1- Complete mix design 2- Loss of stability	For each Project **and** When material quality changes **and** When results are not consistent with the mix design results **and** When requested by the Engineer		
4-4 Asphalt for each layer	<u>At Batching Plant</u> 1- Stability 2- Flow 3- Binder content and gradation 4- Air voids 5- Voids in mineral aggregates 6- Daily Marshall density	Every 3 working days **and** For each batching plant **and** When requested by the Engineer	<u>Behind Spreader</u> 1- Stability 2- Flow 3- Binder content & gradation 4- Air voids 5- Voids in mineral aggregates 6- Marshall density	Every working day **and** Test for each batch **and** When requested by the Engineer
	7- Loss of Stability	Every week **and** When requested by the Engineer	<u>Core Samples</u> 7- Density and thickness 8- Bitumen penetration grade verification	Every 200m per lane and each layer **and** When requested by the Engineer

B. The bulk specific gravity shall be determined in accordance with AASHTO T 166. The specimens shall be prepared from the same material used in the construction, taken from samples of fresh bituminous mix at the mixing plant or from trucks delivering mix to the Site. Oven heating for up to 30 minutes to maintain the heat of the sample is permissible.

C. The bulk specific gravity of the mix as placed and compacted in situ shall be determined from 100 mm nominal diameter core samples or slab samples cut from each compacted layer on the road at locations selected by the Engineer. The Engineer reserves the right to instruct additional tests to determine the limits of areas deficient in density or for verification.

D. Core samples for in-situ bulk specific gravity determination and verification of bitumen binder penetration grade shall be taken in sets of two from each pavement location. The minimum frequency of sampling for each bituminous layer shall be one set/lane/500 m, with a minimum of one set per day of placed bituminous layers.

E. The Contractor shall cut the samples with an approved core drill in the presence of the Engineer. The equipment shall be capable of cutting the mixture without shattering the edges or otherwise disturbing the density of the specimen.

F. The Contractor shall, when necessary, furnish and apply cold water, ice, or other cooling substance to the surface of the pavement to prevent the sampling from shattering or disintegrating. The Contractor shall fill and compact all test holes at his own expense.

4.03.11 SURFACE TOLERANCES

A. The fully compacted and completed bituminous course shall conform to the lines, grades and cross sections as shown on the Drawings.

B. The elevations of the finished course shall be checked by the Contractor in the presence of the Engineer at maximum intervals of 10 metres and at intermediate points as directed.

C. When the finished surface is tested with a 3 meter long straightedge, placed parallel to, or at right angles to the centreline, the maximum deviation of the surface from the testing edge between any two contact points shall not exceed the tolerances specified for each type of bituminous course laid.

D. All areas which exceed the specified tolerances shall be corrected by removing the defective sections of bituminous course and reconstructing them or by adding new material and recomposing and finishing to the specified standard or increasing the thickness of the succeeding course.

E. The tolerances specified for evenness of finished surfaces for all types of bituminous courses shall not invalidate the tolerances specified for construction thickness and elevations of such courses.

4.03.12 DETERMINATION OF LAYER COURSE THICKNESSES.

A. The Contractor shall compensate for minor deficiencies in the thickness of any bituminous course in the pavement structure by increasing the thickness of the subsequent bituminous course.

B. Cylinder core samples shall be taken as specified for in situ bulk specified gravity core samples.

C. Thicknesses of bituminous courses shall be determined by calliper measurements of cores, rounded upwards to the nearest mm.

D. Paved sections to be measured separately shall consist of 300 metre sections in each traffic lane. The last section in each traffic lane shall be 300 metres plus the fractional part of the 300 metres remaining. Other areas such as intersections, entrances, crossovers and ramps shall be measured as one section and the thickness of each shall be determined separately. Small irregular unit areas may be included as part of another section.

E. One core shall be taken from each section by the Contractor at locations approved by and in the presence of the Engineer. When the measurement of the core from any paved section is not deficient by more than 5 mm from the specified thickness, the core shall be deemed to be of the specified thickness as shown on the Drawings.

F. When the measurement of the core from any paved section is deficient by more than 5 mm but not more than 20 mm, 2 additional cores spaced at not less than 100 metres shall be taken and used together with the first core to determine the average thickness of such a section.

G. When the measurement of the core from any paved section is less than the specified thickness by more than 20 mm, the average thickness of such section shall be determined by taking additional cores at not less than 5 metre intervals parallel to the centreline in each direction from the affected location until, in each direction, a core is taken which is not deficient by more than 20 mm. Exploratory cores for deficient thicknesses shall not be used in average thickness determinations.

H. If the deficiency in total asphalt layers thickness is from 0 - 3mm, full payment will be made, on condition that deficiencies are not found in more than 10% of the total project. For deficiencies between 3mm and 10mm, 80% of the full payment for the bituminous courses shall be made.

4.03.13 MEASUREMENT

A. Bituminous Courses shall be measured as prescribed in each of the respective Sections for each type of bituminous course constructed and accepted. Measurement shall not include the rolled edge strips of bituminous courses placed outside the edge of paving as shown on the Drawings.

B. Bituminous prime and tack coats shall be measured as prescribed in Section 4.02 - Bituminous Prime and Tack Coats.

C. Bituminous overlays constructed to correct deficiencies in total thickness of bituminous courses or to compensate for major deficiencies in the thickness of any underlying bituminous course, shall not be measured for direct payment, but shall be considered as subsidiary work; the costs of which shall be deemed to be included in the Contract Prices for Pay Items.

D. Establishment of the Job Mix Formula, surface preparation, construction of joints, hand painting of contact surfaces, remedial treatment of surface irregularities, cutting of cores and slabs for

testing or measurement purposes, reinstatement of core and slab areas of pavement, rolled down longitudinal bituminous edge strips, additional thicknesses of bituminous courses in excess of the specified thickness and other ancillary items shall not be measured for direct payment, but shall be considered as subsidiary work; the costs of which shall be deemed to be included in the Contract Prices for Pay Items.

SECTION 4.04 BITUMINOUS BASE COURSE

4.04.01 SCOPE

The work covered in this Section consists of furnishing materials, mixing at a central mixing plant and spreading and compacting bituminous base course on an approved granular base, sub-base or subgrade as and where shown on the Drawings.

4.04.02 MATERIALS

A. All materials shall conform to the relevant requirements of Section 4.01 - Materials for Bituminous Construction.

B. Unless otherwise shown on the Drawings, bitumen for base course construction shall be 60/70 penetration graded bitumen or PG 64-10.

C. When an approved modifier is to be added and mixed with the bitumen, the bitumen used shall not be of lower penetration than 80/100 grade.

4.04.03 JOB MIX AND PROJECT MIX

A. The Job Mix Formula shall be established by the Contractor in accordance with the procedures and requirements of Section 4.03 - Bituminous Courses.

B. After the Job Mix Formula has been established and approved by the Engineer, all mixes furnished shall conform to it within the stated tolerances (Section 4.03.04).

C. The Job Mix Formula shall be re-established if the source of aggregate, filler or bitumen changes.

4.04.04 EQUIPMENT

Plant and equipment for mixing, hauling, placing and compacting bituminous base course material shall conform to the relevant requirements of Section 4.03 - Bituminous Courses.

4.04.05 CONSTRUCTION OF TRIAL SECTIONS

Trial sections shall be constructed as and where directed by the Engineer and in accordance with the relevant requirements of Section 4.03 - Bituminous Courses.

4.04.06 MIXING PROCEDURES

Handling and mixing of bitumen (including modifier and antistripping agent, if any) and aggregates (including mineral filler if required) shall be in accordance with the relevant requirements of Section 4.03 - Bituminous Courses.

4.04.07 SURFACE PREPARATION

Preparation of the surfaces upon which the bituminous base course mix is to be laid shall be appropriate to the type and condition of such surfaces and shall conform to the relevant requirements of Section 4.03 - Bituminous Courses.

4.04.08 DELIVERY, SPREADING AND FINISHING

A. General

The delivery, spreading and finishing of bituminous mix for base course shall conform with the relevant requirements of Section 4.03 - Bituminous Courses and to the following particular requirements.

B. Rollers

B.1 Initial breakdown rolling shall be carried out using 2 dual-drum vibrating steel-wheeled vibrating rollers each of a minimum weight of 7,000 kg and with vibrating frequency of 2,000-3,000 cycles/min. These rollers shall be purpose-made for compaction of hot bituminous courses.

B.2 Intermediate rolling shall be carried out using least 2 self-propelled, tandem pneumatic smooth-tired rollers each capable of exerting contact pressures of up to 690 kN/mm^2 and ballast - adjustable to ensure uniform wheel loadings.

B.3 Final rolling shall be carried out using two 2-axle tandem steel-tired rollers each of minimum weight 10,000 kg, capable of exerting contact pressures of up to 65 kg/cm.

B.4 The number of rollers used for any stage of rolling may be reduced by the Engineer to one, provided that the base course width being compacted is less than 5.5 m in width, and provided an equivalent standby roller is available on Site as a replacement in the event of breakdown of the operating roller.

C. Standard of Compaction

The compacted density of the bituminous base course shall be 97.5% of the average bulk density for each day's production.

4.04.09 SAMPLING AND TESTING

Sampling and testing shall conform to the relevant requirements of Section 4.03 - Bituminous Courses.

4.04.10 SURFACE TOLERANCES

A. Surface tolerances shall conform with the relevant requirements of Section 4.03 - Bituminous Courses and to the following particular requirements.

B. The tolerances on elevations of the finished bituminous base course surface shall be not greater than plus 10 mm or less than minus 10 mm.

C. When the finished surface is tested with a 3 metre long straightedge, placed parallel to, or at right angles to the centreline, the maximum deviation of the surface from the testing edge between any two contact points shall not exceed 8 mm.

4.04.11 DETERMINATION OF THICKNESS

A. Procedures for determining the average compacted thickness of bituminous base course shall conform with the relevant requirements of Section 4.03 - Bituminous Courses and to the following particular requirements.

B. Cores for thickness measurements shall be used to determine if changes are necessary in the constructed thickness of succeeding bituminous layers to rectify any thickness deficiencies in the bituminous base course.

4.04.12 MEASUREMENT

A. Bituminous Base Course shall be measured by the cubic meter of mix furnished, spread, compacted, completed and accepted. Measurements shall be based on the areas and thickness as shown on the Drawings or as otherwise directed by the Engineer.

B. The rate for Bituminous Base Course used in temporary diversions shall also include for removal and disposal of the base course material and reinstatement of the temporary diversion, to the satisfaction of the Engineer, on completion of use.

C. Bituminous prime and tack coats shall be measured as prescribed in Section 4.02 - Bituminous Prime and Tack Coats.

PAY ITEM	UNIT OF MEASUREMENT
(4.04.1) Bituminous Base Course	Cubic Meter (m^3)

SECTION 4.05 MILLING

4.05.01 DESCRIPTION

This work shall consist of milling the surface of asphalt concrete pavement as shown on the Drawings and as specified in these specifications, or as directed by the Engineer.

4.05.02 REQUIREMENTS FOR MILLING

Milled areas shall begin and end at lines normal to the pavement center-line and shall be centered within the lane width. Milling in any lane shall cover the full lane width.

Milling groove blades shall be 2.41 mm ± 0.13 mm wide and shall be spaced 19 mm on centers. The grooves shall be cut, not less than 3 mm nor more than 7 mm deep.

At the beginning of each work shift, all milling machines shall be equipped with a full complement of grooving blades that are capable of cutting grooves of the specified width, depth and spacing. If during the course of work, two or more grooving blades on any individual milling machine become incapable of cutting grooves, the Contractor shall immediately discontinue work no more than a distance of 15 m of the location where two or more blades became incapable and replace all defective grooving blades before continuing work with the affected milling machine for the remainder of the work shift.

The actual milled area of any selected 0.6 m by 30 m longitudinal area of pavement specified to be milled shall be not less than 95 percent of the selected area. Except for grooves resulting from incapable blade/s within permitted practice mentioned above, any area within the selected area not grooved shall be due only to irregularities in the pavement surface and for no other reason.

Residue from milling operations shall be picked up by means of sweeping and collection and shall not be allowed to flow across the pavement nor be left on the surface of the pavement. Residue from milling shall be collected and disposed of outside the right of way in conformance with the provisions of the Contract Documents. The noise level created by the combined milling operation shall not exceed 86 dBA at a distance of 15 m at right angles to the direction of travel.

4.05.03 MEASUREMENT

PAY ITEM	UNIT OF MEASUREMENT
(4.05.03) Milling	Square Meter (m^2)

DIVISION 5

CONCRETE AND STRUCTURES

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SECTION 5.01 CONCRETE AND CONCRETE MIXES AND TESTING

5.01.01 SCOPE

These works shall consist of the specifications for concrete materials including sampling, testing and storage of such materials, concrete strength requirements, concrete testing procedures and requirements, and job mixes.

5.01.02 MATERIALS

A. Cement

A.1 Cement shall be Portland Cement originating from manufacturers approved by the Engineer and shall comply with AASHTO M85 Type I in the case of Ordinary Portland Cement and with or AASHTO M85 Type II or Type V as directed by the Engineer in the case of Sulphate Resisting Portland Cement.

A.2 Only one type or brand of cement shall be used in any one structural member. Mixing of types or brands will not be permitted.

A.3 All cement shall be subject to approval and shipments of cement shall be accompanied by a manufacturer's Certificate of Guarantee and/or laboratory test certificate. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.4 When tests at the factory or field tests subsequent to the original approval tests show that the cement does not comply with the specifications, the entire consignment from which the sample was taken shall be rejected and the Contractor shall immediately remove the rejected material from the Site and replace it with cement which meets the required specifications.

A.5 Whenever low alkali cement is specified the total alkali content estimated as sodium oxide equivalent shall not exceed 0.60% by weight. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.6 If no local test certificate is available, the Contractor shall obtain from each proposed manufacturer a typical sample of cement which shall be fully and independently tested in accordance with the appropriate standard and the results submitted for approval Primary and secondary sources of the required cements shall be given. All costs associated with the testing shall be allowed for by the Contractor.

A.7 Details shall also be submitted of the manufacturer's name and address of producing works, manufacturer's description of cement type and brand name and standards to which compliance is guaranteed.

A.8 Average values and corresponding maximum and minimum values in respect of the following composition and properties shall be submitted, covering a continuous production period of at least 6 months ending not earlier than 3 months before submission of the data. The Contractor shall state if any material or production process changes have been made since the end of the above period; if any are proposed, brief details shall be given.

Composition	**Properties**
Insoluble residue	Lime saturation factor (LSF)
Silica (SIO_2)	Alumina-iron ratio (A/F)
Alumina (AL_20_3)	Tri-calcium aluminate (Ca3A1)
Total Iron ($Fe_2 O_3$)	Free lime in clinker (as CaO)
Calcium (CaO)	Total acid solution alkalis
Magnesium (MgO)	Heat of hydration
	- at 7 days
	- at 28 days
Potassium ($K_2 O$)	
Sodium (Na_2)	Fineness (m^2./kg)
Sulfate (SO_3)	Setting times
	- Initial (min)
	- Final (min)
Sulfur (S)	
Chloride (Cl)	Soundness (mm)
Loss on ignition	Compressive strength
	- 3 days
	- 7 days
	- 28 days
	- 3 months

A.9 The requirements of item A8 may be dispensed with at the discretion of the Engineer, who shall give such dispensation in writing.

A.10 The manufacturer's bulk average test certificate for each consignment of cement shall be submitted, showing the results for chemical composition and physical properties determined in accordance with the relevant standard. Samples shall be taken for each consignment of cement and tested as directed by the Engineer in an approved independent laboratory, at the cost of the Contractor.

A.11 Where bulk cement deliveries are proposed, the Contractor shall provide all information required by the Engineer concerning off-site storage and loading arrangements and shall provide reasonable facilities for the Engineer to inspect these arrangements for approval purposes. Consignments shall be used in the order in which they are delivered.

A.12 Storage capacity shall be sufficient to meet the schedule of work so that continuous work is achieved. Cement shall be stored in moisture-proof storage sheds. Neither stale, caked, nor reclaimed or re-sacked cement shall be used. The Contractor shall not store cement in areas subject to flooding.

A.13 Cement remaining in bulk storage at the mill, prior to shipment, for more than 6 months or cement stored in bags in local storage by the Contractor or a vendor for more than 3 months after shipment from the mill, may be retested before use and will be rejected if it fails to meet any of the requirements of these specifications.

B. Aggregates

B.1 Potential aggregate sources shall be examined and particular attention shall be paid to the following aspects of the deposits and the actual or proposed extraction and production arrangements:

Name, location, local national grid reference, type of deposit, potential variability, methods of extraction.

Methods and degree of control exercised over extraction.

Processing methods, types of plant, number of processing stages, standards of maintenance and process control, producer's laboratory facilities and technical staffing.

Stockpiling arrangements, loading and supply arrangements.

Potential variations in end-products due to variations inherent in the deposit and in the existing methods of extraction, processing and stockpiling.

Possible modifications to existing extraction, processing, storage and handling arrangements, and to supervision arrangements to reduce end-product variations.

Possible requirements for supplementary processing on site.

Photographs shall be provided of each of the proposed new sources and related production arrangements. The source photographs should preferably include low level (helicopter) aerial photographs and close-ups of working faces.

B.2 Aggregate deposits shall be sampled and tested in an appropriate and systematic manner to assess their potential variability and to assist in determining appropriate methods of extraction and processing.

B.3 The deposit investigation and sampling programs shall be relevant to each type of deposit and shall be devised and supervised by an experienced approved engineering geologist, after he has made a field reconnaissance of the potential deposit areas, or the existing workings.

B.4 Each size of aggregate shall be sampled at the discharge points on the production plant (i.e. conveyors or hoppers, not stockpiles) at three well spaced intervals during the course of each of three consecutive production days; these samples shall be designated “production samples”.

B.5 In addition, selected samples shall be taken from producer’s stockpiles to represent any readily visible variations in physical characteristics, or appearance, or materials ready for loading, these samples shall be designated “stockpile samples”.

B.6 All samples shall be taken by arrangement with and in the presence of the Engineer, or his representative, and shall be tested as required below.

B.7 Representative portions of the above samples shall be taken for reference purposes and shall be split and retained on site by the Contractor and by the Engineer.

C. Testing Aggregates

C.1 Each production sample shall be tested for the following:

Proportion of natural (uncrushed) material (% by weight) gradings, passing 75mm sieve (U.S. Sieve No.200 to AASHTO M92 or ASTM M81) when tested in accordance to AASHTO T 11 .
Total acid soluble chloride content and total acid soluble sulfate content (% by weight).
Flakiness and elongation indices.

C.2 Representative portions of equal weight shall be taken from each of the production samples of each size of aggregate and then combined to provide composite production samples for each size of aggregate. The composite samples shall be tested as for the individual unless otherwise directed by the Engineer.

Potential Reactivity tests for alkali-silicate and alkali-carbonate reactions: petrographic examination in accordance with ASTM C295, rapid chemical method in accordance with ASTM C289 and rock expansion test in accordance with ASTM C586.

If one or more of the tests in sub-item C.2.1 above are positive then the mortar prism test in accordance with ASTM C227 shall be carried out.

Partial chemical analysis, including insoluble residue (ASTM D3042-84), chloride content, sulfate content and calculated approximate composition.

ASTM Soundness Test C88, using sodium sulfate solution or ASTM Soundness Test C88, using magnesium sulfate solution.

Aggregate Impact Value by the Los Angeles test in accordance with AASHTO T96-83 ASTM C 131 -81, ASTM C535-81.
10% Fine Value to BS 812.

Aggregate Abrasion Value to BS 812.

Specific Gravities and Water Absorption to BS 812 or approved ASTM equivalent

C.3 Stockpile samples shall be examined and tested in as many of the above mentioned respects as are considered relevant by the Engineer.

C.4 The properties of the aggregates shall be such that the Drying Shrinkage of concrete prepared and tested in an approved laboratory in accordance with the United Kingdom Building Research Station Digest No. 35 (Second Series) shall not exceed 0.045 percent.

The Initial Drying Shrinkage of all the proposed concrete mixes prepared and tested in an approved laboratory in accordance with BS 1881 shall not exceed 0.06 percent.

C.5 Aggregate for use in concrete or mortar that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground, shall not contain material that is deleteriously reactive with the alkalis in the cement, or any which maybe additionally present in the aggregates and mixing water or water in contact with the concrete or mortar, in amounts sufficient to cause excessive localized or general expansion of concrete or mortar.
Under no circumstances shall the Contractor use Dacite, Andesite, Rhyolites, Opal Cherts and Tuffs.

Coarse and fine aggregates shall be tested for reactivity potential in accordance with the methods listed above and shall satisfy the various criteria given for innocuous aggregates in the relevant standard.

In case the aggregate source has no previous records and no performance history, potential reactivity should be evaluated using the specified tests. However, if the aggregate has been used in previous works in adjacent location and performed well without showing signs of Alkali reaction, the results of these tests should not be used as

the only factor deciding the usage of the aggregate. The Engineer shall then decide on this matter.

The period of the tests is minimum 14 weeks to 26 weeks unless the accelerated test is used instead of the mortar bar test (ASTM C227).

D. Fine Aggregates

D.1 Fine concrete aggregates shall conform to AASHTO M6 and shall consist of natural sand or crushed rock having hard and durable particles or, if approved by the Engineer other inert materials having similar characteristics, 100% passing 9.5 mm sieve and 2% to 10% passing 0.15 mm sieve. It shall not contain harmful materials such as iron pyrites, coal, mica, shale or similar laminated materials such as flat and elongated particles or any materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength, durability and texture of the concrete.

D.2 The Contractor shall, when directed by the Engineer, wash the fine aggregates to remove deleterious substances or for consistency of concrete colour. Such washing shall be carried out using fresh water. The water shall be replaced regularly as deemed necessary to maintain its chloride and/or sulfate content low.

D.3 The total acid soluble sulfate content (BS 812:Part 118 1988) of fine aggregate expressed as sulphur trioxide (S03), shall not exceed 0.40% by dry weight (AASHTO T260-82, BS 812: Part 117). The total acid soluble chloride content expressed as sodium chloride (NaCl) shall not exceed 0.10% by dry weight of fine aggregate. The following additional requirements shall apply to the concrete mix:

Total sulfate content (as S03) of any mix excluding that present in the cement but including any present in the other materials shall not exceed 2.5% by weight of cement in the mix.

Total chloride content (as NaCl) of any mix including any chloride present in the other materials and in the mix water shall not exceed 0.35% by weight of cement in the mix.

D.4 Fine aggregate shall meet the following additional requirements:

Fineness modulus AASHTO M6: ± 0.20% of approved value which shall be not greater than 3.1 or less than 2.3. Sieve analysis to AASHTO T27.

Sodium or magnesium sulfate soundness AASHTO T104: max. 12%, 18% loss respectively.

Content of clay lumps and friable particles, AASHTO T 112-82: 3% max.

Sand equivalent AASHTO T176: min 75% .
Coal and lignite, AASHTO T113-82: 0.5% max.

Organic impurities AASHTO T21-81: not darker than standard colour.

D.5 The amount of hollow shells likely to form voids and present in material retained on a 2.36 mm sieve determined by direct visual separation, shall not exceed 3% by weight of the entire sample.

D.6 When sampled and tested in accordance with the appropriate sections of BS 812 (using BS 410 test sieves) the grading of fine aggregates shall be within the limits of the grading zones given in Table 4 of BS 882. The fine aggregate shall be described as a fine aggregate of the grading zone into which it falls.

D.7 If the fineness modulus varies by more than 0.2 from the value assumed in the concrete mix design, the use of such fine aggregate shall be discontinued until suitable adjustments can be made in the mix proportions to compensate for the difference in gradation.

E. Coarse Aggregates

E.1 Coarse concrete aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel, or crushed stone free from coating of clay or other deleterious substances. It shall not contain harmful or any other materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength and durability of the concrete. If necessary, coarse aggregate shall be washed to remove deleterious substances, or for consistency of concrete colour.

E.2 The total acid soluble sulfate content (BS812: Part 118, 1988) of coarse aggregate expressed as sulphur trioxide (S03), shall not exceed 0.40% by weight (AASHTO T260-82, BS812: Part 117). The total acid soluble chloride contents of coarse aggregates, expressed as sodium chloride (NaCl), shall not exceed 0.05% by weight. These limits are subject to the following overriding requirements:

The total sulfate content (as S03) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix

The total chloride content (as NaCl) of any mix, including any chloride present in the other materials and the mix water, shall not exceed 0.35% by weight of cement in the mix.

E.3 Coarse aggregate shall also meet the following additional requirements:

Sodium or magnesium sulfate soundness AASHTO T104: 5 cycles: max. 12%, 18% loss respectively.

Abrasion, in accordance with AASHTO T96 max 40% loss.

Content of clay lumps and friable particles AASHTO T112-81: max. 1% by weight.

Soft fragments and shale AASHTO M80: max. 5% by weight.

Flakiness index, BS812: 30% max. Elongation index, BS 812:30% max.

Coal and Lignite, AASHTO T113-82: 0.5% max.

E.4 The grading of coarse aggregate shall comply with AASHTO M43.

E.5 The coarse concrete aggregate, when tested according to AASHTO T27, shall meet the following gradation requirements and shall be graded within the limits stated in Table5.1.1.

Table 5.5.1: Limits of Gradation for Coarse Aggregates

AASHTO Sieve Size	mm	Percent Passing by Weight for					
		Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
3'	75	100	-	-	-	-	-
2 ½"	63	-	100	-	-	-	-
2"	50	90-95	95-100	100	-	-	-
1 ½"	37.50	-	-	95-100	100	-	-
1"	25.0	30-65	35-70	-	95-100	100	-
3/4"	19.0	-	-	35-70	-	95-100	100
1/2"	12.5	10-30	10-30	-	25-60	-	90-100
3/8"	9.5	-	-	10-30	-	20-55	40-70
No. 4	4.75	0-5	0-5	0-5	0-10	0-10	0-15
No. 8	2.36	-	-	-	0-5	0-5	0-5
No. 200	0.075	0-1	0-1	0-1	0-1	0-1	0-1

E.6 The type of grading for coarse concrete aggregates shall depend on the maximum size of aggregate, which shal1 not be larger than one-fifth (1/5) of the narrowest dimension between sides of forms, nor larger than two-thirds (2/3) of the minimum clear spacing between reinforcing bars, whichever is least.

E.7 Before batching, all types of coarse aggregate shall be separated into fractions having uniform grading as determined by the Engineer.

E.8 However, the number of fractions and their gradings shall be fixed on the basis of the maximum size of the aggregates in the cement concrete as proposed below:

- For fractions up to 1-1/4":(31.5 mm) between 3/8" and 3/4" (9.5 - 19.0 mm).
- For fractions up 1-1/2" to 3": (37.5-75 mm) between 3/4" and 1-1/4" (19.0 - 31.5 mm)

F. Combined Aggregates

F.1 Combined aggregate is composed of a mixture of coarse aggregates and fine aggregates. They shall be used only in proportions with the prior approval of the Engineer.

F.2 In no case shall materials passing the No. 200 (0.075 mm) sieve exceed 3% by weight of the combined aggregate.

F.3 The combined concrete aggregate gradation used in the work shall be as specified, except that when approved or directed by the Engineer. Grading 7 of Table shall be used for curbs, handrails, parapets, posts and other similar sections or members with reinforcement spacing too close to permit proper placement and consolidation of the concrete.

F.4 Changes from one gradation to another shall not be made during the progress of work, unless approved by the Engineer.

F.5 For the proportion of each fraction of coarse aggregate and for the proportion of fine and coarse aggregate, the combined gradings in Table 512 shall be utilized as a

guideline for the mix proportion design as to guarantee the maximum densities of the concrete. Before batching, however, the Engineer or his representative shall check only the compliance of the grading of the fine and coarse aggregate with the requirements of the Specifications, since the grading of each fraction ultimately remains the sole responsibility of the Contractor.

Table 5.1.2: Limits of Gradation for Combined Aggregates

AASHTO Sieve Size	mm	Combined Aggregate Percent Passing by Weight for						
		Grading 1	Grading 2	Grading 3	Grading 4	Grading 5	Grading 6	Grading 7
3"	75	100	-	-	-	-	-	-
2 ½"	63	88-95	100	-	-	-	-	-
2"	50	78-90	85-95	100	100	-	-	-
1 ½"	37.50	66-81	74-86	80-92	93-98	100	-	-
1"	25.0	51-70	56-75	63-80	70-88	87-96	100	-
3/4"	19.0	43-62	47-67	52-72	60-79	73-86	80-96	100
1/2"	12.5	32-53	36-58	41-60	47-66	57-74	61-80	73-86
3/8"	9.5	27-48	30-53	36-54	40-60	48-68	52-72	61-79
No. 4	4.75	19-38	22-42	23-43	28-49	34-55	38-56	43-64
No. 8	2.36	9-27	10-29	12-30	16-36	24-40	25-41	26-46
No.16	1.18	4-19	5-21	6-22	7-25	9-28	11-29	13-33
No.30	0.600	3-15	4-17	4-19	5-21	7-23	8-24	10-28
No.50	0.300	2-11	2-13	2-14	2-15	4-17	5-19	5-21
No.100	0.150	1-7	1-8	1-8	1-9	2-10	2-11	2-12
No.200	0.075	0-3	0-3	0-3	0-3	0-3	0-3	0-3

G. On Site Storage of Aggregates

G.1 Adequate stocks of tested and approved aggregates shall be maintained on site and the capacity of the storage bins for each type and grading of aggregate shall be sufficient to hold the respective quantities required for the maximum amount of concrete which the Contractor is obliged or intends to pour in any continuous operation in one day. Stockpiles shall be built in layers of 1.50 m maximum height and segregation of the aggregates prevented. Different grades of aggregates shall be totally separated by concrete block walls.

G.2 Dense concrete or bituminous slabs shall be laid with sufficient falls to cover all aggregate stockpile areas or bins and shall extend to cover all surrounding areas where aggregates are likely to be discharged or handled. These areas shall be swept and kept clean at all times to ensure that the aggregates are not contaminated by the adjacent ground through trafficking or otherwise, and shall be constructed with adequate drainage for surplus water.

G.3 Windbreaks shall be provided where aggregates might suffer excessive contamination by windblown materials. During periods of heavy rain the bins or compounds shall be covered by tarpaulins or other approved means.

H. Rejection of Aggregates

H.1 The general or localized build up of fines in aggregate stockpiles shall not be allowed and any material which, in the opinion of the Engineer, is so affected will be rejected after testing.

H.2 Aggregates which have suffered segregation or contamination during processing, handling at source, transportation to the site, stockpiling and handling on site, or which otherwise do not conform with requirements of the Specifications, either locally or generally, will be rejected and shall be removed promptly from the site.

H.3 Aggregates which are found to be contaminated during transportation or during stockpiling or during handling shall be promptly removed from the site by the Contractor notwithstanding any prior approval of the source which may have been given by the Engineer.

I. Washing and Processing Aggregate

The Contractor may be required to carry out on site supplementary processing or effective washing of coarse and fine aggregates where the aggregate producer's methods, in the opinion of the Engineer, may not result in end products which consistently comply with all requirements of the Specifications, or where aggregates suffer unacceptable changes during loading at source or during subsequent transportation to the site, or otherwise.

J. Water

J.1 All sources of water to be used with cement whether for mixing or curing of concrete, or compaction of backfill around the concrete structures, shall be approved by the Engineer. If at any time during construction, water from an approved source become unsatisfactory, the Contractor shall provide satisfactory water from other main sources.

J.2 Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt as determined by the Engineer. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of AASHTO T26 and BS 3148. If the specific conductance is less than 1500 microohms per centimeter the total solids content requirement may be waived.

J.3 Non-potable water may be used when potable water is not available provided the impurities do not exceed the values given in Table 5.1.3.

J.4 Mortar prepared with water submitted by the Contractor for approval shall show no marked change in time of set, no indication of unsoundness and a reduction of not more than ten (10) percent in mortar strength when compared with mortar made with water of known satisfactory quality.

J.5 The water used in the mix design shall be the same as the water approved for site use.

J.6 Water used for prestressed concrete structures or for concrete containing or in contact with aluminum fittings or fixtures shall not contain chloride ions.

Table 5.1.3: Maximum Permitted Impurities in Non-Potable Water

Impurity	Max. Concentration (ppm)	Method
Chloride as (Cl-) a) Prestressed concrete or concrete in bridge Decks b) Other reinforced concrete in moist environment or containing aluminum embedments or dissimilar metals or with stay in place galvanized metals form	 500 1000	 ASTM D5l2
Sulfates as S04	300	ASTM D5l6
Alkalis as(Na_2O+0.658 K_2O)	600	AASHTO T-26
Total solid	5000	

K. Admixtures

K.1 General: The quantity and method of using admixtures shall be in accordance with the manufacturer's recommendations and in all cases shall be subject to the approval of the Engineer.

K.2 In all cases the Contractor shall provide the following information for the Engineer's approval:

- The quantity to be used, in kilograms per kilogram of cement and in kilograms per cubic meter of concrete.
- The detrimental effects caused by adding a greater or lesser quantity in kilograms per cubic meter of concrete.
- The chemical name(s) of the main active ingredient(s).
- Whether or not the admixture leads to the entraining of air.

K.3 The Contractor shall demonstrate the action of an admixture by means of trial mixes.

K.4 The use of calcium chloride in any form is prohibited.

K.5 Reference may be made to ACI Committee 212 report "Guide for Use of Admixtures in Concrete".

L. Admixture to Produce High Workability

L.1 Concrete for use in certain construction shall contain an approved superplasticising agent when so directed by the Engineer. The superplasticiser shall be stored and used strictly in accordance with the manufacturer's instructions and must be fully compatible with all proposed concrete mix constituents. The optimum dosage of the additive shall be determined by site and laboratory trials to the Engineer's approval. The Contractor shall submit to the Engineer full details of his proposed mix design which must ensure that the minimum strength requirements as specified for the particular use of the concrete are achieved. Only when the Engineer has approved the proposed mix design may such a mix be used in full compliance with the Specifications.

L.2 The Contractor's mixing and transporting plant shall be so designed that accurate metering of the superplasticising agent is possible and so that the additive may be introduced immediately before placing.

L.3 The Contractor's rates for concrete listed in the Bill of Quantities shall include for the use of superplasticisers. The rate shall include for the use of superplasticisers. The rate shall be inclusive for compliance with the Specifications together with all necessary testing and trials for concrete containing superplasticisers.

5.01.03 DEFINITIONS

A. Crushing Strength

The crushing strength of a test cylinder shall be prepared in accordance with AASHTO T23 and AASHTO T126. Alternative standard cubes may be tested in accordance to BS specifications.

B. Average Strength

The mean of the crushing strengths of specimens taken from a sample of concrete

C. Characteristic Strength

The value of the crushing strength below which 5% of the population of all possible strength measurements of the specified concrete are expected to fall.

D. Fresh Concrete

Concrete during the initial period of two hours from the addition of water to the cement.

E. Batch

The quantity of concrete mixed in one cycle of operations of a batch mixer or the quantity of concrete conveyed ready-mixed in a vehicle, or the quantity discharged during one minute from a continuous mixer.

F. Sample

A quantity of concrete taken from a batch whose properties are to be determined.

G. Regular Sampling

The sampling of concrete nominally of the same mix received regularly from the same source.

H. Specimen

Cylinder or cube taken from a sample for testing.

5.01.04 CONCRETE STRENGTH REQUIREMENTS

A. Design Mixes

A.1 Mixes for the classes of concrete shown in Table 5.1.4 shall be designed by the Contractor then specified for use in any part of the Works. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and vibrated in the particular locations required. Unless otherwise approved by the Engineer, the mix designs shall be on the basis of continuously graded aggregates and all mix designs shall be submitted to the Engineer for approval.

A.2 The Cement content in any mix shall not exceed 450 kg/m3.

A.3 The 7-day compressive strengths shall not be less than 75% of the specified 28 day strengths. If the 7 days results are below 75% of the required 28 days strength the Contractor may postpone works related to the suspected concrete until the 28 days results are available and successful or if the Contractor decides to continue work he may do so under his own responsibility and risk.

A.4 The ultimate cylinder compressive strength of concrete shall be determined on test specimens obtained and prepared in accordance with AASHTO T23 and AASHTO T 126 except that six inch by twelve inch cylinders shall be used for all compression tests. Alternatively the Engineer may require ultimate compressive strength of concrete to be determined on test specimen obtained by taking and airing cubes in accordance with BS 1881. The Contractor shall furnish single-use cylinder moulds conforming to AASHTO M205 or when approved by the Engineer re-usable vertical moulds made from heavy gauge metal.

Table 5.1.4: CONCRETE CLASS AND DESIGN MIXES

Class of Concrete	Cylinder Works Strength @ 28 days Kg/cm^2	Equivalent Works Cube Strength @ 28 days kg/cm^2	Maximum Size of Aggregate mm	Minimum Cement Content Kg/m3
110/25 (Blinding)	110	140	25	220
140/25	140	180	25	250
170/60	170	210	60	275
210/50	210	260	50	300
210/25	210	260	25	325
210/20 (B20)	210	260	20	325
250/20 (B25)	250	310	20	350
250/30	250	310	30	350
310/20	310	385	20	375
360/20	360	450	20	425
400/20	400	500	20	425

B. Nominal Concrete Mix

B.1 General

Concrete for use as backfilling for structural excavation shall be either no-fines concrete or cyclopean concrete as directed by the Engineer. The cement: aggregate ratio of such nominal mixes shall be not greater than 1:15 and the minimum cylinder strength at 28 days not less than 50kg/cm2.

B.2 No-Fines Concrete

No-fines concrete shall comply with the grading in Table 5.1.5 and shall be mixed and laid in general conformity with this Section 5.01.

B.3 Cyclopean Concrete

Plums used in cyclopean concrete shall consist of non-reactive broken stone spalls or boulders ranging in size from 200 mm to 300 mm. They shall be free from sharp or angular edges and shall not form more than 30% of the total volume of concrete. They shall be evenly graded and shall be soaked in water prior to incorporation in the mix. Plums shall he evenly distributed in the concrete mix with a minimum cover of 100 mm.

TABLE 5.1.5: GRADING FOR NO-FINES CONCRETE

GRADING OF AGGREGATE Sieve Size	% by Dry Weight Passing
90 mm	100
40 mm	85-100
20 mm	0-20
10 mm	0-5

C. Compliance with Strength Requirements

C.1 General

Cylinders (or cubes) from concrete as mixed for the Work will be tested in accordance with AASHTO T22 (BS 1881 for cubes) after seven (7) days and twenty eight (28) days. Test specimens shall be made and cured in accordance with AASHTO T23. These specimens will be the basis for acceptance of the concrete in the structure.

C.2 Preliminary Tests

Prior to the commencement of any concreting work and subsequently, whenever a change is intended, preliminary tests shall be carried out. From each of three samples of materials, a trial mix shall be made. For each class of concrete, the trial mixes shall represent at least two different water cement ratios. From each trial mix, six cylinders (or cubes) shall be made, three for testing at 7 days, and three for testing at 28 days. The average strength of the cylinders (or cubes) tested for each sample shall be taken as the preliminary cylinder (or cube) strength of the mix.

The Engineer will require the preliminary test to be repeated if the difference in strength between the greatest and the least strength is more than 20 per cent of the average.

The water/cement ratio and slump adopted in the preliminary tests for each class of concrete shall be used in the works concrete. It shall be such that, if selected for use at the Site, the concrete can be worked readily into the corners and angles of the forms and around the reinforcement without permitting the materials to segregate, or free water to collect on the surface.

Preliminary tests shall have these minimum ultimate strengths given in Table 5.1.6.

C.3 Works Tests

During the first four days of the commencement of concreting with any particular mix, two sets of six works cylinders (or cubes) in each set shall be made each day. Three cylinders (or cubes) from each set shall be tested at 7 days, and 3 at 28 days. The above works tests shall be carried out for each class of concrete. Subsequently, the frequency of making sets of test cylinders (or cubes) and the number in each shall be as directed by the Engineer.

Table 5.1.6: PRELIMINARY TESTS FOR STRENGTH

Class of Concrete	Cylinder Strength (kg/cm^2)	Equivalent Cube Strength (kg/cm2)
110/25	170	210
140/25	210	260
170/60	240	300
210/50	290	360
210/25	290	360
210/20	290	360
250/20	325	400
250/30	325	400
310/20	395	490
360/20	440	550
400/20	480	600

The cylinders (or cubes) shall be cured in the same manner and environment as the members they represent. The cylinder (or cube) strength shall be accepted as complying with the specified requirement for work cylinder (or cube) strength if none of the compressive strengths of the cylinders (or cubes) falls below the minimum strengths given in Table 5.1.4 or if the average strength is not less than the specified minimum works cylinder (or cube) strength and the difference between the greatest and least cylinder (or cube) strength is not more than 20 percent of the average.

Alternatively, the criterion of acceptable test results shall be that not more than 5 per cent of works cylinders fall below the specified strength. For this to be fulfilled, the mean strengths of works cylinders (or cubes) less 1.64 times the standard deviation should not be less than the required strength. This calculation shall be made for both 7 and 28 day cylinder (or cube) tests as soon as 24 cylinders (or cubes) have been tested at each age. Thereafter, it shall be repeated as further test results become available at a frequency determined by the Engineer. The number of cylinders (or cubes) considered in each calculation shall be the total number of cylinders (or cubes) of the mix in question tested from the commencement of the Works.

Cores shall be taken in accordance with ACI 318-89, article 5.6.4, and tested in accordance with AASHTO T24. Load testing shall be carried out in accordance with ACI 318-89, chapter 20. The Contractor shall hire an authorized independent laboratory to carry out such tests at no extra cost to the Client.

C.4 The Engineer may make additional test cylinders to ascertain the effectiveness of the methods by which the structure is being cured, and also to determine when the structure may be placed in service. These cylinders shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders from all damage.

C.5 The Contractor shall take every precaution to prevent injury to the test cylinders during handling, transporting and sorting. He will be held solely responsible for any test failure caused by improper handling and transportation, or any other cause which may be detrimental to the test cylinder.

C.6 In order that the test cylinders may be transported from field to laboratory undamaged, the Contractor shall provide a minimum of two (2) approved boxes. [One (1) for the Contractor's use and one (1) for the Engineer's use.] Boxes shall be of such size to receive a minimum of six (6) test cylinders and leave space for sawdust packing around all surfaces of the cylinders. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

C.7 When test cylinders fail to meet minimum strength requiremcnts, the Engineer may require core samples to be taken to determine the acceptability of such structures. The Contractor shall, at his own expense, furnish all equipment required for such core samples.

5.01.05 COMPOSITION OF CONCRETE

A. Mix Proportions

A.1 The Contractor shall consult with the Engineer as to mix proportions at least forty five (45) days prior to beginning concrete work. The actual mix proportions of cement, aggregates, and water shall be determined by the Contractor under the supervision of the Engineer.

A.2 The Contractor shall, in the presence of the Engineer, prepare trial-mixes for each class of concrete required for the project, made with the approved materials to be used in the Work. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the cement content specified and meeting the plasticity requirements and the preliminary test strength requirements specified for the designated class of concrete.

A.3 If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the use of admixtures to maintain the water content within the specified limit shall be permitted. At all times the concrete mix shall satisfy the durability requirements by satisfying the minimum and maximum limits specified of cement and water contents respectively.

A.4 The Engineer will review the Contractor's trial - mixes and break the test cylinders at seven (7) and twenty-eight (28) days. The Engineer will then determine which of the trial mixes shall be used. If none of the trial-mixes for a class of concrete meets the specifications, the Engineer will direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

A.5 The approval of the job-mix proportions by the Engineer, or his assistance to the Contractor in establishing those proportions, in no way relieves the Contractor of the responsibility of producing concrete which meets the requirements specified in these specifications.

A.6 All costs connected with the preparation of trial-mixes and the design of the job mixes shall be borne by the Contractor, except that the Engineer shall not charge the Contractor for laboratory supervision and the breaking of the test cylinders.

B. Design Limits

The following will be designated by the Engineer within the limits of the specifications:

The minimum cement content in sacks per cubic meter of concrete.

The maximum allowable water content in liters per sack of cement, or equivalent units, including surface moisture, but excluding water absorbed by the aggregates.

The ratio of coarse and fine aggregates.

Slump or slumps designated at the point of delivery.

C. Changes to Mix Design

C.1 Changes in mix proportions requested by the Contractor to previously approved mix designs shall only be made after new approval by the Engineer.

C.2 When, in the opinion of the Engineer, cement is being lost due to windy conditions, the Contractor shall add additional amounts of cement as directed by the Engineer. No additional payment will be made for the added cement.

C.3 As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions from time to time if conditions warrant such changes to produce satisfactory results. Any such change may be made within the limits of the specifications at no additional compensation to the Contractor.

C.4 When in the opinion of the Engineer, an adjustment for protection against concrete deterioration due to salty environment is necessary, he may require the cement content be increased ten (l0) per cent over and above that cement content used in the approved trial mix design for non-salty environment. Water content shall be adjusted accordingly to obtain a dense workable mix. All bridge footings and column lengths to the first construction joint above the ground surface for the entire project are subject to this increased cement content. No additional payment will be made for the increase in cement content.

C.5 Failure of the mix to meet specifications determined by the Engineer under items A and B in this sub-section will be grounds for the Engineer to reject the concrete.

C.6 Mortar for laying stone for grouted stone riprap, grouted stone wash checks or grouted stone ditch lining shall be composed of one (1) part of portland cement and three (3) parts of fine aggregate by volume with water added to make a workable mix of such consistency as to perform properly the functions required for the work being done. Amount of water added shall be approved by the Engineer.

a) Aggregates for masonry mortar shall conform to AASHTO M45.

b) Portland cement shall conform to AASHTO M85, Type I, II or III.

5.01.06 REQUIREMENTS FOR COMBINING MATERIALS

A. Measurement for Proportioning Materials

A.1 Cement: The cement shall be measured in bulk or as packed by the manufacturer, a sack of cement shall weigh 50 kilograms. Measurement shall be accurate to within 3.0 per cent throughout the range of use.

A.2 Water: The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within 2.0 percent throughout the range of use.

A.3 Aggregates: The aggregates shall be measured by weight. The measurement shall be accurate to within (+ or - 2.0% fine, coarse aggregates) throughout the range of use.

A.4 Additives: Additives shall be measured by volume if in liquid form and by weights if solid. The measurement shall be accurate to within 3.0 per cent throughout the range of use.

B. Assembly and Handling of Materials

B.1 Assembly: Aggregates shall be assembled in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient unsegregated materials having proper and uniform moisture content to ensure continuous and uniform operation. Aggregates shall enter the mixer in a manner approved by the Engineer and so as to ensure that no matter foreign to the concrete or matter capable of changing the desired proportions is included. In the event that 2 or more sizes or types of coarse or fine aggregates are used on the same project, only 1 size or type of each aggregate may be used on one continuous pour.

B.2 Stockpiling of Aggregates: All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content, to provide uniform conditions for proportioning plant control and to aid in obtaining concrete that is uniform as to materials and moisture content. The use of equipment or methods of handling aggregates which results in the degradation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles. All equipment used for handling aggregates shall be approved by the Engineer. Stockpiling of aggregates shall be in the manner approved by the Engineer, and in addition, every precaution shall be taken to prevent segregation. Segregation shall be prevented by making no layer higher than 1.5 meters and if 2 or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer. Aggregates shall not be stockpiled against the supports of proportioning hoppers and weighing devices.

B.3 Segregation: Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform and acceptable gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when ordered by the Engineer.

B.4 Transporting of Aggregates: If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being dumped.

B.5 **Storage of Cement:** Cement may be stored in bulk (unpacked) or in bags in securely locked dry places.

a) All cement bags shall be marked with the date of manufacture. Additionally, all bags shall be marked with the date of storage so that they can be taken out for use in the same order as they were brought in to storage.

b) Cement bags shall be placed on wooden shelves at least 100 mm above ground and 150 mm clear of walls.

c) Unpacked cement shall not be used six months after manufacture and bagged cement three months after manufacture.

d) No cement shall be used which has been affected by humidity, regardless of the date of manufacture.

e) Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within 1.5 hours.

C. Mixing

C.1 Concrete shall be mixed in quantities required for immediate use. Concrete shall not be used which has developed initial set. Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

C.1.1 If washed sand is used while still wet the mixing time starts with the addition of cement to the aggregate, even if the water required for the mixing has not been added.

C.2 The concrete may be mixed at the site of the Works, in a central-mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements of Sub-Section 5.01 .7 "Ready-Mixed Concrete and Central-Mixed Concrete".

C.3 The coarse aggregate shall first be loaded into the mixer followed by the fine aggregate. Some mix water shall be added to the mix before the cement is loaded into the mixer. Water shall be continually added throughout the mixing. Additives, if required and approved by the Engineer, shall be added according to the manufacturers' instructions. Retarders shall be added within one minute or 25% of the total mixing time whichever is the smaller.

C.4 The manufacturers' instructions shall be followed in respect of overloading the mixer and the selections of the rate of revolutions of the mixer.

C.5 To avoid segregation in the fresh concrete, the free drop height on emptying the mixer shall be not greater than 1.5 meters.

C.6 After mixing, the concrete shall be homogeneous and comply with the provisions of these specifications. The Engineer may, if the mix fails to produce concrete of the required strength vary the mix time.

D. Central Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

D.1 Cement: Means provided for storing cement shall be as approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved cement before starting to manufacture concrete for the Works.

D.2 Aggregate: Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregate shall come from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved aggregate before starting to manufacture concrete for the Works.

D.3 Consistency: The Contractor shall be responsible for producing concrete that is homogeneous and complies with the provisions of these specifications.

D.4 Hauling: Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators, non-agitating trucks having special bodies or other approved containers.

D.5 Time of Haul: The time elapsing from the time water is added to the mix until the concrete is deposited in place shall be not greater than:

For concrete produced on site and transported by means other than transit mixers or agitated trucks.

- Thirty minutes when air temperature is 25°C or higher.
- Forty minutes when air temperature is 1 8°C or below.
- Interpolated time between 18°C and 25°C.

For concrete transported by transit mixer or agitators, the time taken for 300 revolutions of the transit mixer or agitator or 20 minutes, whichever is the lesser.

The maximum haul time may be reduced at the Engineer's discretion if the slump changes or there are signs of the concrete beginning to dry.

D.6 Delivery: The Contractor when supplying concrete from a central plant shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be such as to provide for the proper handling, placing and finishing of the concrete. The method of delivery and handling the concrete shall be such as it will facilitate placing with a minimum of rehandling and without damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved, by the Engineer. The Engineer may delay or suspend the mixing and placing of concrete at any site, for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

5.01.07 READY-MIXED CONCRETE AND CENTRAL MIXED CONCRETE

A. General

A.1 "Ready-Mixed Concrete" and "Central-Mixed Concrete" shall consist of a mixture of cement, water and aggregate, without air entraining or water-reducing admixture. When air-entraining or water-reducing or any other type of admixture is required it shall be at the Engineer's discretion. The terms ready-mixed or central-mixed concrete shall include transit mixed concrete and will be referred to hereinafter as ready-mixed concrete.

A.2 Ready-mixed concrete may be used in the construction of all Works, when approved by the Engineer.

A.3 Approval of any ready mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling the materials, the production procedures, the transportation and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

A.4 Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

Mixed completely in a stationary central mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (known as "central-mixed concrete").

Mixed completely in a truck mixer at the batching plant or while in transit (known as transit-mixed concrete).

Mixed completely in a truck mixer at the point of use following the addition of mixing water (known as truck-mixed concrete).

A.5 Permission to use ready-mixed concrete from any previously approved plant may be rescinded at any time upon failure to comply with the requirements of the Specification.

B. Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of Sub-Section 5.01.2 "Materials".

C. Equipment

Equipment shall be efficient, well maintained, and shall be of the type and number as outlined in the Contractor's Program of Work. Transit mixers and agitator trucks shall comply with the standards specified in ASTM C94. Non-agitating equipment used for transporting concrete shall be water tight and be equipped with gates that will permit controlled discharge of concrete and, when required by the Engineer, be fitted with covers for protection against the weather.

D. Supply

D.1 Where transit mixers are used, the constituent materials shall be mixed dry in the mixer and water added directly before pour and mixed at the speed and number of turns in accordance with the manufacturers' recommendations.

D.2 Where concrete is mixed at a central plant on or off site, the concrete may be supplied to the pouring area by agitator trucks or transit mixers which rotate at the speed specified by the manufacturers. Non-agitating trucks may be used if the control plant is on site.

D.3 Time of haul shall not exceed the maximum stated in sub-item D.5 of sub-section 5.01.6 of these Specifications.

E. Uniformity Tests

Four samples of fresh concrete shall be taken, two after 15% of discharge from the truck mixer or agitator truck and two after 85% discharge and within 20 minutes. Slump and compaction factor tests shall be carried out including any other tests specified or required by the Engineer.

F. Samples

F.1 Samples for strength test shall be taken as specified in Clause C of subsection 5.01.4 of these Specifications.

F.2 At least six specimens shall be prepared per sample. Three of these shall be tested at 7 days and three at 28 days.

G. Control of Delivery

G.1 Driver of delivery trucks shall be provided with trip tickets, which shall be signed by a responsible member of the central plant staff, for submission to the Engineer. The ticket shall contain the following information.

- Name and address of the Central Plant.
- Serial number of the ticket and date.
- Truck number.
- Class and/or strength of concrete.
- Cement content of the mix.
- Loading time.
- Slump.
- Any other type of relevant information.

G.2 The Engineer may send his representative to the central plant who may:

- Check the batching and mixing.
- Verify loading time.
- Take a copy of the trip ticket.

G.3 The Contractor and/or concrete supplier shall afford the Engineer and/or his representative, without charge, all facilities necessary to take samples, conduct tests and inspect the central plant to determine whether the concrete is being furnished in accordance with these Specifications.

G.4 Concrete delivered in outdoor temperatures lower than 5 degrees C, or if the temperature is expected to drop below 5 degrees C during the curing period, shall arrive at the Works having a temperature of not less than 10 degrees C nor greater than 32 degrees C.

G.5 In supplying ready-mixed concrete the plant shall have sufficient batching and transporting capacity to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall provide for the proper handling placing and finishing of concrete. If the rate of delivery does not provide a continuous concrete operation the Engineer may suspend all or parts of further concrete work until such time as the Contractor provides sufficient additional delivery equipment which in the opinion of the Engineer will provide for a continuous concrete operation.

5.01.08 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 include mass reinforced and prestressed concrete of both in-situ and precast construction of a general nature but do not include specific components of highway structures such as concrete piles concrete parapets and safety barriers precast concrete curbs and tiles etc. which are separately described in other sections of these specifications.

B. What to measure

B.1 Concrete shall be measured by the cubic meter (m^3) in place and accepted by the Engineer based on dimensions shown on the Drawings or as otherwise directed by the Engineer in writing.

B.2 Different classes of concrete shall be measured separately.

B.3 Concrete formed by different types of form and/or falsework shall be measured separately.

B.4 Concrete of the same class requiring the same falsework but different class of surface finish shall be measured separately.

B.5 Voids, openings or gaps whose size is 0.05 cubic meters or more shall be measured and deducted from the volume of concrete in which they occur.

B.6 All service ducts irrespective of diameter shall be measured and deducted from the volume of concrete in which they are located.

C. Items not measured

C.1 Reinforcing bars shall not be measured for deduction.

C.2 Prestressing ducts, anchors, cones, couplers and grouting tubes shall not be measured for deduction.

C.3 Embedded metals, bolts, nuts, anchorages, hooks etc. shall not be measured for deduction.

C.4 Holes introduced, with the consent of the Engineer, by the contractor for the convenience of transportation, erection or construction shall not be measured for deduction irrespective of the size of the holes and whether or not the holes are made good.

C.5 Additional concrete placed, with the consent of the Engineer, by the Contractor solely for the purpose of facilitating his work shall not be measured for payment.

D. Inclusion in the Rates

The rates for items entered in the Bill of Quantities shall include for:

- Cement, aggregates, water and additives, admixtures and air entraining agents including their testing, storage, handling and transportation.
- Washing of aggregates, if required, and ice added in the mix water, if required.
- Plant, machinery and equipment required for the production of concrete.
- Design of mixes, taking samples and testing specimens.
- Transportation and delivery of concrete to work areas.
- Placing, vibrating and finishing of concrete.
- All formwork irrespective of the material used and the quality of surface finish specified.
- All falsework supporting and stabilizing formwork.
- Curing of concrete.
- Tooling, if required, to achieve the specified surface finish.
- Corrective measures and the means of carrying them out required in the event of the concrete being not in accordance with the drawing and/or specification.
- Handling, transportation and erection of precast concrete members.
- Grout and/or epoxy used in precast construction including material and equipment for temporary prestress, if required.
- Material, plant and equipment associated with particular methods of construction.
- Joint fillers, joint sealants, water stops, dowel bars for water structures as shown on the drawings including material, plant handling, transportation testings storage, workmanship and associated accessories.
- Steel reinforcement.

PAY ITEM	UNIT OF MEASUREMENT
Concrete (Specify type, class and finish)	Cubic meter (m^3)
Stumped Concrete (Specify type, class and finish)	Meter Square (m^2)
Strengthening of Existing Walls (Specify type, class and finish)	Meter Square (m^2)

SECTION 5.02 CONCRETE HANDLING, PLACING AND CURING

5.02.01 SCOPE

These operations shall consist of the placing, compacting and curing of concrete for mass concrete, reinforced concrete and prestressed concrete structures.

5.02.02 MATERIALS

All concreting materials shall comply with section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

5.02.03 PLACING

A. General

A.1 Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval. Besides specifying the characteristics of the concrete to be employed, this plan shall indicate the time at which placing is to start, the way in which it is to be performed, and the time at which it is to finish. The Engineer's approval shall be sought in writing by the Contractor at least 24 hours in advance.

A.2 The method and sequence of pour, the equipment to be used, the method of compaction and curing procedure shall be approved by the Engineer, prior to concrete pour.

A.3 In order to allow proper vibration of the concrete, it shall be placed in horizontal layers which, at no time shall be thicker than fifty centimeters (after vibration).

A.4 If the concrete is placed in successive phases, there shall be no separations, or discontinuity, or difference of appearance between two successive placings. Before each successive placing is made, the surface of the concrete already in place shall be carefully roughened, cleaned, washed free of loose particles and dampened.

A.5 Concrete shall be placed in such a way that it shall be left undisturbed once it is placed (for example, slabs shall be executed by starting to place the concrete at the side opposite the one from which the concrete is poured, so that there shall be no risk of it being disturbed by workers or equipment, or of tools falling in).

A.6 When concrete is placed for upright reinforced concrete structures, the placing must be completed (for small structures) or interrupted (for large structures) before the concrete which has already been placed has started to harden and might, therefore, be disturbed, if the operation of placing were continued. In such cases placing shall be started again only after twenty four hours have passed. This procedure is intended to avoid the risk of the concrete which has already been placed coming away from the reinforcing bars, because it is moved or disturbed during setting and the initial phase of hardening.

A.7 When the concrete is placed, its temperature shall be nearly the same as that of the reinforcing bars, in order to avoid poor adhesion due to the different coefficients of thermal expansion of the two materials. The reinforcing bars shall, therefore, be protected from the sun (or the cold in winter) or cooled by water jets prior to the placing of the concrete, or the pouring shall start during the cooler hours of the day and be suspended when the temperature rises above thirty three degrees C.

A.8 The free-drop height of concrete shall be not greater than 1.5m and the method of placing shall be such as to suit the conditions and prevent segregation.

A.9 Placing of concrete shall be continuous between predetermined points such as construction joints, contraction joints and expansion joints.

A.10 Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point in the forms and then run or worked along the forms, thus causing segregation of the materials.

A.11 The concrete shall be deposited in the forms in horizontal layers and the work shall be carried on rapidly and continuously between predetermined planes agreed upon by the Contractor and the Engineer.

A.12 The slopes of chutes, where used, shall be not greater than 1 vertical to 2 horizontal or smaller than 1 vertical to 3 horizontal. The slope of the chute shall be constant along its length. The capacity of the chute shall be adequate to deliver the required volume of concrete at the required rate.

A.13 Aluminum pipes shall not be used for delivering concrete. The internal diameter of delivery pipes, if used, shall be not less than 8 times the maximum aggregate size. At the point of delivery, pipes shall be vertical.

A.14 Where bucket and hopper are used for delivery of concrete, the discharge opening shall be not less than 5 times the maximum aggregate size. The sides of hoppers shall be sloped al not less than 60 degrees to the horizontal.

A.15 When buggies are used to transport fresh concrete, they shall be run on level tracks which are securely fixed. The buggies shall be run smoothly without sudden jerks and the distance shall be not greater than 60 meters.

A.16 All chutes, buckets and hoppers, buggies and pipes shall be kept clean and free from coatings of hardened concrete by thorough flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

A.17 The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and to bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets, or honeycomb.

A.18 Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement content of the class of concrete being deposited in water shall be increased 10 percent without further compensation and the slump shall be approximately 15 centimeters.

A.19 When depositing in water is allowed, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, by means of a tremie, bottom-dumping bucket or other approved means that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. No concrete shall be placed in running water, and forms which arc not reasonably watertight shall not be used for holding concrete deposited under water.

A.20 When casing is used in drilled shafts, the easing shall be smooth and properly oiled in accordance with the manufacturers' manual and shall extend sufficiently above the

grade of the finish shaft to provide excess concrete to be placed for the anticipated slump due to the casing removal. When the casing is to be pulled, the concrete placed in the casing shall have such a slump and be of such workability that vibrating of the concrete will not be required.

A.21 No concrete work shall be stopped or temporarily discontinued within 45 centimeters of the top of any finished surface unless such work is finished with a coping having a thickness less than 45 centimeters in which case the joint shall be made at the under edge of the coping.

A.22 Concrete in simple slab spans shall be placed in one continuous operation for each span, unless otherwise directed on the Drawings or directed by the Engineer.

A.23 Concrete in in-situ beam and slab construction shall be placed in one continuous operation, or when so shown on the Drawings or approved by the Engineer, may be placed in two separate operations, each of which shall be continuous; first, to the top of the girder stems, and second, to completion. Where a construction joint is permitted between the girder stem and the roadway slab, shop drawings including complete details of key or other methods of bonding will be prepared by the Contractor and submitted to the Engineer for approval. When such a joint is permitted, deck concrete shall not be placed until the concrete in the girder stem has hardened sufficiently so as not to be damaged by the concreting operations of the deck pour.

A.24 Concrete in arch rings shall be placed in such a manner as to load the centering uniformly. Arch rings shall be divided into section such that each section can be cast for the full cross-section in one continuous operation. the arrangement of the section and the sequence of placing shall be as approved by the Engineer, and shall be such as to avoid the creation of initial stress in the reinforcement. The section shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings may be cast in a single continuous operation.

A.25 The method used for transporting concrete batches, materials, or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentrations of materials will be prohibited on floor slabs until the concrete has attained its design strength.

B. Pumping

B.1 The use of pumps will only be allowed after they have been carefully checked and approved by the Engineer. Only low pressure piston type pumps, which will work with a water/cement ratio of not more than sixty five hundredths (0.65), will be allowed. Using superplastizisers to facilitate pumping for low water/cement ratios is allowed subject to Engineer's review and approval.

B.2 In no case will "bell" or any other type of high pressure pump be allowed, since they require too high a water/cement ratio and because the concrete segregates as a result of the high pressure at which it is expelled, even if filled with a suitable nozzle.

B.3 The mix design shall be checked for its suitability for pumping and the concrete shall be tested regularly during pumping for its uniformity and that its properties have not been altered by pumping. If changes to slump, water-cement ratio, consistency or any other characteristics occur, corrective measures shall immediately be taken to ensure that concrete delivered by the pump complies with the requirements of the Specification.

Samples shall be taken at discharge from the mixer/agitator truck, from the pump and at discharge from the pump.

B.4 The internal diameter of delivery pipe of the pump shall be not less than 3 times the maximum aggregate size. The pipes shall not rest on any part of the formwork, they shall be supported independently and securely and be readily accessible so that sections can easily be detached to remove any blockage.

B.5 Before approving the use of a pump, the Engineer shall verify that the Contractor has sufficiently reinforced the concrete placing team and the equipment for placing and vibrating the concrete.

B.6 Pumping will not be permitted from the inside of the foundation forms while concrete is being placed. If necessary to prevent flooding, a seal of concrete shall be placed through a closed chute or tremie and allowed to set.

5.02.04 COMPACTING

A. General

A.1 The vibration of the concrete can be considered completed when a thin layer of cement grout appears on the surface and when no more air bubbles, indicating the presence of voids within the concrete, appear on the surface. At the same time, there must not be too much vibration or this will produce segregation.

A.2 Vibration may be of three types:

- Internal.
- External.
- Mixed.

A.3 Vibration of the concrete and operation shall be undertaken in such a way that the proper and complete vibrations, but avoiding over vibration, is achieved. The guidelines as given in Standard Practice for Consolidation of Concrete (ACI 309) of Part 2 Concrete Practices and Inspection, Pavements, of ACI Manual of Concrete Practice 1988 issued by American Concrete Institute (ACI) shall be followed, if not otherwise directed by the Engineer.

A.4 Internal vibration shall be executed in all sections which are sufficiently large to permit the insertion and manipulation of immersion vibrators, previously approved by the Engineer, in accordance with the following recommended practices:

A.4.1 The concrete shall be placed in horizontal layers not thicker than fifty centimeters.

A.4.2 The vibrator shall be inserted vertically into the concrete to its full length such as to reach the bottom of the freshly placed layer.

A.4.3 The distance between two successive insertions shall not exceed five times the diameter of the vibrator itself.

A.4.4 The vibrator shall not rest on or against either the formwork or the main reinforcing bars.

A.5 External form vibrators shall be used for external vibration when it is impossible to use internal vibrators (heavily reinforced thin walls, pipes or other precast, small cross-section element, etc.). The water/cement ratio shall be low (0.30-0.40) in order to avoid the segregation of the concrete and, at the same time, to provide rapid hardening and, in consequence, the early removal of the formwork and the finished element.

A.6 Mixed vibration shall be used in the construction of reinforced or prestressed concrete beams. External wall vibrators shall also be used. These shall be mounted on the outside of the formwork after this has been suitably reinforced with ribs of U-bars. The mounting places of the wall vibrators shall be welded to these reinforcements. They must be symmetrically positioned on each side of the beam and produce a rotary movement within the concrete during vibration from the bottom towards the top and from the part placed first towards the part placed last.

A.7 Only the vibrators in the zone of the formwork with newly placed concrete will be used. As the casting of the beam advances the vibrators shall be dismounted and remounted as necessary.

A.8 It is absolutely essential that elastic supports be provided both under the bottom of the beam and in correspondence with the braces or tie rods of the formwork walls.

A.9 The network of reinforcing bars and tensioning cables should not move as a result of the vibration. To prevent this from happening either special ties (passing through the formwork walls) or spacers shall be used. It is better if these last are made of concrete and are of a size and shape that will ensure that the reinforcing and tensioning cables do not move.

A.10 Before starting this kind of work the Contractor shall submit to the Engineer for his approval a work plan giving the following details:

The position of the external wall vibrators their power frequency and amplitude and the number that will be utilized at the same time.

The number and type (frequency and size) of the internal vibrators to be used for the consolidation of the concrete.

The position of the spacers or the number of ties to be used to ensure that the reinforcing bar network and the tensioning cables (if any) do not move during vibration.

The way in which the concrete is to be placed and the length of time this operation is expected to take.

A.11 When required vibrating shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

B. Poker Vibrators

B.1 The type and size of poker vibrators shall suit the pour size, density of reinforcement and member dimensions. Unless otherwise authorized by the Engineer, the vibrator shall be selected from Table 5.2.1 below

Table 5.2.1: SELECTION OF POKER DIAMETER FOR SIZE OF POUR

Size of Pour (m^3/h)	Poker Diameter (mm)	Speed (Vibrations/min)
2 - 4	20 - 45	9000
5 - 10	50 - 65	9000
10 - 20	60 - 75	7000
20 - 30	80 - 115	7000
30 - 40	140 - 170	6000

B.2 Poker vibrators shall be inserted into the concrete vertically at regular intervals which shall be no greater than 0.5m. They shall be inserted quickly and withdrawn lowly. The withdrawal rate shall be not more than 75mm/sec. A cycle of insertion and withdrawal shall be between 10 and 30 seconds.

B.3 Poker vibrators shall be kept clear of formwork and concrete previously cast.

B.4 Vibrators shall be so manipulated as to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. Vibrators shall not be used as a means to cause concrete to flow or run into position in lieu of placing.

B.5 Compaction shall be sufficient to achieve maximum density without segregation in the fresh concrete.

B.6 Standby pokers of the same type shall be provided at all times. The standby shall be not less than half the number of pokers used for compacting the pour.

B.7 Vibrating shall only be carried out by professional technicians having experience in this type of work.

C. Other Vibrators

C.1 Form vibrators, vibrating tables and surface vibrators where required shall first be approved by the Engineer and they shall conform to the requirements of ACI-309.

C.2 Where form vibrators are used, the form shall be adequately designed so that the vibration will not cause joints to leak and dimensions and geometry to alter.

C.3 Unless otherwise permitted by the Engineer the use of form vibrators shall be limited to members whose thickness does not exceed 150 mm.

5.02.05 CURING

A. Materials

A.1 Hessian or Burlap: They shall be clean and free from harmful materials. Their unit weight shall be not less than $230g/m^2$

A.2 Impermeable membranes: The following impermeable membranes may with the Engineer's approval be used.

- Clear polyethylene film with no holes tears scratches and contamination of any type.
- Hessian coated with white polyethylene of density not less than 300g/m^2. The coating may be on one side only but shall be not less than 0.1 mm thick and shall not peel during and after use.

A.3 Curing Compounds: These shall conform to AASHTO M148 (AASTM-C309).

A.4 Sand: It shall be natural sand free of silt and clay and contaminants which can be harmful to the concrete.

A.5 Water: It shall satisfy the requirements of Section 5.01 of these Specifications.

B. Method of Curing

B.1 General: The method of curing to be used shall be approved by the Engineer. It shall not cause any undesirable blemishes such as surface discoloration and surface roughness. Curing compounds shall not be used on construction joints and surfaces that are to receive waterproofing, paint or membranes.

B.2 Ponding: Curing by ponding may be used for horizontal surfaces such as bases, pile caps and slabs. Large horizontal surface areas shall be separated into ponds not exceeding 5 sq.m. The ponds shall first be filled between 12 to 24 hours after pour, unless otherwise authorised by the Engineer, and shall be replenished from time to time so as to maintain the ponding for the specified curing period. The concrete temperature and the temperature of the curing water shall be not greater than 10°C.

B.3 Sprinkling: Unless otherwise approved by Engineer, curing by spraying shall commence between 12 and 24 hours after the concrete pour. The concrete shall be maintained damp at all times during the curing period by periodic light sprays.

B.4 Wet Hessian/Burlap: Members to be cured by wet hessian or wet burlap shall be completely wrapped with the material which shall be kept moist at all times during the curing period by regular spraying. Unless otherwise approved by the Engineer, the overlap under normal conditions shall be not less than one-quarter the width of the hessian or burlap and not less than one-half the width in windy and/or rainy conditions. Before members are wrapped for curing, they shall first be evenly moistened. Unless approved by the Engineer, burlaps shall be supplied only in rolls and burlap bags shall not be used. Secondhand hessian and burlap, if approved for use, shall be clean without holes and contamination of any kind that can affect the concrete.

B.5 Waterproof Sheets: Waterproof sheets used for curing shall, unless directed by the Engineer, be spread immediately after the pour. The sheet shall, unless approved by the Engineer, be clear of the concrete surface but be arranged in such a manner as to prevent the movement by air over the concrete surface. Waterproof sheets shall not be used when the air temperature is 25°C or higher.

B.6 Curing Compounds: Curing compounds shall be applied in two applications at a coverage rate of not less than 1 ltr/ 7.4 m^2 per application or as recommended by manufacturer.

The first coat shall be applied immediately after the removal of the forms and the acceptance of the concrete finish and after the disappearance of free water on unformed surfaces. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and curing compound applied just as the surface film of water disappears. The second

application shall be applied after the first application has set. During curing operations, any unsprayed surfaces shall be kept wet with water. The curing membrane will not be allowed on areas against which further concrete is to be placed.

Hand operated spray equipment shall be capable of supplying a constant and uniform pressure to provide uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.

The curing membrane shall be protected against damage for the entire specified curing period. Any coating damaged or otherwise disturbed shall be given an additional coating. Should the curing membrane be continuously subjected to injury, the Engineer may require wet burlap, polyethylene sheeting, or other approved material to be applied at once.

No traffic of any kind will be permitted on the curing membrane until the curing period is completed, unless the Engineer permits the placement of concrete in adjacent sections, in which case the damaged areas shall be immediately repaired as directed.

B.7 Steam Curing

Low Pressure Steam Curing: In accordance with ACI 517 recommendations.

High Pressure Steam Curing: In accordance with ACI 516 recommendations.

C. Curing Time

C.1 The minimum curing time shall be the number of days given in Table 5.2.2 unless the average surface temperature of the concrete during the required number of days falls below 10°C, in which case the period of curing shall be extended until the maturity of the concrete reaches the value given in the Table.

C.2 The minimum curing time given in Table 5.2.2 above shall be compared with the time required for cylinders (cubes), cured under identical conditions to those which the concrete is subjected, to attain 70% of the characteristic strength. The greater shall be taken as the minimum curing time.

5.02.06 HOT WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of these Specifications, Hot Weather is as defined in ACI 305R-77 (Revised 1982) Chapter 1.

B. General

B.1 The production and delivery of concrete, the placing and curing and the testing and inspection of concrete shall, in addition to the requirements of these Specifications, accord with the recommendations of ACI 305R-77 (Revised 1982).

TABLE 5.2.2 NORMAL CURING PERIODS

Minimum periods of protection for different types of cement						
Conditions under which concrete is maturing	Number of days (where the average surface temperature of the concrete exceeds 10°C during the whole period)			Equivalent maturity (degree hours) calculated as the age of the concrete in hours multiplied by the number of degrees Celsius by which the average surface temperature of the concrete exceeds 10° C		
	Other*	**SRPC**	**OPC or RHPC**	**Other***	**SRPC**	**OPC or RHPC**
1.Hot weather or drying winds	7	4	3	3500	2000	1500
2.Conditions not covered by 1	4	3	2	2000	1500	1000

NOTE: Other*includes all permitted cements except OPC, RHPC and SRPC.
OPC = Ordinary Portland cement.
RHPC = Rapid-hardening Portland cement.
SRPC = Sulfate resisting Portland cement.

B.2 No concreting shall commence when the air temperature is 32°C and rising. The Contractor shall schedule his operations to place and finish concreting during the hours that the air temperature will be below 32°C. This should preferably be in the latter part of the day after the maximum temperature has been reached, and subject to the approval of the Engineer.

C. Control of Temperature

C.1 Stockpile of aggregates shall be protected from direct sunlight by suitable covering. If directed by the Engineer, they shall be regularly sprayed with clean water.

C.2 Water shall be stored in tanks away from sunlight and insulated by suitable means so as not to be affected by high air temperature. Water tanks liable to be exposed to sunlight shall be covered with suitable reflective paint such as white gloss paint.

C.3 If directed by the Engineer or as a condition for concreting in adverse weather conditions, sufficient ice shall be added to the mix water to ensure that the temperature of the fresh concrete shall not exceed 32°C.

C.4 The temperature of the concrete at the time of placing shall not be permitted to exceed 33 degrees C. Concrete materials shall be stored in a cool shaded position away from the direct rays of the sun. Aggregates shall be cooled if necessary prior to mixing and water shall be cooled by means of a proprietary water chilling plant. The prices in the Bill of Quantities shall be deemed to cover all such special work.

C.5 Additives as recommended in ACI 305R-77 shall be used to improve workability and/or delay initial setting.

C.6 Retarding admixtures to facilitate placing and finishing of the concrete shall conform to AASHTO M 194, Type D and used only if approved by the Engineer.

D. Mixing and Placing

D.1 The time available for handling and placing of concrete during periods of high temperature may be considerably reduced and the Contractor must take appropriate precautions. Concrete should be protected during transportation by use of damp hessian or similar means. No additional water may be added at the time of mixing without the approval of the Engineer, as this may lead to additional shrinkage of the concrete. On no account shall water be added during transportation or placing of the concrete.

D.2 Aggregates and cement shall be thoroughly pre-mixed before adding water.

D.3 Transit mixers, if used, shall be coated with a reflective paint and while waiting to be discharged, shall be kept out of direct sunlight.

E. Concrete Protection

E.1 Before the concrete can be de-shuttered, the formwork and shutters shall be cooled by spraying with water.

E.2 The concrete and the falsework shall be protected against sunlight, if directed by the Engineer.

E.3 If curing is by hessian, it shall be coated with a white polyethylene backing.

E.4 Members exposed to strong winds shall be provided with windbreakers. The windbreakers shall, if directed by the Engineer, be kept moist by regular spraying.

5.02.07 COLD WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of these Specifications, Cold Weather is as defined in ACI 306.1-87, Section 1, Part 1.2.

B. General

B.1 ACI 306.1-90 "Standard Specifications for Cold Weather Concreting" applies.

B.2 The production and delivery of concrete, the placing and curing and the protection requirement shall be in accordance with the recommendations of ACI 3061t-88 "Cold Weather Concreting".

B.3 No concreting shall commence when the air temperature is 6°C and falling, unless authorized by the Engineer.

C. Mixing and Placing

C.1 Aggregates and water, forms, reinforcement etc. shall be free of snow, frost or ice.

C.2 Aggregates and water may be pre-heated in which case the aggregates and water shall, if directed by the Engineer, be mixed prior to introducing cement in the mix. The aggregates shall not be pre-heated to a temperature in excess of 100°C and the water in excess of 60°C with the additional requirement that the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.3 Water may be pre-heated by boiling and added to aggregates not pre-heated provided the temperature of the water and aggregate mix, before the introduction of cement, does not exceed 38°C.

C.4 The temperature of concrete at the time of discharge shall be between 10 and 27°C and for three days after the pour not less than 5°C.

D. Protection

D.1 When directed by the Engineer, members shall be protected against cold winds by suitable windbreaks.

D.2 Adequate insulation by way of insulation boards, planks, sheets etc. shall be provided to maintain the required minimum concrete temperature during the curing period.

D.3 Protection measures shall be maintained for a period at which the concrete attains a strength of at least 65% of the characteristic strength.

5.02.08 NIGHT CONCRETING

A. Night concreting shall not be carried out unless prior approval of the Engineer, in writing, is obtained.

B. Details of the artificial lighting; system shall be submitted in advance of the proposed concreting for the Engineer's approval. In all cases, at least one stand-by generator shall be available at all times of the concreting operation

5.02.09 MEASUREMENT

The provisions of this section are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of these Specifications.

SECTION 5.03 STEEL REINFORCEMENT AND FIXING

5.03.01 SCOPE

These works shall consist of the supply and fixing of the unstressed steel bars, wires, mesh and mats for the reinforcement of concrete in accordance with the Drawings and Specifications.

5.03.02 MATERIALS

A. Reinforcing Bars

A.1 High tensile steel reinforcement bars shall conform to AASHTO M31 (ASTM A615) Grade 60 (with carbon content not exceeding 0.3%) or to BS 4449.

A.2 Mild steel reinforcing bars shall conform to AASHTO M31 (ASTM A615) Grade 40 or BS 4461.

A.3 High tensile, low-alloy steel deformed bar shall conform to ASTM A706.

B. Welded Fabric Reinforcement

B.1 Welded steel wire fabric shall conform to AASHTO M55 (ASTM A185) or BS 4482.

B.2 Cold drawn steel wire shall conform to the requirements of AASHTO M32 or in the case of hard drawn steel wire to BS 4482.

C. Fabricated Mat Reinforcement

Fabricated mat reinforcement shall conform to AASHTO M54 (ASTM A 184).

D. Certification and Identification

D.1 Three copies of a mill test report shall be supplied to the Engineer for each lot of billet steel reinforcement supplied for use on the project. The mill test report shall be sworn to by a person having legal authority to bind the manufacturer and shall show the following information:

- The process or processes used in the manufacture of the steel from which the bars were rolled.

- Identification of each heat of open-hearth, basic oxygen, or electric furnace and/or each lot of acid bessemer steel from which the bars were rolled.

D.2 The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator before being offered for inspection. The tag shall show the manufacturer's test number and lot number or other designation that will identify the material with the certificate issued for that lot of steel.

D.3 The fabricator shall furnish 3 copies of a certificate which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

E. Inspection and Sampling

The sampling and testing of reinforcement bars may be made at the source of supply when the quantity to be shipped or other conditions warrant such procedure. Bars not inspected and sampled before shipment will be inspected and sampled after arrival at the site.

5.03.03 CONSTRUCTION

A. General

A.1 Reinforcing steel shall be protected at all times from damage. All reinforcement shall be free from detrimental dirt, loose mill scale, scaly rust, paint, grease, oil or other foreign substance. There shall be no evidence of pitting or visual flaw in the test specimen or on the sheared ends of the bars.

A.2 Rust shall be removed by wire brushing or, if directed by the Engineer, by sand blasting. Light rust without visible sign of peeling need not be removed.

B. Storage

B.1 Reinforcement shall be stored clear of the ground on platforms, skids or other supports and be protected against contamination by dirt, grease, oil etc. at all times. If directed by the Engineer, the contractor shall provide cover to the reinforcement.

B.2 Reinforcement of different grades and different diameters shall be stored separately and marked to facilitate inspection and checking.

C. Cutting and Bending

C.1 Cutting and bending of reinforcement shall be based on an approved bar bending schedule.

C.2 Reinforcement shall be cut in specialist cutting machines or cold cut by hand only. Cutting with oxyacetylene torch is strictly forbidden.

C.3 Bars shall be bent to the following bend diameters:

Bar Diameter, d.	Mild Steel	High Yield Steel
Up to 25 mm	4d	6d
25 to 35 mm	6d	8d
35 to 60 mm	10d	10d

C.4 All reinforcement shall be bent at the temperature range of 5 degrees C and 100 degrees C. Bending by heating, if approved by the Engineer, shall be carried out in such a manner as not to impair the physical and mechanical characteristics of the bar.

C.5 The straight bar length for a hook of 180° shall be not less than 4 times the bar diameter or 60mm whichever is the larger.

C.6 The straight bar length of a hook of 90° shall be not less than 12 times the bar diameter.

C.7 The straight bar length after hook in stirrups shall be 6 times the bar diameter or 60mm whichever is the larger.

C.8 Cold worked bars and hot rolled high yield bars shall not be re-bent or straightened once having been bent. Where it is necessary to bend mild steel bars projecting from the concrete, the bend diameter shall comply with the requirements of item C.3 above.

C.9 IS bending, of the bar in accordance with this specification causes the bar to crack, the bar shall be rejected, irrespective of any prior approval that may have been given, and removed from the Site.

C.10 Bars shall be cut and bent to the following tolerances:

Bar length (mm)	Tolerance (mm)
Up to 1000	5
1000 - 2000	+5, - 10
above 2000	+5, - 25

C.11 No adjustment to bar length after bending will be permitted.

D. Fixing

D.1 Reinforcement shall be placed and maintained in the position shown on the Drawings. Unless agreed otherwise by the Engineer, all bar intersections shall be securely tied together with the ends of the wire turned into the main body of the concrete. 1.2 mm diameter stainless steel wire shall be used for in situ members having exposed soffits. 1.6 mm diameter soft annealed iron wire shall be used elsewhere.

D.2 The correct cover to reinforcement on all exposed faces of concrete shall be maintained by using approved proprietary spacers. Where instructed by the Engineer the adequacy of such spacers shall be demonstrated by site trials.

D.3 Concrete cover blocks, where permitted by the Engineer, shall be of approved dimensions and designed so that they will not overturn when the concrete is placed. They shall be made with 10 mm maximum size aggregate and the mix proportion shall be such as to produce the same strength as the adjacent concrete. Tying wire shall be cast in the blocks for subsequent tying to the reinforcement.

D.4 Wherever it is necessary for the Contractor to splice reinforcement at positions other than those shown on the Drawings, the approval of the Engineer shall be sought and obtained before the reinforcement is placed. Splices shall be staggered where possible and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress.

D.5 Proprietary mechanical splicing devices shall be used only with prior approval of the Engineer in writing. They shall be able to withstand without any slippage a force of not less than 1.25 times the characteristic yield stress of the smaller bar spliced multiplied by the cross-sectional area of the smaller bar.

D.6 Mesh reinforcement shall comply with the sizes of sheets and diameter and spacing of bars as shown on the Drawings. The sheets of mesh shall be lapped as shown on the Drawings. The method of placing the mesh and securing it in position shall be approved by the Engineer.

D.7 Welding of reinforcement bars, if allowed by the Engineer, shall be carried out in accordance with the latest publications of the American Welding Society publication "Structural Welding Code for Reinforcing Steel", and shall be able to withstand a force of not less than 1.25 times the characteristic yield stress of the smaller of the welded bars multiplied by the cross-sectional area of the smaller bar.

D.8 Cold worked steel bars shall not be welded.

D.9 Where galvanizing or epoxy coating is required to be applied to the reinforcement, specific instructions will be given by the Engineer taking into account the particular design conditions which apply.

D.10 Dowel Bars: coat half of each bar with approved proprietary debonding compound or fit with approved plastics sleeve. Fix bars securely at required level, perfectly level, at right angles to and centered on the joint. Fit compressible caps to debonded ends of bars.

5.03.04 MEASUREMENT

A. Unless indicated otherwise, measurement of different grades of steel reinforcement will be based on the theoretical quantity of metric tons complete in place as shown on the Drawings or placed as ordered by the Engineer. No allowance will be made for clips, wire or other fastening devices for holding the reinforcement in place. Measurement will not be made of reinforcement chairs to separate slab steel or similar reinforcement to retain wall steel or similar usage elsewhere. Measurement of splices in reinforcement not shown on the Drawings will not be made, unless such splices were agreed or authorized by the Engineer.

B. Calculated weights shall be based upon Table 5.3.1

Table 5.3.1: WEIGHTS OF REINFORCING BARS

Diameter mm	Weight kg/m	Diameter mm	Weight kg/m	Diameter mm	Weight kg/m
5	0.154	18	2.000	34	7.130
6	0.222	20	2.470	36	7.990
7	0.302	22	2.980	38	8.900
8	0.395	24	3.550	40	9.870
10	0.617	26	4.170	45	12.500
12	0.888	28	4.830	50	15.400
14	1.210	30	5.550		
16	1.580	32	6.310		

C. Separate measurement for bars of different diameter but of the same grade shall not be made.

D. Fabric mesh reinforcement shall be measured separately and will be based on tile theoretical quantity of metric tons complete in place as shown on the Drawing or placed as ordered by the Engineer. No separate measurement shall be made for different mesh sizes or different wire diameters.

E. Work is deemed to include:

- Preparing schedules for bar bending.
- Fixing bars in any position and in any member.
- Fixing bars horizontally, vertically and sloping.
- Any diameter, section and length of bars.
- Forming straight bent and curved bars and links.
- Cutting, lapping and jointing (including special joints).
- Hooks, tying wire, spacers, chairs and the like.
- The weight of surface treatments and rolling margin.
- Tests and quality control procedures.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Mild steel bar reinforcement	Tonne (T)
(2) High tensile steel bar reinforcement	Tonne (T)
(3) Fabric wire mesh reinforcement	Tonne (T)
(4) Fabric bar mesh reinforcement	Tonne (T)

SECTION 5.04 FORMS, FORMWORK AND FALSEWORK

5.04.01 SCOPE

These works shall consist of the design, supply and use of forms, formwork and falsework for the construction of concrete road structures.

5.04.02 DEFINITIONS

A. Forms and Formwork

The section of the temporary works used to give the required shape and support to poured concrete. It consists primarily of sheeting material, such as wood, plywood, metal sheet or plastic sheet, in direct contact with the concrete and joists or stringers that directly support the sheeting.

B. Falsework

Any temporary structure used to support a permanent structure while it is not self-supporting.

C. Scaffold

A temporarily provided structure that provides access, or on or from which persons work, or that is used to support material, plant or equipment.

D. Tower

A composite structure, usually tall, used principally to carry vertical loading.

E. Camber

The intentional curvature of the formwork, formed initially to compensate for subsequent deflection under load.

5.04.03 MATERIALS

A. Wood

A.1 National Wood: Soft wood free of faults such as splitting, warping, bending, knots etc.

A.2 Imported Wood: When imported softwood or hardwood is used for falsework, the minimum timber grade, determined in accordance with B.S 4978 shall be SC3.

A.3 Hardwood used as load-bearing wedges and packing shall be limited to those listed in Table 5.4.1.

Table 5.4.1: Permitted Hardwoods for Load-Bearing Wedges and Packing

Standard name	Botanical species
ash	Fraxinus excelsior
beech	Fagus sylvatica
greenheart	Ocotea rodiaei
jarrah	Eucalyptus marginata
karri	Eucalyptus diversicolor
keruing	Dipterocarpus spp
oak	Quercus spp

B. Plywood

When plastic coated plywood is used, the Phenol resin on melamine shall be not less than 20% of the total coating weight.

C. Steel

Steel shall conform to the requirements of Section 5.16 "Structural Steelwork and Metal Components".

D. Aluminum

Aluminum shall conform to the requirements of ASTM B221.

E. Other Materials

Other materials, with the approval of the Engineer, may be used for falsework. These include, but not limited to, fibre-glass reinforced plastic, polystyrene, polyethylene, PVC, rubber, concrete, brick etc.

5.04.04 DESIGN

A. General

A.1 Forms and formwork and falsework shall be designed by the Contractor and submitted to the Engineer with full design calculations, detailed drawings, material specification and test certificates for approval. Falsework shall be capable of temperature changes without causing damage to the concrete.

A.2 Falsework design shall be in accordance with B.S 5972 "Code of Practice for Falsework".

A.3 If the Contractor intends to use ready made proprietary type of falsework, he shall submit all relevant data, including independent test certificates, which will enable the Engineer to determine whether or not the Contractor's proposed falsework are acceptable.

A.4 Notwithstanding any approval of falsework design by the Engineer, the Contractor will not be relieved of his responsibility for the adequacy and correctness of the design, manufacture and assembly of the falsework.

B. Forms and Formwork

B.1 **F**ormwork shall be sufficiently rigid so as to prevent any grout loss during concreting and shall not distort due to environmental effects and concreting operations so that member dimensions, shape, required finish and texture are within the tolerances specified.

B.2 Forms and formwork shall be designed to be readily assembled stripped and transported without distortion to panels and members of the formwork.

B.3 The method of stripping forms without damaging the concrete or special textured surface finish if incorporated shall be fully considered in the design.

B.4 If form liners are to be used to achieve the specified surface finish samples of a size as direeted by the Engineer shall be submitted for approval.

B.5 Form lining shall not bulge warp or blister nor shall it stain the concrete. Form lining shall be uscd in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same direction (all horizontal or all vertical). Thin metal form lining will not be permitted. Undressed lumber of uniform thickness may be used as backing for form lining. Wooden plyform of adequate thickness which is properly supported to meet the above requirements may be used in lieu of the lined forms specified herein.

B.6 Metal forms if used shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust grease or other foreign matter. Under such circumstances the continued use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels or panels with metal frames and wood or combination shall be so designed as to leave no lipping or ridges in the finished concrete.

B.7 The width and thickness of the lumber the size and spacing of studs and wales shall be determined with due regard to the nature of the Work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

B.8 Form bolts rods or ties and removable ties through plastic (PVC) pipes shall be made of steel. They shall be the type which permit the major part of the tie to remain permanently in the structure or removed entirely. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. Form ties will not be permitted through forms for handrail. Pipe spreaders shall not be used unless they can be removed as the eonerete is placed. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts will not be permitted except in unusual situations and then only with approval of the Engineer.

B.9 Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the terms immediately before placing the concrete.

B.10 Unless otherwise directed by the Engineer, the exterior side of forms shall be painted with an approved, good quality high gloss white oil base enamel paint prior to placing concrete. Paint shall be applied to metal forms only. When complete coverage is not obtained with one coat, the Engineer will order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

B.11 Unless provided otherwise on the Drawings or directed by the Engineer, all exposed edges shall be beveled by using dressed, millcut, triangular molding, having 20 millimeter sides.

B.12 Forms shall be maintained after erection to eliminate warping and shrinkage.

C. Falsework

C.1 Falsework and centering shall be designed to provide the necessary rigidity to support all loads placed upon it without settlement or deformation in excess of the permissible tolerance for the structure given in the Specifications. Falsework columns shall be supported on hardwood, concrete pads or metal bases to support all falsework that cannot be founded on rock, shale or thick deposits of other compact material in their natural beds. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsevvork 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.

C.2 All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing, and the splices shall be scabbed in a manner approved by the Engineer.

C.3 The Contractor shall compute falsework settlement and deflection for bridges so that when the final settlement is complete, the structure will conform to the required camber, section and grade as shown on the Drawings.

C.4 The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete, and shall provide a competent observer to observe and correct the settlement.

C.5 Screw jacks, if used, shall be designed for use with a slenderness ratio not exceeding 60. The slenderness ratio shall be taken as the ratio of the clear distance between effective bracing in both horizontal directions to the diameter of the screw jack measured at the root of the thread. The manufacturers' certificate showing the ultimate load capacity of the screw jack shall be submitted with the design calculations for the falsework. If directed by the Engineer, the Contractor shall furnish a test certificate carried out at an approved independent laboratory.

C.6 Props and towers supporting forms or partially completed structures shall be interconnected in plan orthogonally at levels to be determined in the design. They shall also be interconnected by diagonal bracings in orthogonal vertical planes.

5.04.05 FINISHES

A. Formed Finishes

A.1 **Class F1.** This class of surface finish denotes a special finish required from aesthetic considerations. In additions to the requirements of Class F2 finish, the following additional requirements shall apply.

A.1.1 It is of major importance that the special finishes required on F1 surfaces arc uniformly and consistently maintained with no variation in the color or consistency of the concrete within the same structure. In order to achieve this, the Contractor shall make trial panels of the formed finishes specified. These panels shall be not less than 1.5 m high and 1 m wide and 250 mm thick and shall be cast in the manner and with materials as proposed for the actual Work. These panels are for the approval of the liners and are preliminary to the test samples carried out on site.

A.1.2 The Contractor shall provide at his own expense as many panels as required by the Engineer until a satisfactory trial panel has been accepted by the Engineer. In addition, the Engineer will require samples of pier, part of a deck, section of retaining wall and/or underpass wall and typical precast edge unit to be cast on site in the same manner as proposed for the prototypes. The Contractor shall submit to the Engineer and obtain his approval for all details before commencement of trials. These samples when approved, will form the standard against which the corresponding finishes on the actual work will be judged. In all cases of approvals, the decision of the Engineer alone will be final.

A.1.3 Where forms and form-liners to be used for the special finishes specified are manufactured outside the Country, the forms and form-liners shall not be permitted on Site until the Engineer has inspected the forms and form-liners and is satisfied that they are suitable for the Works. Samples and trial panels carried out at the place of manufacture to demonstrate to the Engineer that the forms and formliners and the methods of assembling and de-shuttering them are acceptable shall not be paid for and will not relieve the Contractor of the requirement for carrying out trial panels on site as described above.

A.1.4 If the required finish in the opinion of the Engineer, has not been obtained in the Works, the Contractor shall promptly carry out at his own expense all measures required by the Engineer to obtain the specified finish. These may include grit blasting followed by the application of polyester or epoxy paint. Where such remedial action is ordered by the Engineer, the entire exposed surface shall be so treated irrespective of whether or not the detective areas are localized or extensive.

A.2 **Class F2** Formwork shall be lined with a material approved by the Engineer to provide a smooth finish of uniform appearance. This material shall leave no stain on the concrete and shall be so joined and fixed to its backing so that it imparts no blemishes. It shall be of' the same type and obtained from only one source for any one structure. The Contractor shall make good any imperfections in the finish as directed by the Engineer. Internal ties and embedded metal parts will not be permitted unless otherwise approved by the Engineer.

A.3 **Class F3.** Irregularities in the finish shall be no greater than those resulting from the use of wrought thick square edged boards arranged in a uniform pattern. The finish is intended to be left as struck. Imperfections such as fins and surface discoloration shall, however, be made good as and when required by the Engineer.

A.4 **Class F4.** No special requirements.

A.5 Permanently exposed concrete surfaces to classes Fl, F2 and F3 finish shall be protected from rust marks and stains of all kinds. Internal ties and embedded metal parts will not be permitted.

A.6 The Contractor shall submit to the Engineer all details of' formwork liners joints and materials including fabrication drawings and stating procedures involved in the use of formwork for approval before commencement of any work on fabrication. No formwork shall be brought to site without the prior approval of the Engineer. Adequate time shall be allowed by the Contractor in his program for these approvals after consultation with the Engineer.

B. Unformed Finishes

B.1 **Class U1.** The concrete shall be uniformly leveled and screeded to produce a plain or ridged surface as described in the Contract. No further work shall be applied to the surface unless is used as the first stage for Class U2 or Class U3 finish.

B.2 **Class U2.** After the concrete has hardened sufficiently the concrete Class U1 surface shall be floated by hand or machine sufficiently to produce a uniform surface free from screed marks.

B.3 **Class U3.** When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface a Class U I surface shall be steel-trowelled under firm pressure to produce a dense smooth uniform surface free from trowel marks.

5.04.06 TOLERANCES

A. The tolerances in the forms and formwork shall be such that members formed shall be within the tolerances for the size and type of the member specified elsewhere in these Specifications.

B. Falsework shall be fixed such that the completed structure shall be within the required tolerances in plan elevation and slope for the size and type of structure specified elsewhere in these Specifications.

C. Surfaces which are to receive deck waterproofing shall be finished to an accuracy such that when tested with a three meter long straight edge the maximum depression shall not exceed five mm.

5.04.07 CONSTRUCTION REQUIREMENTS

A. The forms and falsework shall be inspected by the Engineer after assembly on the work area and immediately before concreting. No pour shall commence until the forms and falsework have been approved by the Engineer.

B. The inside surfaces of all forms shall, except for pavement formwork, or unless otherwise agreed by the Engineer, be coated with a release agent approved by the Engineer. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with the reinforcement or prestressing tendons and anchorages. Different release agents shall not be used in formwork which will be visible in the Finished work.

C. Immediately before concrete is placed, all forms shall be thoroughly cleaned out.

D. Forms that are to be re-used shall be thoroughly cleaned and re-oiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber will be condemned by the Engineer, and shall be removed from the Site.

E. Formwork shall be constructed so that the side forms of members can be removed without disturbing the soffit forms. If props are to be left in place when the soffit forms are removed, these props shall not be disturbed during the striking.

F. Runways used to move plant, equipment or materials shall be clear of the reinforcement and shall be robust enough not to deflect excessively or cause movement to the forms due to dynamic effects.

G. During concreting, the forms and their supports shall be constantly monitored for signs of imminent failure. There shall be skilled operatives in constant attendance during concreting who are qualified to make immediate adjustments to the forms and falsework so that concreting can satisfactorily be completed.

H. The engineer may suspend concreting operations it; in his opinion, the forms and falsework are in danger of failure and that the actions taken by the Contractor are insufficient or inadequate to guarantee the sate and satisfactory completion of concreting. In such an event, the Engineer may instruct the Contractor to remove, at his expense, the concrete already poured.

I. If at any period of work during or after placing of concrete the forms show signs of sagging or bulging the Contractor at his own expense shall remove the concrete to the extent directed by the Engineer bring the forms to the proper position and place concrete.

J. Immediately after the removal of the forms all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of 1 part by volume of Portland cement and 2 parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar so that when dry the color will match the surrounding concrete. Patches shall be moistened prior to mortaring to obtain a good bond with the concrete. When directed by the Engineer the Contractor shall al his own expense substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgment of the Engineer pockets are of such extent or character as to materially affect the strength of' the structure or to endanger the life of the steel reinforcement he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.

5.04.08 REMOVAL OF FORMWORK AND FALSEWORK

A. To facilitate finishing forms on handrails ornamental work, and other vertical surfaces that require a rubbed finish shall be removed as soon as the concrete has hardened sufficiently that it will not be injured as determined by the Engineer. In determining the time for the removal of forms consideration shall be given to the location and character of the structure weather and other conditions influencing the setting of the concrete.

B. Formwork shall be removed in a manner not to damage the concrete and at times to suit

the requirements for its curing and to prevent restraint that may arise from elastic shortening shrinkage or creep.

C. Any remedial treatment to surfaces shall be agreed with the Engineer following inspection immediately after removing the formwork and shall be carried out without delay. Any concrete surface which has been treated before being inspected by the Engineer shall be liable to rejection.

D. Where the concrete compressive strength is confirmed by tests on concrete cylinders (cubes) stored under conditions approved by the Engineer that simulate the field conditions formwork supporting concrete in bending may be struck when the strength is 10 N/sq.mm or three times the stress to which it will be subjected which ever is the greater.

E. For ordinary structural concrete made with ordinary Portland cement only, in the absence or control cylinders (cubes) the period before striking shall be in accordance with the minimum periods given in Table 5.4.2 unless otherwise directed by the Engineer.

Table 5.4.2: Minimum Period Before Striking for Ordinary Structural Concrete Made With Ordinary Portland Cement

Type of Formwork	**Minimum period before striking** **Surface Temperature of Concrete**		
	16°C	**7°C**	**t°C**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	300 hours t + 10
Soffit formwork to slabs	4 days	6 days	100 days t + 10
Props to slabs	10 days	5 days	250 days t + 10
Soffit to formwork to beams	9 days	14 days	230 days t + 10
Props to beams	14 days	21 days	360 days t + 10

5.04.09 MEASUREMENTS

A. The provisions of this section of these Specifications are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

B. Test panels carried out by the Contractor to demonstrate to the Engineer's satisfaction that the specified F1 finish can be achieved shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.0l "Concrete and Concrete Mixes and Testing" of the Specification. Test panels not accepted by the Engineer shall not be measured for payment.

C. Test samples, such as a section of retaining wall or a complete pier, carried out by the Contractor and approved by the Engineer for use as reference bench marks for the quality to be attained in the Works shall be measured for payment for the appropriate class of concrete measured for payment under the provision of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification. Test samples not accepted by the Engineer shall not be measured for payment.

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SECTION 5.06 NOT APPLICABLE

SECTION 5.07 REINFORCED CONCRETE BOX CULVERTS

5.07.01 SCOPE

These Works shall consist of furnishing materials and the construction of reinforced concrete box culverts and headwalls. All monolithic reinforced concrete box culverts including headwalls and pipe culvert headwalls shall be constructed in conformity to the lines, grades and dimensions as shown on the Drawings and in accordance with Section 2.09 "Excavation and Backfill for Structures", 5.06 "Reinforced Concrete Structures", 5.03 "Steel Reinforcement" and other pay items in the Bill of Quantities which are to constitute the complete structure.

5.07.02 MATERIALS

A. The materials shall conform to the sub-sections "Materials" of each of the following sections:

- For concrete Section 5.01 & 5.02
- For Reinforcement Section 5.03
- For Formwork and Falsework Section 5.04

B. Concrete classes shall be those prescribed on the relevant Drawings for the several items which are to constitute the complete structure.

5.07.03 CONSTRUCTION

A. Box culverts shall be constructed in sections such that expansion joints are located at intervals which shall be so spaced as to prevent the box culvert from behaving; as a long beam unless such structural action has been allowed for in the design. Unless shown on the Drawings or directed by the Engineer, the spacing, of expansion joints shall be no greater than 20 meters. Expansion joints shall also be used at the culvert ends where the culvert meets the wingwalls and apron slabs.

B. Where box culverts are located in road embankments, the embankments shall first be constructed in accordance with Section 2.06 "Embankment Construction". The compacted embankments shall then be excavated in trenches for the culverts This requirement may be dispensed with by a written permission from the Engineer to so do. Where a culvert is to be constructed under a high embankment, this requirement may be relaxed or dispensed with provided the fill is designed to arch over the culvert or the culvert is specially designed for an increased surcharge load from the embankment.

C. For culverts located below firm ground, the excavation shall be carried out in trenches in accordance with Section 2.09 "Structural Excavation and Backfill".

D. Backfilling and compaction shall be carried out in layers not exceeding 200 mm and the difference in the levels of backfill on either side of the culvert shall at no time exceed 500 mm.

E. All concreting shall be carried out in the dry.

F. Unless otherwise shown on the Drawings or instructed by the Engineer, the base slab of the box culvert for its entire length shall first be completed before proceeding with the

walls and roof slab.

The construction joints in the walls shall be located at not less than 100 mm above the top of the base slab. Unless shown otherwise on the Drawings or directed by the Engineer, the walls and roof slabs shall be concreted in one pour between expansion joints.

5.07.04 MEASUREMENT

A. The Works prescribed in this section shall be measured in accordance with the provisions of Sections 5.01 and 5.03 of the Specifications.

B. Where Pay Items for any items are not provided in the Bill of Quantities, the works prescribed in respect of such items shall not be measured for direct payment but shall be considered as subsidiary works the cost of which shall be deemed to be included in the Contract Prices for Pay Items.

C. The amount of completed and accepted work measured as provided above shall be paid for at the unit prices bid for each Pay Item, which prices shall be compensation for furnishing all materials, labor, equipment, tools, supplies and all other items necessary for proper completion of the Works.

SECTION 5.08 PIPE CULVERTS

5.08.01 SCOPE

These Works shall consist of furnishing materials, and installing and testing pipe culverts for cross drainage as shown on the Drawings.

5.08.02 MATERIALS AND PIPE MANUFACTURE

A. Concrete and Mortar

A.1 Concrete and cement mortar materials shall conform with the relevant requirements of section 5.01 - "Concrete and Concrete Mixes and Testing". The type of cement to be used in the manufacture (or in situ construction) of all concrete pipes and in mortar intended for application to pipe joints shall be as specified in the Project Specifications or as shown on the Drawings.

A.2 Unless otherwise shown on the drawings, concrete for pipes shall conform with the requirements of AASHTO M 170M, Class IV Reinforced Concrete Pipe.

A.3 Concrete for cradles, haunching and pipe encasement shall be Class 250/20, unless shown otherwise on the Drawings.

A.4 Concrete bedding for pipes shall be Class 110/25.

B. Reinforcement

Reinforcing steel and steel wire fabric shall conform with the relevant requirements of Section 5.03 - "Steel Reinforcement and Fixing".

C. Jointing Materials

C.1 Wherever rubber ring joints are used, the rings or gaskets shall conform to ASTM C 443M (for concrete pipe).

C.2 Approved types of proprietary bitumastic or plastic sealants or flexible elastomeric gaskets may be used in lieu of mortar for concrete pipe jointing.

C.3 Where flexible joints are required at pipe joints in concrete bedding, haunching and pipe encasement, they shall consist of an approved type compressible fibrous board of 20 mm thickness.

D. Bedding Materials

Granular material used as bedding for pipes shall consist of sand or sandy soil essentially free from clay or organic material, and with 90-100% passing 4.75 mm (No. 4) sieve and 0-5°S, passing 0.075 mm (No. 200) sieve.

E. Backfill Material

Backfill material around and over pipes shall conform with the relevant requirements of Section 2.09 - "Excavation and Backfill for Structures" unless otherwise shown on the Drawings or specified herein.

F. Precast Reinforced Concrete Pipe

F.1 Unless otherwise stated on the drawings, precast concrete pipe for culverts and storm drains shall conform with the requirements of AASHTO M 170M, Class IV, BS 5911 Class H or DIN 4032 Class KW.

F.2 Internal and external pipe surfaces shall be smooth and sound and the pipe correctly dimensioned.

F.3 The manufacture of precast pipe shall conform with the relevant requirements of AASHTO M 170M Class IV, except in any instance where there is conflict with the Employer's Standards in which case the Employer's requirements shall prevail.

F.4 Tests shall be performed in accordance with AASHTO T 280 on at least 0.5% of all pipes furnished to determine the external load crushing strength (by 3-edge bearing method). The minimum D loads to produce a 0.3 mm crack and to produce the ultimate load shall be as per Table 4 of AASHTO 170M.

F.5 Absorption tests shall be performed in accordance with AASHTO T 280M on samples from at least 0.5% of all pipes furnished. Sampling procedures and the maximum acceptable absorption shall be as specified in AASHTO M 170M.

F.6 If the Contractor elects to precast pipes on site, details of the casting yard and proposed plant and equipment and methods shall be submitted for approval before precasting commences. The manufacturing process shall conform with all relevant requirements of Section 5.01 – "Concrete and Concrete Mixes and Testing", Section 5.02 "Concrete Handling Placing and Curing" and Section 5.03 - "Steel Reinforcement and Fixing".

F.7 Crushing strength tests shall be performed in accordance with AASHTO T33.

F.8 Precast pipes represented by sets of test samples which have an average strength less than 85% of the specified strength shall not be incorporated in the Works. Such pipes shall either be destroyed or permanently scored or marked as directed and removed from the Site by the Contractor.

F.9 Precast pipes represented by sets of test samples which have an average strength 85-90% of the specified strength may be incorporated in the Works provided they are laid on a concrete cradle and haunched. The cradle shall cover the full trench width and extend below the underside of the pipe to a depth of at least 0.25x external pipe diameter. The concrete haunching shall extend above the underside of the pipe to a height of 0.5 x external pipe diameter and be keyed into the surface of the cradle in an approved manner.

G. Testing

All pipe and material testing shall be carried out at an approved laboratory.

5.08.03 CONSTRUCTION AND INSTALLATION

A. General

A.1 Proper care shall be taken during handling and installation not to chip of damage the barrels or ends of precast concrete.

A.2 Where damage to pipes cannot be satisfactorily repaired, in the judgment of the Engineer, they shall be replaced at the Contractor's expense.

B. Excavation and Backfilling

All excavation and backfilling for culverts, storm drains, and ducts, including preparation and shaping of trench foundations and pipe bedding, shall be in accordance with the relevant requirements of Section 2.09 - "Excavation and Backfill for Structures".

C. Pipe Installation Generally

C.1 No pipes shall be installed until the excavations, foundations and bedding have been approved.

C.2 Provision of pre-camber by the Contractor for any pipeline to allow for possible future settlement shall on no account be attempted unless precise details and instructions in respect of such pre-camber are issued by the Engineer.

C.3 The inside of each pipe shall be cleaned and brushed out and the pipe inspected for any major or minor damage immediately prior to laying. Pipes with minor damage shall be reinspected by the Engineer following completion of field repairs and, if approved, may be installed in the Works. Pipes with major damage shall be rejected.

C.4 All pipes shall be fully and firmly bedded over the entire length of each pipe and shall be laid true to line, level and grade, commencing at the downstream end unless otherwise approved. Inverts shall be properly matched to form a continuous line free of appreciable irregularities.

C.5 Bedding for precast concrete pipe shall be shaped to suit the pipe contour and, where practicable, carried up as haunching on both sides to one quarter of the external diameter of the pipe.

C.6 Multiple pipe culverts shall have a clear separation between adjacent pipelines of 300 mm or 0.5 x external pipe diameter whichever is larger, unless shown otherwise on the Drawings. Backfills between pipe culverts shall be placed and compacted in equal layers not exceeding 150mm such that the difference in backfill levels on either side of individual pipes does no exceed 150mm at any time.

C.7 Installed pipe that is subsequently found to be damaged misaligned disturbed or displaced by construction traffic, plant or equipment or other causes, at any stage prior to completion of the Works, shall be repaired (if practicable and if damage is minor), realigned, or removed and replaced as directed, at the Contractor's expense.

D. Installation of Precast Concrete Pipe

D.1 Precast concrete pipe shall be installed with the bell (i.e. socket) end facing upstream the pipes shall be fully engaged. Internal gaps of more than 20 mm will not be accepted.

D.2 Pipe ends shall be cleaned and dampened immediately prior to mortar application. The joint shall then be sealed completely watertight by filling and neatly finishing with a 1: 2 cement / sand mortar of sufficiently stiff workability to remain in position without sagging. Internal mortar joints shall be finished flush with the pipe surface.

D.3 External surfaces of mortar joints shall be covered with burlap which shall be kept continuously moist for at least 3 days after completion of the joint.

D.4 Alternatively, joints may be sealed using approved type bitumastic or plastic sealants or elastomeric gaskets or rubber rings or gaskets. Sealing of concrete pipe joints using proprietary type joint sealants and gaskets shall be carried out in accordance with the manufacturer's instructions and as directed.

D.5 Where in situ concrete haunching or encasement of precast pipe is ordered, the specified Class of concrete shall be placed, compacted and cured in accordance with the relevant requirements of Section 5.02 - "Concrete Handling, Placing and Curing". Fibrous board vertical joints shall be constructed in the haunching or encasement at approved intervals along the line of pipe.

E. Concrete Headwalls, Aprons, Wingwalls

E.1 All unreinforced and reinforced concrete headwalls, aprons, endwalls and wingwalls at the ends of pipe culverts, shall conform with the relevant requirements of Section 5.06- "Plain and Reinforced Concrete Structures".

F. Cleaning and Inspection

F.1 After completion of headwalls, endwalls and wingwalls for culverts, and after backfilling has been completed, the pipelines shall be cleared of all sand, silt and other debris, flushed from end to end with water and left clean and free from obstructions.

F.2 After clearing and cleaning, the larger pipelines (750 mm or larger diameter) will, where practicable, be inspected by the Engineer from the inside. The Contractor shall provide any required facilities and assistance for such inspections.

5.08.04 MEASUREMENT

A. Single pipe Culverts and Multi-Pipe Culverts shall be measured by lin.m of each size and type furnished, installed or constructed, backfilled, completed, and accepted.

B. Measurement of pipe culverts and pipe arch culverts shall be of the centerline slope length of single pipe culvert or multi-pipe culvert installation. The length measured shall extend from end to end of pipe in the absence of headwall or end wall, or shall extend between inside faces of headwall and endwall.

C. Reinforced Concrete Headwalls, Endwalls and Wingwalls shall be measured as prescribed in Section 5.01 - " Concrete and Concrete Mixes and Testing".

D. Excavation, (except for unsuitable material below bedding) foundation preparation, bedding and backfilling (excluding reinstatement of pavement courses) shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Pay Items.

E. Unsuitable foundation material ordered excavated from below the pipe bedding shall be measured for payment as prescribed in Section 2.09 – “Structural Excavation and Backfill”.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Pipe Culvert	Linear meter (m)

SECTION 5.09 DRAINAGE AND UTILITY STRUCTURES

5.09.01 SCOPE

This work shall consist of the construction of catch pits manholes curb ditch inlets and outlets and similar structures in connection with the drainage of groundwater from the surface and below the surface of land and paved surfaces

5.09.02 MATERIALS

A. Concrete shall conform to the requirements as specified in Section 5.01 "Concrete and Concrete Mixes and Testing".

B. Reinforcement shall conform to the requirements as specified in Section 5.03 "Steel Reinforcement and Fixing".

C. Structural steel shall conform to the requirements as specified in Section 5.16 Structural Steelwork and Metal Components".

D. Concrete pipes and tiles shall conform to the requirements of:

- AASHTO M86 Concrete sewer storm drain and culvert pipe
- AASHTO M 175 Perforated concrete pipe
- AASHTO M 1 76 Porous concrete pipe
- AASHTO M178 Concrete drain tile

E. Precast concrete manhole sections shall conform to the requirements as specified in

- AASHTO M 199 Precast reinforced concrete manhole sections

F. Precast concrete culverts shall conform to the requirements as specified in

- AASHTO M206 Reinforced concrete arch culvert storm drain and sewer pipe
- AASHTO M207 Reinforced elliptical culvert storm drain and sewer pipe
- AASHTO M259 Precast reinforced concrete box sections for culverts storm and
- M173 drains and sewers

G. Bricks for masonry manholes shall be from local manufacturers and shall conform with BS 3921.

H. Precast concrete blocks for Masonry walls shall conform to BS 6073.

I. Vitrified clay pipes and tiles shall conform to the requirements as specified in

- AASHTO M65 Vitrified clay pipe, extra strength, standard
- (ASTM C700) strength and perforated clay drain tile
- AASHTO M179 Clay Drain Tile

J. PVC pipe shall conform to the requirements as specified in

- AASHTO M278 Class P5 50 PVC pipe

K. Corrugated aluminum alloy culverts and underdraws shall conform to the requirements as specified in

- AASHTO M196 Corrugated Aluminum Alloy Culverts and Underdrains

L. Asbestos-Cement pipes, couplings and fittings shall conform to the requirements of ASTM C663.

M. Grey cast iron castings shall conform to AASI-ITO M105 (ASTM A48) Class 25 or higher. Castings shall be manufactured to the sizes and dimensions shown on the Drawings.

N. Test bars shall be prepared and tested as specified in AASHTO M105.

O. Steel castings: mild to medium strength castings shall conform to AASHTO M103 (ASTM A27). Unless otherwise shown on the Drawings or instructed by the Engineer, castings shall be grade 65-35 fully annealed. Steel castings shall conform to the dimensions shown on the Drawings. Test bars shall be prepared and tested as specified in AASHTO M 103.

P. Wrought iron plates and shapes shall conform to the dimensions shown on the Drawings. Rolled wrought iron bars and shapes shall conform to the requirements of ASTM A207 Wrought iron plates shall conform to ASTM A42.

Q. Safety steps and hand bars shall be manufactured of 20mm diameter mild steel deformed reinforcing bars and hot dip galvanized in accordance with ASTM A153.

R. Testing and Certification: the Contractor shall submit to the Engineer all specified test coupons and Manufacturers' Certificates of Guarantee for all structural steel cast iron cast steel and wrought iron parts stating that the materials supplied meet the appropriate AASHTO or ASTM specification. The submission of such test certificates shall not relieve the Contractor of his obligations to carry out independent tests at an approved laboratory as directed by the Engineer at his own expense.

5.09.03 CONSTRUCTION

A. Excavation

The method of excavation shall conform to the requirements of Section 2.09 “Structural Excavation and Backfill”.

B. Pipe Installation

B.1 No pipes shall be installed until the excavations foundations and bedding have been approved.

B.2 Each pipe shall be inspected before laying and damaged pipes shall be rejected.

B.3 Pipes shall be laid true to line and grade commencing at the downstream end unless otherwise approved.

B.4 Bedding haunching and surrounding operations shall be carried out strictly in accordance to dimensions shown on the Drawings. The plant equipment and methods used for such operations shall be approved.

C. Concrete

C.1 The composition, consistency, proportioning, batching, mixing and transportation of the concrete shall conform to Section 5.01 “Concrete and Concrete Mixes and Testing”.

C.2 The formwork for, and the placing, curing, and protection of the concrete shall conform to the requirements of Section 5.06 "Plain and Reinforced Concrete Structures".

C.3 Class 210/25 concrete shall be used unless otherwise shown on the Drawings or ordered by the Engineer

D. Ready-Mix Concrete

When concrete is manufactured by a commercial ready-mix plant, the handling of cement and aggregates, composition, consistency, proportioning, batching and mixing shall conform to the requirements specified in Section 5.01 "Concrete and Concrete Mixes and Testing" and in this Section, "Drainage and Utility Structures".

E. Masonry

E.1 When so indicated on the Drawings or approved by the Engineer, brick or concrete block masonry may be used in lieu of concrete for the walls of catch basins, manholes or curb inlets. Masonry manholes may be constructed circular, with an inside diameter equal to the greater of the inside dimensions indicated on the Drawings for the concrete manhole.

E.2 When masonry is used in lieu of concrete for square or rectangular structures, the inside dimensions of the structure shall be of the dimensions shown on the Drawings unless ordered otherwise by the Engineer. The mortar for masonry shall be as specified in Section 5.01 "Concrete and Concrete Mixes and Testing ". The brick or concrete block shall be laid with full mortared joints and with sufficient header courses to tie the masonry together properly as approved by the Engineer.

F. Reinforcement

The method of reinforcing shall conform to the requirements of Section 5.03 "Steel Reinforcement and Fixing.

G. Placing Castings

Castings shall be set in full mortar beds or otherwise secured as shown on the Drawings and approved by the Engineer. Mortar for setting and casting shall be mixed as specified in Section 5.01 "Concrete and Concrete Mixes and Testing". Castings shall be set accurately to correct elevation so that no subsequent adjustment is necessary.

H. Backfilling

Backfilling shall conform to the requirements of Section 2.09 “Structural Excavation and Backfill”.

I. Cleaning

All catch basins, catch pits, drop inlets, manholes, inlets and outlets shall be thoroughly cleaned of any accumulations of silt, debris or foreign matter of any kind, and shall be free from such accumulations at the time of final inspection.

J. Painting

Structural steel cover plates shall be painted with one shop coat of Paint Number 2, one field coat of paint Number 6, and one field coat of Paint Number 7. Painting, shall be in accordance with the requirements of Section 6.09 "Painting of Structures". Painting of castings will not be required.

K. Testing of Manholes

Plug the manhole inlets and outlets, fill it with water and allow for at least 24 hours or such longer period to allow for complete absorption. Refill with water. Allowable leakage is not to exceed 1 % over 24 hours, otherwise make good and retest.

5.09.04 MEASUREMENT

A. Manholes, drop inlets, catchbasins, catchpits, curb inlets, ditch inlets and ditch outlets shall be measured by the number of each type constructed, completed as shown on Drawings and accepted including protective painting, furnishing and installation of all materials, frames, grates, covers and steps.

B. Channel grating basins shall be measured by the linear meter of each clear opening width, constructed, completed and accepted including furnishing and installation of all materials, frames and grates.

C. No separate measurement or payment shall be made for any excavation, shoring, sheeting or backfilling, or for breaking into existing pipes, channels or culverts in order to install new manholes, catchbasins, catchpits, Drop inlets, curb inlets, ditch inlets, ditch outlets and channel grating basins, all such work being considered subsidiary to the relevant Pay Items.

D. No separate payment shall be made for blinding, protective and bituminous painting, equipment, forms, tools, furnishing and placing materials, labor, or any other item necessary for the proper completion of the work.

PAY ITEM	UNIT OF MEASUREMENT
(1) Manhole (specify dimension and depth)	Number (Nr)
(2) Catch basin	Number (Nr)
(3) Catchpit	Number (Nr)
(4) Curb Inlet,	Number (Nr)
(5) Ditch inlet	Number (Nr)
(6) Ditch outlet	Number (Nr)
(7) Channel grating basin	Linear Meter (m)
(8) Drop Inlet (specify dimension and depth)	Number (Nr)

DIVISION 6

INCIDENTAL CONSTRUCTION

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SECTION 6.01 TEMPORARY SAFETY MEASURES.

6.01.01 SCOPE

These Works shall consist of temporary measures taken during the construction works to protect public from any damages due to the construction works. These works include but limited to providing signs, barriers, warning lights, etc..

6.01.02 REFERENCES

All materials, color code, locations, etc.. shall be in accordance with the drawings and Lebanese standards (Libnor). In case of any contracdition, Libnor will be the final and only reference while the drawings are only for guidance.

6.01.03 EQUIPMENT

The equipment used used in this section are as listed below but not necessary limited to the following:

6.01.03.1 Warning Signs

Warning signs and mandatory signs of any type shall be furnished with all relevant fixation. Ismanteled and relocated for each temporary job ans as directed.

6.01.03.1.1 Measurement

Warning signs and mandatory signs of any type shall be measured by the number of signs intalled and accepted by the Engineer.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Warning sign type KD or KA Type B.	Number
(2) Warning sign Type KC of size more than 1 sq.m and less than 2 sq.m.	Number

6.01.03.2 Plastic Barrier

Plastic water-filled Barrier must be linked together in an approved manner in accordance with the manufacturer's guidance to form a continouous delineation boundary. The plastic barrier shall be used in accordance with the related Traffic Control Plan and subject to the Engineer's approval.

6.01.03.2.1 Measurement

PAY ITEMS	UNIT OF MEASUREMENT
(1) Plastic Barrier 145cm long and 40cm wide installed and accepted on site.	Number

6.03.03.3 Solar Flashing Beacon

6.03.03.3.1 Scope

The work covered in this section consists of purchasing and installing solar flashlight as shown on the Drawings or as directed by the Engineer.

6.03.03.3.2 Materials

A. Shell material: Polycarbonate (PC) engineering plastic, metal covering

B. Light-emitting area size: Ø300 mm

C. LED No.: 95 pcs Yellow Led /pc

D. LED wavelength: 590±5 nm for yellow

E. Led luminance: >8000 mcd Power:>10w

F. LED lifespan: ≥10,0000 hours

G. Working mode: 24 hours continuous working or light-sensor control

H. Flashing frequency:45 times/minute

I. Visibility: ≥1000 m

J. Battery type: 12V /7AH Lead-acid battery

K. Solar panel type:18V/8W, mono-crystalline silicon solar cell, lifespan more than 25 years.

L. Working temperature: -20~ 70°C

M. Working hours: can working continuously more than 120 hours(exceed 5days) in cloudy and rainy days.

N. Wind load resistance: ≥1.5KN/m2

6.09.03.3.3 Measurement

The Solar Flashlight shall be measured by the number of flash lights installed, functioning and accepted by the Engineer as per the details Drawings and the material specifications.

6.03.03.4 Flashing Arrow or Chevron Boards

6.03.03.4.1 Scope

The work covered in this section consists of purchasing and installing Flashing Arrow Boards (FAB) as shown on the Drawings or as directed by the Engineer.

6.03.03.4.2 Description

Flashing Arrow Boards (FAB) displaying arrow or chevron 'Route Deviation' symbols shall be located within the Transition Area to supplement 'Keep Left' or 'Keep Right' signs, or Route Deviation chevron boards, particularly on high-speed roads. FABs shall be mounted also on trucks or trailers for both stationary and moving operations shadow vehicles. Arrow boards should have a solid rectangular appearance.
FABs shall meet minimum requirements for size, legibility distance, number of elements, and other factors as per the following:

Minimum Size (arrow length x arrow-head width)	**Minimum Visibility Distance**	**Minimum Number of Elements**	**Application** (regular posted speed limit)
244 cm x 120 cm	1,000 m	15	Short or Long duration work ≥ 70 km/h

Vehicle-mounted arrow boards should have remote controls and elements capable of at least 50% dimming from full brilliance. Full brilliance should be used for day-time operations, and a dimmed mode should be used for night-time operations.

A FAB is mounted on a vehicle, trailer, or other suitable support.

The minimum mounting height measured vertically from the bottom of the board to the roadway should be 2.0 m. Vehicle-mounted arrow boards are mounted at a height of at least 1.0 m.

A FAB should always be used in combination with appropriate signs, channelizing devices, and/or other temporary traffic control devices.

6.03.03.4.3 Operation

For flashing and sequencing arrow boards, the minimum element "on time" shall be 50% for the flashing mode, with equal intervals of 25% for each sequential phase. The flash rate should be between 25 and 40 flashes per minute.
Sequencing arrow panels have several arrowheads that flash in a series, directing traffic to the right or left.

An arrow board in arrow or chevron mode can be used only for stationary or moving lane closures on multilane roadways.

6.03.03.4.4 Measurement

The Flashing Arrow Boards shall be measured by the number of boards installed, functioning and accepted by the Engineer as per the details Drawings and specifications.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Flashing Arrow or Chevron Boards installed and accepted on site.	Number

SECTION 6.02 ROAD SIGNING

6.02.01 SCOPE

A. These Works shall consist of furnishing and installing highway signs, post assemblies and overhead structures, including construction of all necessary concrete and reinforced concrete foundations and including all sign panel lettering, as shown on the Drawings.

B. All signs shall be lettered in both French and Arabic, unless otherwise specified.

6.02.02 MATERIALS

A. Concrete

A.1 Unless otherwise shown on the drawings, concrete for reinforced concrete footings shall be Class 250/20. Unreinforced concrete to support single post signs shall be of Class 210/20.

A.2 All concrete materials shall conform with the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

B. Reinforcement

Reinforcement steel shall conform with the relevant requirements of Section 5.03 - "Steel Reinforcement and Fixing".

C. Sign Supports

C.1 Standard industrial steel sign supports shall be fabricated from billet or rail steel conforming to ASTM A 120, Schedule 40.

C.2 Pipe posts shall be hot dipped galvanized according to ASTM A 123 after yielding holes are drilled or punched with an absolute minimum outside diameter of 73 mm according to ASTM A 120.

D. Steel Channels

Steel channels shall conform with the relevant requirements of Section 5.16- "Structural Steelwork and Metal Components".

E. Galvanized

Unless otherwise shown on the Drawings, all steel supports, shall be galvanized in conformity with ASTM A123. All bolts, nuts, and washers shall be galvanized in conformity with ASTM A 153.

F. Paint

All paint materials shall conform with the relevant requirements of Section 6.09 – “Painting of Structures”.

G. Sign Materials

G.1 Aluminum alloy panels, sheets and miscellaneous hardware shall conform with ASTM B 209, B 211, or B 221, as appropriate. All aluminum alloys shall have a minimum tensile strength of 2,500 kg/ cm^2 and a minimum yield strength of 2,000 kg/ cm^2.

G.2 Extruded aluminum panels shall have a minimum thickness of 2.7 mm. Panels shall normally be 30 cm nominal width, except when smaller widths are necessary to size a given sign correctly.

G.3 Sheets for plain aluminum signs shall have a minimum thickness of 3 mm unless otherwise specified.

G.4 Steel sheets shall conform to ASTM A 366, minimum 1.5 mm thickness unless otherwise shown on the Drawings.

G.5 Stainless steel bolts, washers, and self-locking nuts shall conform to ASTM A276, chromium-nickel grade with a minimum yield strength of 2,000 kg/cm^2.

G.6 Vulcanized Fiber Washers shall conform to ASTM D 710, gray, commercial grade.

G.7 Hard rubber washers shall be as approved by the Engineer.

G.8 Nylon and/or neoprene washers spacers sleeves etc. shall be as approved by the Engineer.

H. Reflective Sheeting

Reflective sheeting shall be of the "Engineering Grade" type unless otherwise specified.

Reflective sheeting shall consist of synthetic sheet resin or other approved noncellulostic materials, transparent plastic of the colors specified, and a retro-reflective system (i.e. glass spheres). These spheres shall adhere to the synthetic sheet resin and be embedded beneath a flexible transparent plastic film forming a smooth flat surface.

The reflective sheeting shall have a precoated pressure sensitive adhesive backing, or a precoated tack-free solvent or heat activated adhesive backing. The sheeting shall adhere tightly to the prescribed surfaces when applied in accordance with the manufacturer's recommendations. The precoated adhesive shall not require additional adhesive coats on the reflective sheeting or application surface.

After 48 hours ageing at 24 degrees C from time of application, the precoated adhesive shall be capable of withstanding 8 hours of soaking in water at 24 degrees C without appreciable decrease in adhesion.

The precoated adhesive shall have no staining effect on the reflective sheeting and shall be mildew resistant. The protective liner for preventing contamination or premature adhesion shall be removable by peeling without the necessity of soaking in water or other solvents.

The Contractor shall submit samples of each color of reflective sheeting for approval. Unless otherwise specified, flat angle 'scotchlite' type colors shall be used for all sign face lettering, symbols and borders. Colors shall conform to International Road Sign colors and any modifications for use in this Country.

The Reflective Sheeting shall meet the requirements and satisfy the tests as laid down in the US Federal. SpecifictionL-5-300B.

H.1 Samples

The representative sample of the whole stock, differentiated in terms of type of sign, will consist of a particular number of traffic signs of a single type, equivalent to what is given in Table 1.

Table 1: Criteria for the selection of a representative number of a stockpiled signs of a single type.

SIZE OF THE BATCH DIFFERENTIATED BY TYPES OF SIGNS	SIZE OF THE SAMPLE OF SIGNS OF A SINGLE TYPE
2 to 8 9 to 15	2
16 to 25	3
26 to 50 51 to 90	5
91 to 150	8
151 to 280	13
281 to 500	20
501 to 1,200	32
1,201 to 3,200	50
3,201 to 10,000	80
10,001 to 35,000	125

H.2 Definition of signing terms:

H.2.1 **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 footcandle unit area.

H.2.2 **Divergence Angle:** The angle at the reflector between the observer's line of sight and the axis of the incident light beam.

H.2.3 **Entrance Angle:** The angle at the reflector between the axis of the incident light beam and the normal to the reflective surface.

H.2.4 **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 meters.

H.2.5 **Legend:** Characters, letters, numbers and symbols including the border appearing on the background on the sign face.

H.2.6 **Sign Face:** That part of a sign panel facing toward oncoming traffic.

H.2.7 **Sign Panel:** The structural part of a sign made of assembled units or sheet metal, including reflectorized material applied to the face and bearing a legend, but excluding the supporting posts or structure.

H.3 Materials Pre-qualification:

Retro-reflective traffic signs of Class 2 related to the French Standards AFNOR - NFP98 520 - 3M type or similar) Grade reflective sheeting offered to the road authorities must be pre-qualified as follows:
The manufacturer of the traffic signs shall submit with each lot or shipment a certification which states that the retro-reflective sheeting used for the manufacturing of the signs has been approved by an official European laboratory in charge.

H.4 Aluminum Sign Panels

All sign plates shall be manufactured either from sheet Aluminum or extruded aluminum channels shall be used for all Guide Signs and shall be as shown on the drawings. For traffic sign manufacturing, the retro-reflective sheetings class II should be applied to properly prepared unpainted aluminum.

H.5 Application of a Background Sheeting

Application of compatible retro-reflective materials shall be made in accordance with the instruction of the manufacturer of the retro-reflective sheetings. Therefore the following conditions must be fulfilled.

a) The background reflective sheeting shall be applied to the aluminum sign panels or extruded channels, which have been prepared as described above, in the manner recommended by the manufacturer. 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 millimeters beyond the edges.

b) Type II 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. The legend, for signs which will have the legend screened onto a Type II (heat activated adhesive) reflective sheeting (see below), shall be added to the background before the sheeting is applied to the panel.

c) When vacuum applied, the pre-coated adhesive on the back of the Type II sheeting shall be activated by a minimum temperature of 85 Degrees Centigrade and with a minimum vacuum pressure of 635 millimeters of mercury. This operation shall be in effect for a minimum of 5 minutes. After aging for 48 hours at 24 Degrees Centigrade the adhesive shall form a bond equal to or greater than the strength of the reflective sheeting.

d) Splicing of reflective sheeting shall not be permitted on signs or panels with dimensions up to and including 1.2 meters in height or width unless the reflective sheeting specified does not come in this width, then the widest 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 millimeters. The fabricator shall endeavor to use the least number of seams possible with the horizontal lap preferable. Roller applied or reverse screened sheeting may butt-jointed with joint gap not to exceed one (1) millimeter. No splice shall fall within 5 centimeters of the edge of the panel.

e) Signs faces comprising two or more pieces of reflective sheeting must be carefully matched for color at the time of sign fabrication to provide uniform appearance and brilliance, both day and night. Nonconformance may result in non-uniform shading and an undesirable contrast between adjacent width of applied sheeting which will not be acceptable.

f) Damaged reflective sheeting due to poor workmanship or defective material will be rejected, and shall be replaced at the Contractor's own expense.

H.6 Visual Classification

Retro-reflective traffic signs of Class 2 materials shall be provided with visual identification marks integrated into the sheeting during production by the manufacturer of the retro-reflective sheeting. The visual identification mark shall not be retro-reflective sheeting without irreparable damage of the retro-reflective system, and shall be visible for the same period of effective performance life as stated for the retro-reflective sheeting. The visual identification mark is designed to prevent falsifications so that only approved and released retro-reflective sheeting are being used for the manufacturing of traffic signs.

The design and the layout of the visual identification mark must indicate the manufacturing location and the number of years of the effective performance life of the retro-reflective sheeting. The visual identification mark shall be visible under retro-reflected light when the surface of the reflective sheeting is illuminated perpendicular.

H.7 Quality requirements:

Retro-reflective traffic signs, manufactured as described in sections G.4 and G.5, shall meet the following quality requirements when they are in new condition and before they are erected on roads and highways.

a) Coefficient of Retro-reflection for Class 2 Materials.

Table A: Minimum coefficient of retro-reflection R' (CD x LX-1 x .M-2).

		Traffic Sign Colors							
*	**	White	Yellow	Red	Green	Green(2)	Blue	Brown	Orange
0.2°	5°	250	170	45	45	20	20	12.0	100
	30°	150	100	25	25	15	11	8.5	60
	40°	110	70	15	12	6	8	5.0	29
0.33°	5°	180	122	25	21	14	14	8.5	65
	30°	100	67	14	12	11	8	5.0	40
	40°	95	64	13	11	5	7	3.0	20
1.0°	5°	15	9	2.5	2.0	1	0.5	0.4	4.5
	30°	7.5	4.5	1.5	1.0	0.5	0.3	0.2	2.5
	40°	4.5	3.0	1.0	0.5	0.2	0.2	0.1	2.0
2.0°	5°	5	3	0.8	0.6	0.6	0.2	0.2	1.5
	30°	2.5	1.5	0.4	0.3	0.3	0.1	0.1	0.9
	40°	1.5	1.0	0.3	0.2	0.2	-	-	0.8

* Observation - Angle α

** ($\beta 2 = 0$ for $\alpha = 0.2^{o}$), otherwise Entrance - Angle $\beta 1$)

Notes:

- For screenprinted transparent colored areas on white sheeting, the coefficients of retro-reflection shall not be less than 70% of the values for colored sheeting given in the above table.

- When yellow sheetings are screenprinted with transparent red process ink, the coefficients of retro-reflection shall not be less than 50% of the values for the red colored sheeting given in the above table.

b) Color

Table B: Chromaticity coordinates of the corner points in the CIE 1931 chromaticity diagram determining the permitted color area for retro-reflecting materials in use.

Illuminant: CIE standard D_{65}
Measured with 45 / 0 geometry

Reflective Color		1	2	3	4	Minimum Luminance Factor class 2
White	X	.350	.300	.285	.335	0.27
	Y	.360	.310	.325	.375	
Yellow	X	.545	.487	.427	.465	0.16
	Y	.454	.423	.483	.534	
Red	X	.690	.595	.569	.655	0.03
	Y	.310	.315	.341	.345	
Green	X	.007	.248	.177	.026	0.03
	Y	.703	.409	.362	.399	
Green(2)	X	.313	.313	.248	.127	0.04
	Y	.682	.453	.409	.557	
Blue	X	.078	.150	.210	.137	0.01
	Y	.171	.220	.160	.038	
Orange	X	.610	.535	.506	.570	0.14
	Y	.390	.375	.404	.429	
Brown	X	.455	.523	.479	.558	0.03
	Y	.397	.429	.373	.394	

Non-reflective color		1	2	3	4	Luminance Factor	
						Min.	Max.
Grey	X	0.305	0.350	0.340	0.295	0.08	0.10
	Y	0.315	0.360	0.370	0.325		
Black	X	0.300	0.385	0.345	0.260	≤ 0.02	
	Y	0.270	0.355	0.395	0.310		

c) Adhesive to Substrate:

The retro-reflective sheeting shall form a durable weather resistant bond to the traffic sign substrate.

When tested in accordance with Section G.8, the retro-reflective sheeting shall not be removable by peeling from the substrate without damaging the retro-reflective material.

d) Impact Resistance:

The retro-reflective sheeting shall show no separation from the sign substrate or cracking when impacted by a steel ball, as specified in G.8.

e) Resistance to Corrosion (Salt-Spray)

When tested as specified in G.8, the test specimen sign shall show no corrosion, discoloration or cracking on the surface. The coefficient of retro-reflection and chromaticity requirements shall be as specified in G.7 (a and b).

f) Heat Resistance:

The retro-reflective traffic sign shall show no cracking, flaking, crazing or lack of adhesion when exposed to 24 hours to an oven at 71° C ± 3° C.

g) Cold Resistance:

The retro-reflective traffic sign shall show no cracking, flaking, crazing or lack of adhesion
when exposed for 72 hours at a temperature of -35° C ± 3° C.

h) Field Performance Requirements:

Retro-reflective traffic signs, in normal vertical stationary exposure, and manufactured in normal vertical stationary exposure, and manufactured in accordance with G.4 and G.5 shall perform effectively under Lebanese climatic conditions for seven year when Class 2 high performance material has been used.

H.8 Test Methods and Interpretation of Results

a) Test Conditions

Finished Class 2 retro-reflective traffic signs, or cut-out test specimens from the signs when required for testing, shall be conditioned for 24 hours at standard room temperature of 23° C ± 2° C and 50 RH ± 5% before testing.

b) Interpretation of Test Results:

All test results shall be interpreted as the average results from at least three specimens of each test sign.

c) Coefficient or Retro-reflection:

The values of the minimum coefficient of retro-reflection, given in G.7a Table A, are described as the average of representative readings covering the entire surface of a retro-reflective traffic sign measured on cut-out test specimens. The coefficient of retro-reflection shall be measured in accordance with CIE Publication No. 54, retro-reflection, 1982, using CIE Standard Illuminant A.

d) Color:

The color of retro-reflective traffic signs shall conform to G.7b Table B, when measured as specified in CIE Publication No. 15.2, material is illuminated by CIE Standard

Illuminant D65 at an angle of 45° with the normal to the surface, and the observation is made in the direction of the normal (CIE 45 / 0 geometry)

e) Adhesion to Substrate:

The traffic signs of cut-out specimens from the signs to be tested, shall be conditioned for at least 24 hrs at conditions described in Section a. With a tool (razor blade of knife), the retro-reflective sheeting shall be peeled off from one edge of the sign substrate so that an approx. 2x2 cm piece remains attached on one edge only. It should then be attempted to further peel off that piece by hand only. This should not be possible without damaging the reflective sheeting. If it is impossible to peel up a 2x2 cm piece to start the test, the sheeting shall be considered to have passed the test.

f) Impact Resistance:

A 15x15 cm cut-out specimen from the retro-reflective traffic sign shall be supported on its edges over 10x10 cm open area. Subject the center of the test specimen face to impact from a 51 mm diameter steel ball of 540 g weight, dropped from a height of 25 cm.

g) Resistance to Corrosion (Salt-Spray):

Subject a test specimen cut-out from a finished retro-reflective traffic sign to the action of a saline mist for two cycles of 22 hours each. The cycles shall be separated by an interval of 2 hours at room temperature during which the specimen is allowed to dry.

The saline mist shall be produced by atomizing at a temperature of 35° C ± 2° C, a saline solution obtained by dissolving 5 parts by weight of sodium chloride in 95 parts of deionized water. After the test, the test specimen shall be washed with deionized water and dried with a cloth for examination.

h) Heat Resistance:

A test specimen of 15 cm length, 7.5 cm width shall be exposed in an oven at 71° C ± 3° C for 24 hours, conditioned at standard room temperature for 2 hours and then examined as specified in G.7f.

i) Cold Resistance:

A test specimen of 15 cm length, 7.5 cm width shall be exposed to an air temperature of -35° C ± 3° C for 72 hours, conditioned at standard room temperature for 2 hours and then examined as specified in G.7g.

H.9 Sign Face Layout

The preparation of the legend and background to be applied to the structural portion of the sign panel shall comply with the following specifications:

a) Sign Layout, Traffic Signs. As specified herein and as shown on the drawings. The legend shall be applied to the reflectorized sheeting in the manner recommended by the manufacturer.

b) Sign Layout, Guide Signs. The shape, size, legend and colors of all guide signs shall be as shown on the drawings or as instructed by the Engineer.

The lettering shall consist of the Arabic and French letters and numbers applied to the background in the sizes and spacing shown on the drawings or as instructed by the Engineer.

H.10 Application of Lettering

a) The legend for the standard international signs shall be applied directly to the Class II background sheeting (3M type or similar) by the reverse silk-screen method recommended by the manufacturer and approved by the Engineer.

b) Black letters on a white or yellow background shall be screened with an opaque black stencil paste, as recommended by the manufacturer of the reflective sheeting. The signs with silver-white letters on a red, blue, brown or green background shall be applied to the sheeting using the reverse screening process on a silver-white sheet reflecting background, and using screen pastes meeting the recommendations of the manufacturer of the silver-white sheeting and approved by the Engineer.

c) For all other signs, the Arabic letters shall be screened directly onto the background sheeting wherever possible. Where the sign panel and/or letter are too large for the letters to be screened onto a strip of Class II reflective sheeting each letter shall be adhered to the background by the method recommended by the manufacturer and approved by the Engineer.

d) French letters may be applied directly to the background sheeting by the reverse screening method if the height of the letters shown on the drawings is 20 centimeters or less, and if the sign panel can be accommodated by the vacuum applicator. Letters higher than 20 centimeters shall be made using the cut-out method. All letters in any one line of copy shall be applied using only one method.

e) When the cut-out method is to be used for French letters, the Contractor or the sheeting manufacturer shall prepare templates for each letter and each height shown on the drawings, and these templates shall be approved by the Engineer. The templates shall be used as guides for cutting the letters out of Type II reflective sheeting. Legend and borders shall be reflective sheeting of the color specified on the drawings and shall be applied directly to clean, dust-free reflective sheeting background panels, and shall be applied in a manner specified for the manufacture of the traffic control signs by the sheeting manufacturer.

f) Legend and / or borders shall be cut neatly at intersecting panel edges.

g) The legend and border shall have clean, clear edges, true to line, and be strictly in accordance with the plans as to design of letters and positioning on the sign.

h) Applied legend and borders shall be finished with the materials and in a manner specified by the sheeting manufacturer. Finish shall be as indicated:

- Class II adhesive coated sheeting legend and / or borders shall be edge sealed with clear coated Class II backgrounds.
- Sheeting cuts at intersecting panel edges shall be edge sealed with “Finishing Clear” following application.
- After message and/or border application, the complete sign including edges shall be finished by clear coating approved by the sheeting manufacturer.

6.02.03 CONSTRUCTION AND INSTALLATION

A. Sign Faces

A.1 The type color design and size of all sign faces shall be as shown on the Drawings or in accordance with the Employer's latest design standards or shall meet the standards adopted in the "European Rules concerning road traffic signs and signals" agreed at the 1968 Vienna Convention and subsequent supplementary provisions in the 1971 Geneva Agreements.

A.2 The Contractor shall prepare and submit for approval, 3 sets of detailed working drawings for the sign faces, in respect of all required danger, warning, regulatory and informative signs. Complete details of arrangement and spacing for French and Arabic lettering, and mounting hole locations, shall be shown on these drawings.

A.3 Mounting hole spacing for screws, bolts or rivets shall not exceed 200 mm Characters shall be secured to the sign using non-twist, corrosion resistant screws, bolts or rivets.

A.4 The correct French and Arabic spelling of the official names of towns, districts, roads and streets etc., will be supplied by the Engineer. Sizes and style of lettering and arrows shall be as shown on the Drawings or as recommended by the Engineer.

A.5 The rear sign face of all signs shall be painted with 2 coats of priming paint pigmented with chromates or chromes (excluding lead chromes) plus 2 coats of weather-resisting dull silver gray paint. Where connection of large aluminum sheet signs to a steel stiffening frame is required, the studs or screws, bolts and washers shall be painted on the sign face to properly match the color of the surrounding material.

A.6 Where the bill of quantities or the drawings indicate stiffening of sign plates, this shall be achieved in compliance with BS 873 Part 6, AMD 6658, in a manner such that the sign face material is not punctured or otherwise damaged to accommodate the stiffening.

A.7 Signs delivered for use on a project shall be stored off the ground and under cover in an approved manner. Any sign damaged, discolored, or defaced during transportation, storage, or erection will be rejected and shall be replaced at the Contractor's expense.

B. Footings

B.1 Post footings shall be excavated to the dimensions shown on the Drawings. Footings shall be installed and backfilled flush with the finished ground surface. Class 250/20 concrete shall be placed against the undisturbed excavated faces, except that the top 150 mm of each footing shall be formed. Forming of the entire footing will not be permitted unless approved. Concrete shall be thoroughly rodded and spaded to minimize voids. Tops of footings shall be finished with a wood float and all exposed edges shall be rounded with an edger.

a) Footings for Ground-Mounted Signs: The stub posts are to be imbedded in drilled shaft foundation holes and held vertically in place by an approved template before the concrete for the foundation is placed. The forms and templates supporting the sign posts shall not be removed until the concrete has aged a minimum of 24 hours. Springing or raking of posts to secure proper alignment will not be permitted.

b) Foundations for Overhead Sign Frames: The electrical conduit (where required) and anchor bolts of the size, length and number as shown on the drawings shall be

positioned before the concrete is placed. Anchor bolt groups shall be set and maintained in position with a template during the placement of that portion of concrete into which anchor bolts are embedded. Care shall be taken to obtain the orientation of the anchor bolts and spacing of the anchor bolt groups as shown on the drawings.

B.2 All excavation required for footings shall be done through whatever materials are encountered, and to the dimensions and elevation shown on the drawings or as established by the Engineer, and in accordance with the requirements of Section 2.09, Excavations and Backfill. Backfill, where needed, shall be thoroughly compacted using mechanical tempers. Care shall be taken to prevent damage to the finished concrete. Backfill shall be brought up to finished ground level.

B.3 Pipes or posts to be set in concrete bases shall be firmly supported with the correct orientation and plumbed vertical before any concrete is placed. Posts or pipes that are found to be out of plumb after installation will not be accepted and shall be replaced at the Contractor's expense.

B.4 All concrete work at sign foundations, including reinforcing steel, shall be concrete Class B25 or 250/20. All parts of the concrete foundations extending above the natural or finished ground line shall be given a rubbed surface finish. The footings for ground-mounted signs shall not extend more than 10 centimeters above the finished grade.

B.5 No structure or post shall be erected on a concrete foundation nor shall any traffic sign be attached to a sign post embedded in concrete until the concrete has aged at least seven days.

B.6 All backfilling and compaction shall be completed prior to the erection of any sign on the structure.

B.7 Where embankment protection or surfacing is removed for placing foundations for traffic signs, it shall be replaced with suitable material as directed by the Engineer.

C. Sign Posts, Sign Supports and Support Assemblies

C.1 Signs shall normally be erected so that the edge and face of the sign are truly vertical and the face is as indicated on the Drawings or as required by the Engineer so they will be most effective and so as to avoid specular reflection and glare. On grades signs can be tilted forward or backward from the vertical to improve the viewing angle.

C.2 The Engineer will establish the longitudinal location of each sign which shall be laterally positioned from the shoulder or curb as shown on the Drawings. The Contractor shall establish the location of the sign supports and shall be responsible for the proper elevation off-set and orientation of all signs. If any stakes are lost damaged displaced or removed the Contractor shall have them reset at his own expense.

C.3 Post lengths shown on the Drawings for small signs are approximate only. The Contractor shall be responsible for determination of post lengths to provide the required vertical clearance. Field cutting of posts shall be performed by sawing off the bottom end.

C.4 a) The length of the posts for each traffic sign shown on the drawings shall be determined by the Contractor before ordering in order to meet the existing field conditions and to conform with sign-mounting heights shown on the drawings.

After fabrication the post and stub post shall be galvanized in accordance with the "Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars and Strips", ASTM Designation A123 or French Norms. All fabrication shall be completed and ready for assembly before galvanizing. No punching, drilling or cutting shall be permitted after galvanizing. All welds shall be mechanically cleaned before galvanizing. Any part of the pipe from which the galvanizing has been damaged in fabrication, handling transit or erection or when bare metal is exposed will be rejected or may be repaired by application of galvanizing repair compounds (zinc alloy stick method) approved by the Engineer.

b) The "break-away" assemble when needed, shall be constructed by attaching the post to the stub post with high strength bolts and one flat washer on each bolt between the plates as shown on the drawings. Shims may be used between the plates to align the posts. The bolts shall be tightened in a systematic order to the required torque. Then each bolt in turn shall be loosened and retighten to the required torque in the same order as the initial tightening. The threads shall be burred or center punched at the junction of bolts and nut to prevent the nut from loosening.

c) The size and number of posts required to support each sign panel installation shall be as shown on the drawings.

d) The post or posts shall be vertical. When two posts support the same panel, they shall be erected vertical and parallel with each other with the tops of the posts at the same height.

e) The Footing for Ground-Mounted Signs: The contractor shall prepare shop drawings details showing the size of the footings required to support each sign and shall have the approval of the Engineer prior to starting construction works.

   The sign posts shall be erected in a vertical position on a previously prepared foundation, with the tops of the posts in each sign installation even, level with each other, and extending 10 centimeters above the top of sign panel. The faces of the supporting posts shall be flush with the sign throughout the contact areas.

   Springing or raking of posts to secure proper alignment will not be permitted.

f) Structural Supports for Overhead Signs: The overhead sign Gantries which are to be employed to support sign panels over the Road (independent of other Road structures) shall be as shown on the drawings. Design of overhead signs, gantries has to meet the requirement of the French standards NFP98 550, B.S. or ASTM related to the design of structures.

   - Span. The type of Gantry shall be as shown on the drawings.

   - Structural galvanized steel Supports. Three sets of shop fabrication drawings for the structural sign posts, including overhead beams shall be submitted to the Engineer for approval prior to fabrication. All detailed calculations shall be submitted in 2 copies to the Engineer prior to the fabrication.

g) Any structural members having welds deemed to be unsatisfactory shall be removed by mechanical means, reannealed, re-welded and reheat treated, or they

shall be replaced by new structural members having satisfactory welds. Flame cutting will not be permitted.

h) When the Gantries placed on the concrete foundation, the nuts supporting the post base plates shall be adjusted to bring the bottom of base plate level with the top of the cap foundation and to bring the end frame or post to a true vertical plane. The nuts on top of the base plate shall then be tighten securely. Springing or taking of frames will not be permitted.

After the base plates of the Gantry are at their proper elevation and the post is in a true vertical plane, 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 that shall be forced under the base plate after the post is in place so that, after curing, it will 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.

The contractor shall notify the Engineer in writing at least two weeks prior to the date the Contractor wishes to erect the Frames.

The vertical clearance is measured from the bottom of the horizontal portion of the hanger arm to the highest point of the Highway cross section. The minimum vertical clearance under the lowest point of sign panels, gantries other related construction for signs over Highway shall be 5.5 meters or as shown on drawings and directed by the Engineer.

i) Gantry support must be protected by special guardrails as shown in the drawings.

C.5 Zinc alloy sticks for repair work on galvanizing shall be cast from zinc tin and lead in combination with fluxing ingredients. The compound shall be completely liquid at a temperature not lower than 240 degrees C. The area to be regalvanized shall be thoroughly cleaned including removal of slag on welds. The surface shall be heated with oxyacetylene torch to approximately 315 degrees C and the alloy stick rubbed over the surface to fix a deposit. While the alloy is still liquid, the deposit shall be smoothed evenly over the area using a wire brush. If a heavy deposit or build-up is required to match the original coating, more alloy shall be added immediately to the initial bond deposit and spread with a paddle or brush until the required thickness is obtained. Edges of drilled holes shall be coated with commercially available zinc-rich paint.

C.6 The Contractor shall submit 3 copies of the fabricator's certificates stating that the material supplied conforms with all of the specified requirements.

C.7 All exposed steel surfaces, except galvanized surfaces, shall receive one shop coat of Paint No.1 and two field coats consisting of Paint No.5 followed by Paint No.4. All painting procedures shall conform with the relevant requirements of Section 6.09 - "Painting of Structures".

D. Fastening Signs to Posts

D.1 Sign panels larger than 1 sq.m in area shall be supported on 2 or more posts as shown on the Drawings.

D.2 Signs shall be fastened to sign supports in accordance with the requirements of the plans, recommendations of the sign manufacturer and to the satisfaction of the Engineer. Fasteners shall be vandal resistant to the maximum extent practicable.

D.3 All bolt heads, screw heads, and washers used to install signs on support shall be such that they do not protrude from the surface of the sign. The heads of bolts or screws shall be as nearly as practicable the same color as the background or message area at the point where the hardware is exposed.

D.4 Fastener systems shall as far as practicable be designed so as not to require the drilling of the sign face.

D.5 When steel signs are mounted with aluminum hardware or where aluminum signs are mounted with steel hardware or on steel posts, approved asphalt, nylon or neoprene insulation shall be installed at all points where dissimilar metals may come into contact.

E. Overhead Sign Support Structures

Design and construction of gantry and cantilever structures shall conform with the requirements of the latest edition of AASHTO specifications for "Design and Construction of Structural Support for Highway Signs".

Works in respect of furnishing and erection of overhead sign support structures (sign gantries) shall conform with all relevant requirements of Section 5.16 - "Structural Steelwork and Metal Components".

F. Installation of Ground Mounted Signs

F.1 Unless otherwise noted, the location of the signs shown on the drawings are approximate and the exact location will be established by the Engineer in the field.

F.2 It shall be the responsibility of the Contractor to determine the location of any underground electric cable, drainage structures, or utility lines in the vicinity before beginning his work, and he shall conduct his work so as to avoid damage to these installations. The Contractor shall contact the Engineer for assistance in location utilities, drainage installed during the construction of the Road. Any damage caused by the Contractor’s operation shall be repaired by him, at his own expense, and to the satisfaction of the Engineer.

F.3 The Contractor shall be responsible for the proper elevation, offset and effective orientation of all signs. They shall be erected so that the face of the sign is vertical and at an angle of 93 degrees to the centerline of the adjacent Highway measured from the back tangent counterclockwise. Signs on ramps or curves shall be oriented as indicated on the drawings, or by the Engineer, to provide the most effective display for both day and night. All signs shall be complete and installed to the satisfaction of the Engineer at the time of acceptance of the work. Sign faces shall be examined by the Engineer both during conditions of daylight and darkness.

F.4 When so notified by the Engineer, the Contractor shall cover certain signs to facilitate and control the operation of the project. The covering shall consist of burlap dyed with a green waterproof dye and shall extend over the edges of the sign and fastened on the back. The Contractor shall not use any type of sign and be fastened on the back. The 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.

F.5 The Contractor shall replace, at his own expense, any sign or sign support included in the Contract which is damaged from any cause whatsoever, including traffic damage, prior to acceptance by the Engineer.

G. Post Mounted Sign Panels

G.1 Sign panels shall be erected so that the bottom of the sign is as shown on the drawings, or as directed by the Engineer.

G.2 Extruded panels shall be horizontal, unless specified otherwise, and the panel faces shall be flush within commercial extrusion tolerances after erection of the sign is complete.

G.3 Sign panels shall have bent edges of minimum 20 mm height.

G.4 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 30 centimeters 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 30centimeters maximum centers.

G.5 Lock nuts on the 3/8 inch (9.5 millimeters) aluminum post clip bolts shall be torqued to 373 kilogram-meters when using dry, clean, unlubricated threads.

H. Gantry Mounted Sign Panels

H.1 Sign panels of equal height mounted on Frames shall be centered vertically between the two front chords of the Frames. When signs of different heights are to be mounted on the same side of the beam, the sign of smaller height shall be centered on the Frame 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. Further, the length of the vertical portion of all hanger arms shall be that which will result with horizontal arms being at the same elevation across the span.

H.2 All overhead sign panels shall be erected so that the panel or panels are centered over the lanes for which the message is intended. The sign shall be mounted on the Gantry in the manner shown on the drawings and as recommended by the manufacturer.

H.3 Extruded panels shall be horizontal, unless specified otherwise, with the panel faces normal to the centerline of the Highway and tilted down at a 5 degree angle.

I. Execution of the Works

I.1 Selection of the Material:

The type of retro-reflecting material to be used in the traffic signs within the scope of the project is established on the basis of the criteria specified in this (technical specification).

The Contractor must communicate, in writing, to the Engineer:

a) The name and address of the manufacturing companies of all the materials used in the manufacture of the traffic signs within the scope of the project.

b) The commercial trade mark, or reference, that the suppliers give to those materials.

This communication shall be accompanied by the document accrediting the certification of the signs offered and of their technical characteristics, as specified in these specifications.

During the time elapsed until this certification of conformity to standards (approved quality mark) is obtained, this communication must be accompanied by a copy of the test report carried out by an official or accredited laboratory (according to EN 45000, series of standards), in which appear the characteristics both of the materials used and of the finished traffic sign, in accordance with that specified in the corresponding part of this document.

J. Quality Control of the Works

J.1 This section describes the fundamental criteria and test methods used for carrying out quality control of the vertical signing works, including the traffic signs held in stock and those already installed.

J.1.1 Control over Reception of Signs:

- The criteria described for carrying out quality control of the traffic signs held in stock will not have obligatory application in those retro-reflecting signs that have the approved quality mark.
- In case of being compulsory, to check that the signs to be installed meet the general technical requirements specified in these specifications, it is necessary to proceed to their control once the samples have been selected from among those found in stock. Prior to this, the awarded company must send with each consignment the corresponding information appearing in Section I.2.
- Tests on the Signs: on each of the samples selected, the following non-destructive tests will be conducted.
- Photometric characteristics
- Colorimetric characteristics

J.1.2 Control over Installed Signs:

The installation works having been completed, and before the guarantee period ends, periodic controls will be conducted on the traffic signs with the aim of determining their essential characteristics and checking, in situ, that their minimum requirements are met.

- Sampling: at the end of the work and during the guarantee period, the Engineer (or the accredited testing laboratory) shall randomly select from among the traffic signs of the same type as those within the scope of the project, a representative sample of them according to the criteria established in Table 1.
- Test on the Signs: on each selected signs of a single type, the following non-destructive tests will be conducted; Photometric Characters and Colorimetric Characters

J.2 The acceptability of signs of a single type, whether held in stock or installed, will be determined in accordance with the sampling plan established in Table1 acceptable quality level (AQL) of 4.0 for normal inspection. When the sample is subjected to the tests specified in Section J.1, non-compliance with any of the requirements stated in these specifications will be considered a defect and any sign showing one or more defects shall be considered a defective sign (Table 2).

Table 2: Assessment criteria for a representative sample of traffic signs of a single type, whether held in stock or installed.

Size of the Sample	Acceptable Quality Level: 4.0	
	Max. No. of Defective Units for Acceptance	Min. No. of Defective Units for Rejection
2 to 5	0	1
8 to 13	1	2
20	2	3
32	3	4
50	5	6
80	7	8
125	10	11

Stockipled or installed traffic signs of a single type which have been rejected will be able to be submitted to a new inspection once the manufacturer accredits, by means of a written declaration, that all the units have again been examined and tested, and all defective ones have been eliminated or the defects corrected.

6.02.04 MEASUREMENT

A. Triangular and Circular Signs and Small Rectangular Signs (up to 1 m^2 in surface area) shall be measured by the number of such signs furnished and installed (excluding sign post supports) and accepted.

B. Rectangular and Trapezoidal Signs over 1m^2 in surface area and intended for ground mounting shall be measured by sq. m of surface area furnished installed for each panel (excluding sign post supports) and accepted. Each sign area shall be measured to the nearest 0.01 m^2.

C. Rectangular signs intended for mounting on overhead support structures shall be measured by m^2 of surface area furnished installed (including sign stiffening but excluding sign support brackets) and accepted. Each sign area shall be measured to the nearest 0.01 m^2.

D. Single post Sign Supports (including Breakaway Single Post Sign Supports) shall be measured by the number of each type of such supports furnished installed and accepted.

E. Multiple Post Sign Support Assemblies (including Breakaway Multiple Post Sign Support Assemblies) shall be measured by the number of each type of such assemblies furnished installed and accepted.

F. Excavation, backfilling, concrete, base and foundations reinforcement and other ancillary items shall not be measured for direct payment, but shall be considered as subsidiary Works, the costs of which will be deemed to be included in the Contract prices for the Pay Items.

PAY ITEM		UNIT OF MEASUREMENT
(1)	Small Signs (not exceeding 1 m^2 area)	Number (Nr)
(2)	Large Ground Mounted Signs (exceeding 1 m2 area, each type)	Number (Nr)
(3)	Rectangular Signs for Overhead Mounting	Square meter (m^2)
(4)	Single Post with Breakaway Sign Supports	Number (Nr)
(5)	Multiple Post with Breakaway Sign Support Assemblies	Number (Nr)

SECTION 6.03 STEEL GUARDRAIL AND CONCRETE SAFETY BARRIER

6.03.01 SCOPE

These Works shall consist of the furnishing, construction and erection of steel guardrail, concrete barriers, impact attenuators, and glare screens as and where shown on the Drawings.

6.03.02 MATERIALS

A. Metal Beam Guardrail

A.1 Rail elements and backup plates for W-Beam rail shall conform to AASHTO M 180, Class A, Type 2 galvanized. Rail elements for triple corrugated beam rail used in Guard Rail Energy Absorbing Terminal (G.R.E.A.T.) proprietary impact attenuators shall conform to AASHTO M 180, Class B, Type 2 galvanized. Rail element joints shall be fabricated to lap not less than 300 mm and be bolted.

A.2 Rail metal shall withstand a cold bend, without cracking, of 180 degrees around a mandrel of a diameter equal to 2.5 times the thickness of the sheet metal plate.

A.3 Rail elements to be erected on a radius of 45 m or less shall be shaped in the shop. The radius of curvature shall be stenciled on the back of each section of rail.

A.4 Rail elements shall be designed to be spliced at intervals not to exceed 4 m and such splices shall be made at posts, unless otherwise shown on the Drawings.

B. Box Beam Guardrail

B.1 Rails shall be hot-formed welded and seamless carbon steel structural tube or cold-formed welded. Posts, splice tongues, and plates shall conform to ASTM A 36. Rails shall conform to ASTM A 500, Grade A or B, or ASTM A 501.

B.2 Mill transverse welds will not be permitted on rail sections. Longitudinal welds shall be made by the resistance, gas shielded arc, submerged arc or plasma arc welded process and shall be sound, free from defects, and shall not be repaired. The welded joint, in cold and hot-formed welded rail, shall have a minimum tensile strength specified for the railing when subjected to the tensile strap test specified in ASTM E8M (metric).

B.3 Rail sections for tangent runs shall be not less than 6 m in length. Rail splices shall be a minimum of 400 mm from the centerline of any post.

C. Wire Rope

C.1 Wire rope for cable guardrail, cable guardrail anchor terminals and metal beam guardrail anchor terminals, shall conform to AASHTO M 30, Type II, Class A. Equivalent galvanized wire rope with a minimum breaking strength of 19,400 kg will be acceptable.

C.2 Wire rope restraining cable for G.R.E.A.T. Hi-Dro and Hi-Dri impact attenuators shall be minimum 22 mm nominal diameter galvanized wire rope conforming to ASTM A 603, Class A.

C.3 Pull out and secondary cable for Hi-Dro and Hi-Dri impact attenuators shall be minimum 9.5 mm nominal diameter galvanized wire rope conforming to ASTM A 603, Class A.

D. Pedestrian Guardrail

Pedestrian Guardrail shall be welded structural hot dipped galvanized steel complying with the requirements of AASHTO M 232 (ASTM A 153) zinc coating (hot dip) on iron and steel hard ware

E. Posts and Miscellaneous Hardware

E.1 Unless otherwise shown on the Drawings, all steel posts, plates, angles, channels, brackets and anchor assembly units shall conform to ASTM A 36. Cold rolled post sections shall conform to ASTM A 446, Grade B.

E.2 The swaged fittings for anchor terminals shall be machined from hot-rolled carbon steel conforming to ASTM A 576, Grade 1035 and shall be annealed in a manner suitable for cold swaging. A lock pinhole shall be drilled through the swage fitting head to accommodate a 7 mm, plated, spring steel pin to retain the stud in the proper position. The stud shall be steel conforming to ASTM A 449. Prior to galvanizing, a 10 mm slot for the locking pin shall be milled into the stud end. The swaged fitting, stud, and nut shall develop the full breaking strength of the wire cable.

E.3 Anchor rod eyes shall be hot forged or formed with full penetration welds. After fabrication, anchor rods with eyes that have been formed with any part of the eye below 870 degrees C during the forming operation or with eyes that have been closed by welding shall be thermally stress relieved prior to galvanizing. The completed anchor rod, after galvanizing, shall develop a strength of 23,000 kg.

E.4 Clevises shall be drop forged galvanized steel and shall develop the full specified breaking strength of the wire cable.

E.5 The concrete insert assembly for Type 4 anchor terminals (beams of corrosion resistant steel - AASHTO M180) shall be fabricated as shown on the Drawings. Ferrules shall be steel conforming to ASTM A 108, Grade 12 L 14. Inserts shall be tapped to the dimensional requirements specified in ASTM A 563 for nuts receiving galvanized bolts. Insert assembly wires shall conform to ASTM A 510, Grade 1030, and have a minimum tensile strength of 686 MN/sq.m (7,000 kg/sq.cm). Welded attachment of wire to ferrule shall develop the full tensile strength of the wire.

E.6 Turnbuckles shall be steel of commercial quality and shall have a minimum breaking strength of 1,500 kg. Turnbuckles shall be galvanized in accordance with ASTM A 153. Compensating and non-compensating cable ends shall be cast steel conforming to ASTM A 27 or malleable iron conforming to the requirements of ASTM A 47M (metric). Compensating devices shall have spring constants of 8,000 kg/m plus or minus 500 kg/m and permit a travel of 150 mm plus or minus 25 mm. All elements shall be galvanized.

E.7 Cable connecting hardware shall develop the full strength of the wire rope. At all locations where the cable is connected to a cable end with a wedge type connection, one wire of the wire rope shall be crimped over the base of the wedge to hold the cable firmly in place.

E.8 Restraining chains for G.R.E.A.T. impact attenuators shall be 12 mm nominal size and shall conform to ASTM A 413, Grade 28.

F. Glare Screens

F.1 Glare screen fabric shall be chain link mesh conforming to ASTM A 491 or ASTM A 392. Mesh size and wire diameter shall be as specified on the Drawings.

F.2 Posts shall be galvanized steel pipe conforming to ASTM A 153 and of the diameter shown on the Drawings. Posts shall be furnished with galvanized watertight caps.

F.3 Tension wire shall conform to ASTM A 641M (metric)- Class 1, Hard Temper, with a minimum diameter of 4.5 mm.

F.4 Tension cable shall conform to ASTM A 474 or A 475, 6 mm minimum diameter, high strength grade.

F.5 All hardware shall be typical of the types shown on the Drawings and shall be galvanized in accordance with ASTM A 153.

F.6 If shown on the Drawings, the fence fabric, posts and all exposed galvanized hardware shall be coated with a minimum 0.25 mm coating of bonded PVC. PVC shall be applied by the thermal extrusion process and shall withstand a minimum exposure of 1,500 hr at 62 degrees C without any deterioration when tested in accordance with ASTM D 1499.

F.7 Slats, when required, shall be either wood or plastic and of the dimensions shown on the Drawings. Wood slats shall be treated with a suitable preservative.

F.8 Plastic slats shall be tubular polyethylene, color pigmented material consisting of high density polyethylene and color pigments designed to retard ultraviolet penetration. The material shall have a minimum wall thickness of 0.7 mm and shall remain flexible without distortion and without becoming brittle through a temperature range of zero degrees C to 60 degrees C.

F.9 Plastic slats shall be retained in place by means of U-shaped retainer members at the bottom and top of the glare screen. Retainer members shall be of the same material as the slats.

F.10 Samples for the color of plastic slats shall be submitted for approval before use.

G. Bolts, Nuts, and Other Fittings

G.1 All bolts shall conform to ASTM A 307, except those designated on the Drawings as high strength, which shall conform to ASTM A 325 or A 449.

G.2 All nuts shall conform to ASTM A 563, Grade A or better, except those designated on the Drawings as high strength, which shall conform to ASTM A 563, Grade C or better.

H. Galvanizing

H.1 All of the exposed materials for guardrail, guardrail anchor terminals, impact attenuators, glare screen, and delineators, which consist of steel or iron, shall be galvanized after fabrication unless otherwise specified. Whenever a galvanizing

requirement is not included in the Specifications, it shall be in accordance with ASTM A 123 or ASTM A 153 as appropriate.

H.2 All components shall be fabricated and galvanized for installation without additional drilling, cutting, or welding. When field modifications are approved or when minor damage to the galvanized coating occurs, the exposed surface shall be repaired by thoroughly cleaning and applying 2 applications of zinc dust-zinc oxide primer, as specified in Section 6.09 - "Painting of Structures".

I. Concrete

I.1 All concrete shall conform to the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

I.2 Unless Otherwise shown on the drawings classes of concrete shall be as follows:

- Concrete for post supports, buried footings and anchors shall be Class 170/60.
- Concrete for New Jersey concrete barriers and terminal sections shall be Class 360/20.
- All other concrete shall be Class 210/20.

J. Reinforcement

Reinforcing steel shall be of the size and type shown on the Drawings and shall conform to the requirements of Section 5.03 "Steel Reinforcement and Fixing".

K. Other Materials

Other materials shall be as shown on the Drawings. Special materials for impact attenuators shall be as specified by the manufacturer.

6.03.03 CONSTRUCTION AND INSTALLATION

A. Metal Beam and Cable Guardrail

A.1 Guardrail shall be installed as and where shown on the Drawings. Posts shall be installed by driving plumb to the required elevations or shall be set in concrete, as shown on the Drawings.

A.2 If ground conditions are such that pilot holes are necessary to prevent damage to posts during driving, all space around steel posts after driving shall be filled with dry sand or fine gravel.

A.3 When posts are set in concrete, the concrete shall be placed against the excavated earth unless otherwise approved.

A.4 Continuous lengths of rail or cable shall be installed and alignment checked and adjusted before final tightening of bolts, etc. Unless otherwise specified, bolted connections shall be torqued to between 6 and 7 kg-m. Lapped rail shall be installed with exposed ends away from the stream of traffic.

B. Pedestrian Guardrails

B.1 All prefabricated or ready-assembled pedestrian guardrails shall be welded in accordance with Section 5.16 "Structural Steel work and metal components"

B.2 When directed by the Engineer before fabrication has commenced, welding procedure trials shall be carried out using representative samples of materials to be used in the work.

B.3 During guardrail erection, all members shall be securely held in their positions until the post fixings have gained sufficient strength to withstand the design load required. The assessment of the strength of the post fixing shall be subject to the Engineer's agreement. Finished guardrails shall be true to line throughout their length.

B.4 The rails and posts of pedestrian guardrails shall be closed section presenting no visible seam welds or exposed bolt heads. The exact shape of the posts and rails shall be in accordance with the drawings and to the approval of the Engineer.

C. Guardrail Anchor Terminals

C.1 Guardrail anchor terminals shall be installed as and where shown on the Drawings.

C.2 Posts, anchors and footings shall be driven or installed in concrete as required. Concrete shall be placed against the excavated earth unless otherwise approved.

C.3 Bolted connections shall be torqued as for guardrail bolts.

C.4 Cable guardrail end assemblies shall be attached to the breakaway anchor angle and turnbuckles tightened to provide the spring compression as shown on the Drawings. Backfill above the tops of concrete anchor footings shall not be placed before cables are tensioned. Cables shall be uniformly tensioned prior to bending tabs on end post caps.

D. New Jersey Concrete Barriers and Terminal Sections.

D.1 Concrete barriers shall present a smooth, continuous, uniform appearance in their final position, conforming to the horizontal and vertical lines shown on the Drawings, and shall be free of lumps, sags, or other irregularities. The top and exposed faces of the barrier shall not vary more than 6 mm between any 2 contact points when tested with a 4 m straightedge laid on the surfaces.

D.2 Concrete barriers may be precast, cast in situ with fixed forms, or extruded with slip forms. Concrete barriers constructed by casting in situ using fixed forms, shall conform to the relevant requirements of Section 5.06- "Reinforced Concrete Structures."

D.3 Unless otherwise shown on the drawings, traverse expansion joints of 10 mm thick premolded filler shall be provided in all cast in situ concrete barriers at spacing not exceeding 15 meters center to center.

D.4 If concrete barriers are constructed by means of an extrusion machine or other similar type equipment, the concrete shall be thoroughly consolidated and the exposed surfaces shall conform to the relevant requirements of Section 5.06 - "Reinforced Concrete Structures" and as specified herein.

D.5 The Contractor shall furnish evidence of successful operation of the proposed extrusion machine or other equipment, by constructing a trial section of barrier or by other evidence acceptable to the Engineer.

D.6 Concrete shall be fed to the extrusion machine at a uniform rate. The machine shall be operated under sufficient uniform restraint to forward motion to produce a thoroughly consolidated mass of concrete free from surface pits larger than 20 mm in diameter and requiring no further finishing. The concrete shall be of such consistency that, after extrusion, it will maintain the shape of the barrier without support. The grade for the top of the concrete barrier shall be indicated by an approved offset guide line.

D.7 The forming portion of the extrusion machine shall be readily adjustable vertically during the forward motion of the machine to conform to the predetermined grade line. A grade line gauge or pointer shall be attached to the machine in such a manner that a continual comparison can be made between the barrier being placed and other established grade line as indicated by the offset guide line. Other means of controlling barrier grade may be approved.

D.8 Expansion joints shall be constructed in the extruded concrete by sawing through the barrier section to its full depth. If sawing is performed before the concrete has hardened, the adjacent portions of the barrier shall be firmly supported with close fitting shields. When sawing is performed after the application of curing compound, the exposed faces of the barrier in the vicinity of the joint shall be treated with curing compound after sawing the joint.

D.9 If stationary forms for concrete barriers are used, they shall be removed as soon as possible after the concrete has set sufficiently to maintain the shape of the barrier without support. The surface shall be free from pits larger than 20 mm in diameter and shall be given a final soft brush finish with strokes parallel to the line of the barriers. Finishing with a brush application of grout will not be permitted.

D.10 Concrete surfaces shall be finished as necessary to produce smooth, even surfaces of uniform texture and appearance, free of bulges, depressions and other imperfections. The use of power sanders, carborundum stones, or disks may be required to remove bulges or other imperfections.

D.11 Exposed surface of concrete barriers shall be cured by membrane curing as specified in Section 5.02 - "Concrete Handling, Placing and Curing."

E. Impact Attenuators

Impact attenuators shall be installed as and where shown on the Drawings and in accordance with the manufacturer's recommendations and instructions. A copy of these recommendations and instructions shall be submitted to the Engineer upon delivery of the impact attenuator materials and before any installation commences.

F. F. Glare Screens

F.1 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, which is on the outside of the curve.

F.2 Fabric shall be stretched taut and securely fastened to posts as shown on the Drawings. Fabric shall be cut and each span attached independently at all pull and brace posts.

Rolls of wire fabric shall be joined by weaving a single strand into the end of the rolls to form a continuous mesh between pull posts.

6.03.04 TESTING

A. Copies of all Certificates of Guarantee and test reports for all manufactured items shall be submitted to the Engineer.

B. The Engineer may request additional sample materials for testing for strength, galvanizing, or other parameters.

6.03.05 MEASUREMENT

A. Steel Guardrail shall be measured by the linear meter furnished, including dismantling and dumping damaged steel guardrail where exist, installing completing and accepting Measurements shall be based on the dimensions as shown on the Drawings and shall include Terminal Sections and Transition Sections.

B. Concrete Safety Barrier free-standing or on top of retaining walls. Concrete class 360/20, including steel reinforcement, blinding concrete, terminal unit, and all complementary works (i.e. stone clading, galvanized steel tubes, etc,) completed all as specified and as shown on drawings.

C. Impact Attenuators shall be measured by the unit of each type furnished, constructed or installed, completed, and accepted.

D. Excavation, backfilling, concrete footings, anchors, lifting device, dowel bars and other ancillary items, shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for Pay Items.

PAY ITEMS		UNIT OF MEASUREMENT
(1)	Steel Guardrail (specify type)	Linear meter (lm)
(2)	Safety Concrete Barrier (specify type)	Linear meter (lm)
(3)	Impact Attenuators (specify type)	Nr

SECTION 6.04 DELINEATORS, MARKER POSTS AND MONUMENTS

6.04.01 SCOPE

A. These Works shall consist of the furnishing and installation of post-mounted or barrier-mounted reflective delineators, reflective marker posts and concrete monuments, at the locations and as shown on the Drawings.

B. Delineators are post-mounted or barrier-mounted reflector units located at regular intervals along the side of the highway in selected locations to indicate the highway alignment.

C. Marker posts may include kilometer posts, and posts marking obstructions and hazards within or adjacent to the highway such as bridge or underpass piers and abutments, culvert headwalls, abrupt changes in alignment, discontinuation or abrupt narrowing of shoulders, etc.

D. Right-of-way (ROW) monuments are precast concrete posts permanently installed at predetermined intervals along both ROW boundaries.

E. Survey and reference monuments are concrete posts semi-permanently (or permanently) installed within the ROW at predetermined and accurately surveyed points required for construction setting out and related Works.

6.04.02 MATERIALS

A. Concrete

Unless otherwise shown on the drawings, concrete shall be Class 210/20 for ROW monuments and Class 170/60 for post footings. All concrete shall conform with the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

B. Reinforcement

Reinforcing steel shall conform with the requirements of Section 5.03 - "Steel Reinforcement and Fixing".

C. Steel Posts

Steel posts for delineators and marker posts shall be hot-dip galvanized to AASHTO M111 standard and shall conform with the steel post requirements in Section 6.02 " Road Signing ".

D. Metal Work, Nuts and Bolts

D.1 Hardware, steel plates, and pipe shall be furnished or fabricated as shown on the plans. Where galvanizing is specified the metal work shall be hot-dip galvanized to AASHTO M111 standard.

D.2 Nuts, bolts and washers for posts shall be hot-dip galvanized to AASHTO M232 standard.

D.3 Self-locking nuts, bolts and washers for sign panels shall be stainless steel conforming to ASTM A276.

E. Sheet Metal for Panels

Sheet metal for delineator panels and marker post panels shall be either steel sheet or aluminum alloy sheet as shown on the Drawings and conforming with the relevant requirements of Section 6.11 - "Highway Signing".

F. Reflective Sheeting

Reflective sheeting shall be an approved "low intensity" type unless shown otherwise on the Drawings and shall conform with the relevant requirements in Section 6.02 " Road Signing ".

G. Delineators

G.1 Post-mounted and barrier-mounted delineators shall be approved type, highly durable plastic molded, prismatic reflectors of the colors specified and conforming to MUTCD requirements, unless otherwise shown on the Drawings.

G.2 Where reflectorized paint is specified in lieu of, or in association with, prismatic reflectors, the paint material shall be of the type as shown on the Drawings and shall conform with the relevant requirements of Section 6.03 - "Road Way Markings ".

6.04.03 INSTALLATION

A. All posts for delineators, object and marker posts, survey and ROW monuments, shall be installed at the locations shown on the Drawings.

B. Construction of concrete footings, installation of steel posts and erection of panels, reflective sheeting and reflectors, shall be in accordance with the relevant requirements of Section 6.02 - "Raod Signing".

C. Reflectorized paint for marker posts shall be as shown on the drawings and accord with the relevant requirements.

D. Concrete monuments shall be installed in the correct positions, truly vertical and complete with inset steel plates or other indented or painted identification markings, as shown on the Drawings for each type of monument.

E. Backfilling with approved material shall be in accordance with the relevant requirements of Section.

6.04.04 MEASUREMENT

A. Delineators shall be measured by the number including furnishing and erection of posts.

B. Marker Posts shall be measured by the number furnished and erected including reflective signs and reflectorized painting, completed, and accepted.

C. Monuments shall be measured by the number of each type furnished, installed, completed, and accepted.

D. Excavation, backfilling and other ancillary items shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for the Pay Items.

	UNIT OF MEASUREMENT	PAY ITEMS
(1)	Barrier-Mounted Delineators	Nr
(2)	Post-Mounted Delineators	Nr

**** END OF SECTION ****

SECTION 6.05 GABION AND MORTARED MASONRY WALLS

6.05.01 SCOPE

A. These Works shall consist of the furnishing of all materials and the construction of gabion, mortared masonry walls and mortared concrete block masonry, as and where shown on the Drawings.

6.05.02 MATERIALS

A. Stones

A.1 Stones for masonry walls shall consist of field stones furnished in broad flat shapes to the maximum extent practicable. All stone shall be hard, sound, durable, highly resistant to weathering and shall be suitable as protection material for the intended purpose.

A.2 Samples of the stone material proposed for use in the Works shall be submitted to the Engineer for approval prior to its use in the Work.

A.3 The minimum apparent specific gravity shall be 2.5 and the maximum absorption shall be 6% when tested in accordance with AASHTO T 85. The stone shall have an abrasion loss not greater than 45% when tested in accordance with AASHTO T 96.

A.4 Stones for gabion walls shall be angular, neither elongated nor flat. Dimensions shall range from 250 mm to approximately 125 mm diameters. Not more than 5% shall be smaller than 100 mm.

A.5 The weight of stones for Gabion walls shall he as follows:

% of Total Weight Smaller than Size Shown	Weight of Stone (kilograms)
95-100	50
50-100	20
0-50	5
0-10	1

B. Mortar

B.1 Mortar for mortared masonry walls shall consist of 1:3-4 cement: sand mortar by volume with a compressive strength at 28 days of 5 Mpa. Water added shall be the least amount which will yield a mix of suitable consistency to ensure proper mortaring of masonry. Sand and cement shall conform with the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

B.2 Mortar for masonry walls shall be composed of 300 kg of cement to one cubic meter of sand and shall be thoroughly mixed prior to the addition of water.

C. Gabions

C.1 Gabions shall consist of approved type galvanized steel wire mesh baskets (or other approved types such as heavy duty plastic mesh) filled with selected riprap before installation.

C.2 Galvanized steel wire mesh shall conform to ASTM A 390 Class 3, or equivalent and with the requirements shown on the Drawings. The wire mesh shall be twisted to form hexagonal or rectangular openings of uniform size. The maximum nominal opening size shall be 100 mm. Mesh shall be constructed so as to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section is cut.

C.3 Baskets shall be furnished in one or more sizes which can be assembled to provide the minimum dimensions, stability, and structural integrity of the installation specified. Sizes of gabion baskets will normally be 2 m long by 1 m wide by 1 m high. Non-standard sizes shall be provided to suit the particular installation, as shown on the Drawings.

C.4 Baskets shall be fabricated in such a manner that the sides, ends, lid, and diaphragms can be assembled on Site into rectangular baskets of the specified sizes. Gabion baskets shall be of single unit construction. Long gabions assembled with diaphragms between adjacent baskets, for use as foundation mattresses, etc., may not require lids.

C.5 Base, lid, ends and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in such a manner that strength and flexibility at the point of connection is at least equal to that of the mesh.

C.6 All perimeter edges of the mesh forming the basket shall be securely clip bound or selvedged so that the joints formed by tying the selvedges have at least the same strength as the body of the mesh.

C.7 Perimeter (edge), tie, and connection wires shall conform to ASTM A 641, Class 3, Medium Temper, and the minimum diameters shown on the Drawings.

D. Concrete Blocks

D.1 Concrete Blocks: unless otherwise specified, are to be to BS 6073 Part 1, ASTM C90 nominal size 400 x 200 mm and to the thicknesses shown on the Drawings. Minimum average net-area compressive strength shall be 10N/mm2 (10 MPa).

D.2 Concrete masonry units shall be manufactured from ordinary Portland cement to BS 12 and natural aggregates to BS 882. Concrete facing blocks are to have true undamaged surfaces and clean and sharp arises.

D.3 Web thickness for units less than 100mm thick shall be not less than 20mm.

D.4 Web thickness for units 150mm thick shall be not less than 25mm.

D.5 Web thickness for units 200mm thick and over shall be not less than 35mm.

D.6 For units in walls supporting stone cladding, web thickness shall be less than 40mm.

6.05.03 CONSTRUCTION

A. Preparation of Surface

A.1 The surfaces upon which foundations and bases are to be placed shall be excavated and compacted to the required grades and lines. Subgrade or base shall be firm or compacted as directed.

B. Mortared Masonry Walls

B.1 The construction of masonry walls shall be carried out in layers perpendicular to the vertical wall surface and no layer shall be started before completion of the previous layer.

B.2 Stones in mortared masonry walls shall be laid on a full even bed of cement mortar with joints between stones filled and not less than 12 mm wide. Bonding stones of a length two thirds the thickness of the wall shall be built, one to every square meter of each side of the retaining wall and staggered. Expansion joints shall be constructed at every 10 meters or at the intervals or places shown on Drawings.

B.3 Cross drains shall be formed in masonry retaining walls as shown on the Drawings. Approved granular materials shall be filled behind masonry retaining walls to a width of 300 mm and to the full depth of the wall as directed by the Engineer.

C. Gabions

C.1 Each gabion basket shall be assembled by binding together all vertical edges with wire ties on approximately 150 mm spacing or by use of a continuous piece of connecting wire stitched around the vertical edges with a coil every 100 mm.

C.2 Empty gabion units shall be installed to line and grade as shown on the Drawings. Wire ties or connecting wire shall be used to join the units together in the same manner as described for assembling. Internal tie wires shall be uniformly spaced and securely fastened in each cell of the structure. A standard fence stretcher, chain fall, or iron rod may be used to stretch the wire baskets and hold alignment.

C.3 The gabions shall be filled with stones as specified, placed by hand or machine to assure alignment and avoid bulges with minimum voids. Alternate placing of rock and connection wires shall be performed until the gabion is filled. After filling with riprap, the lid shall be bent over until it meets the sides and edges, and shall be secured to the sides, ends, and diaphragms with wire ties or connecting wire in the manner described for assembling.

D. Concrete Blocks

D.1 The Contractor shall observe the following:

- Do not use autoclaved concrete bricks or blocks when still warm from the manufacturing process,
- Do not use non-autoclaved concrete bricks or blocks until at least four weeks after casting,

- Do not wet concrete bricks or blocks before laying; use an approved water-retaining admixture in the mortar to counteract suction.

D.2 Construct Unit Masonry: All materials shall be fully bonded or tied together to ensure compliance with design requirements for stability and strength as relevant.

D.3 Connection Between Walls and Partitions: Walls and partitions should generally be bonded, tied or dowelled to one another at angles and junctions. Where it is necessary for a partition to be connected to an adjacent wall or column, this should be done by toothing or block bonding unless otherwise specified.

D.4 The block walling to concrete structural elements with metal ties approved for the purpose.

D.5 Wet Weather: The Contractor shall protect newly erected masonry during interruption through rain and at completion of each day's work by covering.

D.6 Uniformity: The Contractor shall carry up work including both leaves of cavity work, with no portion more than 1.2 m above another at any time, racking back between levels. The Contractor shall not carry up work higher than 1.5 m in one day.

D.7 The Contractor shall lay blocks on full bed of mortar with joints filled to consistent thickness of not more than 12 mm.

D.8 The Contractor shall lay hollow blocks with cavity downwards. Do not fill cavities in hollow blocks. Use cut or special shape blocks to make up courses and piece-in.

E. Stone Cladding

E.1 Performance Requirements:

Thickness: Minimum thickness of stone cladding shall be 30mm.

E.2 Submittals:

A. Product Data: For each variety of stone, stone accessory, and other manufactured products indicated.

B. Samples for Initial Selection: For joint materials involving color selection.

C. Stone Samples for Verification: Sets for each color, grade, finish, and variety of stone required; not less than 300 mm square.

E.3. Quality Assurance:

A. Source Limitations for Stone: Obtain each variety of stone, regardless of finish, from a single quarry, with resources to provide materials of consistent quality in appearance and physical properties.

B. Source Limitations or Mortar Materials: Obtain mortar ingredients of uniform quality for each cementitious component from a single manufacturer and each aggregate from one source or producer.

E.4. Delivery, Storage, and Handling

A. Store and handle stone and related materials to prevent deterioration or damage due to moisture, temperature changes, contaminants, corrosion, breaking, chipping, and other causes.

1. Lift stone with wide-belt slings; do not use wire rope or ropes that might cause staining. Move stone, if required, using dollies with cushioned wood supports
2. Store stone on wood skids or pallets with non-staining, waterproof covers. Arrange to distribute weight evenly and to prevent damage to stone. Ventilate under covers to prevent condensation.

B. Store cementitious materials on elevated platforms, under cover, and in a dry location. Do not use cementitious materials that have become damp.

E.5 Coordination:

A. Coordinate installation of inserts that are to be embedded in concrete or masonry, flashing reglets, and similar items to be used by dimension stone cladding Installer for anchoring, supporting, and flashing of dimension stone cladding system. Furnish setting drawings, templates, and directions for installing such items and deliver to Project site in time for installation.

B. Time delivery and installation of dimension stone cladding to avoid extended on-site storage and to coordinate with work adjacent to dimension stone cladding.

F. Products

F.1 Stone

A. Local sandstone to the approval of Engineer, free from faults, and complying with ASTM C 568.

B. Stone blocks and panels shall be built and fixed with cement and sand mortar, as indicated, and reinforced with galvanized steel anchors and dowels.

C. Colour: Beige colour, or as otherwise advised by Engineer.

F.2 Mortar Materials:

A. Portland Cement: ASTM C 150, Type I. Provide natural color or white cement as required to produce mortar color indicated.

B. Hydrated Lime: ASTM C 207.

C. Portland Cement-Lime Mix: Packaged blend of Portland cement complying with ASTM C 150, Type I, and hydrated lime complying with ASTM C 207.

D. Aggregate: ASTM C 144; except for joints narrower than 6 mm and pointing mortar, use aggregate graded with 100 percent passing No. 16 (1.18-mm) sieve.

E. White Aggregates: Natural white sand or ground white stone.

F. Mortar Pigments: To BS EN 12878, natural and synthetic iron oxides, compounded

for use in mortar mixes. Use only pigments with a record of satisfactory performance in mortar and containing no carbon black.

G. Water: Potable.

G. Execution

G.1 Examination

A. Examine surfaces to receive dimension stone cladding and conditions under which dimension stone cladding will be installed, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance.

G.2 Setting Dimension Stone Cladding, General

A. Execute dimension stone cladding installation by skilled mechanics and employ skilled stone fitters at Project site to do necessary field cutting as stone is set.

B. Set stone to comply with requirements indicated on Drawings and Shop Drawings. Install anchors, supports, fasteners, and other attachments indicated or necessary to secure dimension stone cladding in place. Shim and adjust anchors, supports, and accessories to set stone accurately in locations indicated with uniform joints of widths indicated and with edges and faces aligned according to established relationships and indicated tolerances.

G.3 Installation Tolerances

A. Variation from Plumb: For vertical lines and surfaces of walls, do not exceed 6 mm in 3m, 10 mm in 6 m, or 12 mm in 12 m or more. For external corners, corners and jambs within 6 m of an entrance, expansion joints, and other conspicuous lines, do not exceed 3 mm in 3 m, 6 mm in 6 m, or 10 mm in 12 m or more.

B. Variation from Level: For lintels, sills, water tables, parapets, horizontal bands, horizontal grooves, and other conspicuous lines, do not exceed 3 mm in 3 m, 6 mm in 6 m, or 10 mm maximum.

C. Variation in Cross-Sectional Dimensions: For thickness of walls from dimensions indicated, do not exceed plus or minus 6 mm.

G.4 Adjusting and Cleaning:

A. Remove and replace broken, chipped, stained, or otherwise damaged stone, defective joints, and dimension stone cladding that does not match approved samples and mockups. Damaged stone may be repaired if Engineer approves methods and results.

B. Replace in a manner that results in dimension stone cladding's matching approved samples and mockups, complying with other requirements, and showing no evidence of replacement.

C. Final Cleaning: Clean dimension stone cladding no fewer than six days after completion of pointing and sealing, using clean water and stiff-bristle fiber brushes. Do not use wire brushes, acid-type cleaning agents, cleaning agents containing caustic compounds or abrasives, or other materials or methods that could damage stone.

6.05.04 MEASUREMENT

A. Gabion, walls and mortared masonry walls shall be measured by cu.m furnished, installed, completed and accepted. Dimensions shall be as shown on the Drawings.

B. Concrete block walls shall be measured by sq.m., stating the thickness, furnished, completed and accepted.

C. Stone cladding shall be measured by sq.m. furnished, installed, completed and accepted.

D. Excavation, backfilling, furnishing, transporting, storing, surface preparation, cyclopean concrete, wire fabric weepholes, baskets, riprap, ties and other ancillary items shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for Pay Items.

E. Permeable Drainage Layer behind retaining walls (permeable backing) shall be measured and paid separately as specified in Section 2.09 "Structural Excavation and Backfill".

PAY ITEMS		UNIT OF MEASUREMENT
(1)	Gabion Walls	Cubic Meter (m^3)
(2)	Mortared Masonry Walls	Cubic Meter (m^3)
(3)	Stone Cladding	Square Meter (m^2)
(4)	Concrete Block Walls (specify thickness)	Square Meter (m2)