REPUBLIC OF LEBANON

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

Routine Maintenance for Bridges and Streets in Beirut

Tender Documents

Volume 2

Technichal Specifications

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DIVISION 1

GENERAL REQUIREMENTS

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SECTION 1.01 DESCRIPTION OF WORK AND SITE

1.01.01 Background

The works include but not limited to essential routine maintenance activities on selected bridges and streets in Beirut, as listed the following tables.

The maintenance works for bridges listed in table-1 will primarily focus on the expansion joints of the identified structures. This involves the replacement and/or repair of damaged joints in full compliance with the requirements and technical specifications outlined in the Tender Documents.

Table-1: Bridges Scope of Works table

Location	**Bridge Reference**	**Bridge Name**
Beirut Municipality	BR-I.1	Charles Helou Bridge
	BR-I.2	Joseph Chader Bridge
	BR-I.3	Salim Salam (Bridge and Tunnel)
	BR-I.4	Adlieh Bridge
	BR-I.5	Ring Bridge
	BR-I.6	Fiat Bridge
	BR-I.7	Hawd Al Wilaya Bridge
	BR-I.8	Sassine Tunnel Bridge

The maintenance activities for the streets listed in Table-2 will primarily focus on repairing defective pavement areas to enhance safety and ensure smoother traffic flow. These works will be carried out in addition to miscellaneous routine maintenance operations.

Table-2: Streets Scope of Works Table

Location	**Scope of Works**
Beirut Municipality	Routine Maintenance of Gouraud Street
	Routine Maintenance of Jeane d' Arc Street
	Routine Maintenance of Ouzaai Street **(Optional)**
	Routine Maintenance of Makdessi Street **(Optional)**
	Miscellaneous Routine Maintenance Works

1.01.02 Scope of Works

1) Maintenance of the bridge expansion joints

The maintenance of Bridge Expansion Joints shall focus on preserving the road facility during the projected design life, in a good condition to provide an acceptable level of service for the users.

The maintenance work shall mainly include the following:

- Maintenance for the damaged expansion joints, as well as repair works for the concrete supports and the asphalt approach areas.
- Traffic Management Plan during different construction phases.

The Maintenance of the existing expansion joint includes mainly one of the following cases:

(i) In case of minor defects, the repair of existing joints consists of replacing the damaged parts of the joint and restoring/repairing the deteriorated parts of anchorage systems without full replacement of existing joints.

(ii) In case of major defects, the rehabilitation of deck expansion joints includes mainly replacing the existing one with a new one as specified in the project tender documents and according to the method statement presented hereafter.

It is noted that the rehabilitation operation of existing elastomeric joints shall include mainly the following activities:

- Install as necessary the temporary signing and channelizing devices for the TCP in the working area.
- Dismantling of the existing expansion joints and all related materials and accessories.
- Milling the existing pavement from both sides of the expansion joint.
- Base joint preparation by cleaning and removal of the damaged parts by using an electrical hammer.
- Installing of steel reinforcement where required (Utilization of epoxy mortar for steel anchor).
- Base releveling and pouring of deteriorated parts by using high strength and fast hardening micro-concrete (Sikacrete or equivalent).
- Joint installation including drill and fixation of anchor bolts by epoxy resin.
- Milling and surface asphalting from both sides of the expansion joint.
- Clean and fill the transition strip (Epoxy Based) on both sides of the expansion joints.
- Dismantle the temporary signing and channelizing devices.

2) Maintenance for streets

- Pavement repair works
- Sidewalk maintenance works
- Clearing of roadway limits that includes remove within the limits of road limits all vegetation, surface debris and scattered stones and rocks etc.…
- Repair of damaged manhole covers completed as specified and to the Engineer's satisfaction.
- Cleaning of waterways, hydraulic structures, drainage pipes, and manholes,
- Remove of damaged Galvanized Steel Guardrail and replace by new one.
- Concrete Repair Works: including repair of existing concrete channels, box culverts, safety barriers

The Works shall be executed and completed by the Contractor in accordance with the Contract Documents.

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 of bridge joints under scope of works which shall includes but not limited to the works limits, dimensions, 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

1.02.04.01 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.

1.02.04.02 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.

1.02.04.03 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 General Traffic Management Plan (GTMP) and Specific Traffic Management Plans (specific TMPs)

The Contractor should submit for consultant approval the General Traffic Management Plan (GTMP) and the Specific Traffic Management Plans (specific TMPs) related to each bridge during the first 28 days from notice to commence and in accordance with the contract requirements.

The General Traffic Management Plan (GTMP) shall focus on construction staging during different phases of maintenance/repair/construction, factors impacting traffic and constructing staging; project area characteristics of each bridge; work zone lane restrictions, traffic management and operation strategies; type of sign that shall be used during construction (as Diversion sign, Regulatory signs, Informative signs); Proposed working hours; potential mobility issues; incident management plan, etc…

The Temporary Traffic Control/ Management Plans (STTCP/ STMP): shall include various traffic diversion plan layouts for various type of activities; Analysis of impacted roads; Risk Assessment; Protection of Work Zones and road users including pedestrians. Noting that these plans shall be be approved by the Consultant prior the execution of work.

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 & Laboratory

1.03.03.01 Contractor's Temporary Offices

Not Included.

1.03.03.02 Temporary Laboratory

The Contractor is responsible for conducting all material testing as mandated by the Specification. These tests should be performed by a third-party laboratory that is suitably subject to the Engineer approval.

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.

1.03.05 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 Telephones

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

1.03.05.03 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.

1.03.05.04 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.

1.03.05.05 Digital Camera

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

1.03.05.06 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.

DIVISION 2

PREPARATION & REPAIR WORKS

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SECTION 2.01 DISMANTLING DAMAGED EXPANSION JOINTS

2.01.01 SCOPE

These Works shall consist the removal of the existing damaged expansion joints including existing anchors and all other steel attachment joint strips and all related components all as specified in the contract drawings and as directed by the Engineer

2.01.02 CONSTRUCTION

A.1 Saw cutting of the exiting asphalt and removal the transition strips from both side of expansion joint and,

A.2 Careful removal the existing damaged joints and frames, and anchorage systems storage by using power hammer equipment where required no heavier than the nominal 15-pound class.

A.3 Removal of existing dirty and debris within the gap and in the vicinity of the bridge expansion joints

A.4 The Contractor shall dispose all removed materials to the approved dump site.

2.01.03 MEASUREMENT

The rate shall also include all manpower, equipment materials and accessories necessary to complete the work including but not limited to removal of existing damaged joints and all related elements, including but not limited to saw cutting of the existing asphalt layer and removal transition strips and anchor bolts in addition to removal all dirty inside the joint gap and in the vicinity of the bridge all as specified and directed by the Engineer.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Dismantling of damaged expansion joints including all related accessories and cleaning joint gaps from dirty and debris.	(lm).

SECTION 2.02 DEMOLITION AND REMOVAL OF THE DAMAGED CONCRETE

2.02.01 SCOPE

These Works shall consist the demolition and removal of the existing damaged (cracked/not sound) concrete joint support and cleaning demolished part all as specified and as directed by the Engineer.

2.02.02 CONSTRUCTION

A.1 Careful removal the existing damaged concrete by using power hammer equipment where required no heavier than the nominal 15-pound class. All necessary measures should be taken to ensure the bridge structural elements are not damaged during demolition.

A.2 Removal of existing dirty and debris within the gap and in the vicinity of the bridge expansion joints

A.3 Clean the existing steel reinforcement from concrete and debris

2.02.03 MEASUREMENT

The rate shall also include all manpower, equipment materials and accessories necessary to complete the work including:

Provision of adequate scaffolding and work surfaces to enable work to be carried out under good condition including supply and installation of scaffolding towers or others to ensure access to the work areas in the soffit of the tunnel slab ensuring that one lane is available and safe for the use of motorists in each direction;

- Demolition, removal and carting away to approved dumping areas existing concrete cover of slab to the level of the reinforcing steel;

- Surface preparation by Bush Hammering and removal of all damaged or weak concrete to the existing slab, but not to an extent to go beyond the reinforcement cover, except by the express instructions of the Engineer;

- Provision of daily and final cleaning;

For the demolition and removal of the damaged concrete joint support. Measurement shall be made separately for each joint support, corresponding to each side of the joint element.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Demolition and removal of the damaged concrete joint support.	(lm).
(2) Demolition and removal of the damaged concrete surface.	(m^2).

SECTION 2.03 REPAIR WORKS OF THE EXISTING JOINTS

2.03.01 SCOPE

These Works shall consist of repair of existing joints, by tensioning the anchorages system and clean and pour joints transition strips with epoxy resin all as directed by the Engineer.

2.03.02 CONSTRUCTION

A.1 Saw cutting of the existing asphalt adjacent to joint, and clean the transition zones between the joint elements and the road surface (from both sides of joint).

A.2 Releveling the existing joints where needed.

A.3 Examine the structural conditions of existing joint, anchor bolts and other joints elements.

A.4 Tensioning the anchorages, pour in the anchorage's reservation epoxy resin, and fill in the transition zones with epoxy resin.

2.03.03 MEASUREMENT

The rate shall also include all manpower, equipment materials and accessories necessary to complete the work including but not limited to, saw cutting of the existing asphalt layer clean the transition zones between the joint elements releveling where needed, examine the structural conditions of existing joint, anchor bolts and other joints elements, Tensioning the anchorages, pour in the anchorage's reservation epoxy resin, and fill in the transition zones with epoxy resin.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Repair works of the existing joints	(lm).

SECTION 2.04 REPAIR OF MANHOLES COVERS,

2.04.01 SCOPE:

These Works shall consist of repair of existing manhole covers and frames, by adjusting the level of the existing manhole neck, and reinstallation of the existing manhole and frames covers or replace by new one where required.

2.04.02 CONSTRCUTION

A.1 Careful removal of existing manhole covers and frames, storage of existing covers and frames for reuse or providing new manholes cover where required.

A.2 Saw cutting of the existing asphalt layer, where applicable, excavating around the manhole (or the like) to the ceiling level, demolishing deteriorated part of the access shaft, removing, cleaning demolished part.

A.3 Adjusting the level of the manhole neck, and reinstallation of the manhole covers and frames. reinstalling the existing manhole cover and frame (or the new cover if required) to the finished grade according to the methods of installation for the frame, whether embedded in a concrete ring base, precast or cast in situ, placed and secured over an adjustable concrete bricks or cast in place with instated part of the concrete access shaft.

A.4 Provide additional concrete ring as specified and the required steel reinforcement around the reinstated access shaft. In cases where the top concrete ring is left exposed, the concrete used shall be covered with an anti-abrasion epoxy mortar which rate is included.

2.04.03 MEASUREMENT

The rate shall also include all manpower, equipment materials and accessories necessary to complete the work including but not limited to removal of existing manhole, saw cutting of the existing asphalt layer and demolition of existing concrete shaft, reinstallation of the existing manhole covers or new ones where required covers manhole and frames, Provide additional concrete ring (as specified), the steel reinforcement around the reinstated access shaft, and the temporary cover steel plate (1500x1500x20mm thick) where needed. Repair of manholes covers levels item shall be measured by the number of manholes lowered or raised to the required levels, as specified and accepted.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Repair and re-leveling of damaged concrete frame manholes by reuse the existing cover, the class of concrete to be used for frame manholes shall be 450/20 including SBR additive.	(Nr).
(2) Supply and install new ductile iron heavy-duty circular manhole covers with a load capacity of 40 tons to replace existing damaged or missing units. The new covers shall match the existing type and standard size, with an internal diameter up to 80 cm.	(Nr).
(3) Supply and install new ductile iron (heavy-duty) square grating covers to replace existing damaged or	(Nr).

missing ones. The new covers shall match the existing type and standard size, with an internal side dimension up to 70 cm.

SECTION 2.05 REMOVAL OF DAMAGED BLOCK PAVEMENT AND UNDERLYING LAYERS

2.05.01 SCOPE

This item covers the complete removal of damaged block pavement areas, including the underlying base and subgrade layers, within the designated limits as specified by the Engineer. Removal shall be carried out to a depth of up to 80 cm or as otherwise directed by the Engineer on site.

2.05.02 EXECUTION

A. Verification and Marking

- Prior to commencement, the extent and depth of removal shall be confirmed and clearly marked on site by the Engineer.
- Any discrepancy or unforeseen conditions encountered during removal must be reported immediately to the Engineer.

B. Removal Operations

- Removal of block pavement shall be executed carefully to avoid damage to adjacent undisturbed pavement or buried utilities.
- Suitable mechanical equipment such as hydraulic breakers, excavators, or pneumatic tools shall be used; hand tools may be employed where mechanical means are impractical or risk damage.
- Excavation of the underlying base and subgrade layers shall be performed within designated limits to the specified depth (up to 80 cm or as directed).
- All removed materials include broken blocks, base aggregate, and subgrade soil.

C. Site Cleanliness and Safety

- Dust and noise control measures shall be implemented during all demolition and excavation works, including wetting down surfaces as necessary.
- Barricades, warning signs, and other protective measures shall be provided to safeguard workers and the public.
- All works shall comply with applicable health, safety, and environmental regulations.

D. Disposal of Materials

- All debris and unsuitable materials shall be promptly removed and disposed of in accordance with project environmental requirements and local regulations.
- No materials shall be stockpiled on site without prior approval from the Engineer.

2.05.03 MEASUREMENT

- Measurement shall be based on the actual area (m^2) or length (lm) of damaged block pavement removed, including the excavation of the underlying base and subgrade layers to the specified depth.

- The unit rate shall include all labor, equipment, tools, disposal fees, traffic management, and any other costs necessary to complete the removal works as specified and directed by the Engineer.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Removal of damaged block pavement including base and subgrade excavation.	(M2).

SECTION 2.06 CLEANING OF DRAINAGE PIPES USING JETTING.

2.06.01 SCOPE

These Works shall consist of the cleaning drainage pipes weather sanitary waste water and/or storm water pipes of any size using a water jetting machine of a capable capacity.

2.06.02 EQUIPMENT

A. Jetting Machine

This machine shall be a truck mounted water jetting machine and pump capable of cleaning the needed pipes of any existing size in the project without causing damage to the pipes, manholes and any other related item in the road under work. The type of this machine is illustrated on the drawings. It shall be equipped with a water tank of enough size for the job and a pump capable of providing enough pressure to clean the largest pipe in the system.

B. Nozzels

Nozzels used to jet water shall be of suitable size and type to provide enough pressure for cleaning in a reasonable time. Different nozzels shall be used for different pipe sizes.

C. Pressure Hose

Hozes shall be capable of taking the highest pressure possible during the works and protected with a sleeve strong enough to prevent damaging the hose and resilient enough to prevent any damages to the manhole.

2.06.03 WORKMANSHIP

Jetting shall start from the upstream manhole towards the down steam manhole. The illustration of this procedure is shown on the drawings. During the cleaning works a suitable debris trap shall be placed downstream just after the manhole end to prevent debris from leaving one pipe towards the adjacent downstream pipe. Manholes then shall be cleaned and all accumulated debris collected and disposed of in an approved dumping place.

2.06.04 MEASUREMENT

This item shall be measured per meter length of cleaned pipe from one manhole to the next. This shall include the cleaning of manholes and any other item needed to clean the segment of piping system under cleaning works.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Cleaning pipes by water jetting	Linear meter (lm)

SECTION 2.07 INSPECTION AND REPAIR METHODOLOGY FOR TUNNEL WATER LEAKAGE

2.07.01 SCOPE

This work shall consist of inspecting, examining, and documenting all water leakage areas in the tunnel walls and the soffit of the tunnel top slab. The Contractor shall prepare and submit for the Engineer's approval all necessary shop drawings showing the exact locations of water leakage, identification of components requiring repair, and detailed repair methodology. The works shall be performed to the satisfaction of the Engineer and in full coordination with the relevant local authorities.

2.07.02 MATERIALS

A. Survey and Documentation Tools

The Contractor shall utilize appropriate surveying, inspection, and documentation equipment including moisture meters, water tracing dyes, high-resolution cameras, and mapping software.

B. Shop Drawings and Documentation

Shop drawings shall be produced in accordance with project CAD standards and shall clearly mark all leakage points, proposed repair details, and sequences.

C. Repair Materials

All materials required for sealing, crack injection, or other repairs shall be approved by the Engineer prior to use and shall conform to applicable standards for waterproofing and structural repair.

2.07.03 CONSTRUCTION

A. Inspection and Examination

- Carefully inspect the tunnel walls and soffit of the top slab for signs of active and passive water leakage.
- Record all locations using a systematic grid reference system agreed upon with the Engineer.
- Identify associated structural components impacted by leakage.

B. Shop Drawings and Method Statements

- Prepare comprehensive shop drawings illustrating the exact leakage locations.
- Include details of components requiring repair and the proposed repair methodology.
- Submit to the Engineer for review and approval prior to commencing any remedial works.

C. Coordination

- Coordinate with all relevant local authorities for necessary permits, access approvals, and traffic management where applicable.

D. Execution of Repairs

- Only commence repair works following the Engineer's approval of shop drawings and repair methodology.
- Execute all repairs strictly as approved and under the supervision of the Engineer.

2.07.04 MEASUREMENT

Measurement shall be by lump sum for inspection, documentation, preparation of shop drawings, and submission of repair methodology, completed and approved by the Engineer.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Inspect, document, and submit repair methodology for tunnel leakage	lump sum

SECTION 2.08 NEGATIVE CRYSTALLINE WATERPROOFING AND PROTECTION FOR TUNNEL UPPER SLAB

2.08.01 SCOPE

This work shall consist of supplying and applying crystalline negative waterproofing treatment to the upper surface of the tunnel slab, both after completion of repairs and at other specified areas. The material shall penetrate deep into the concrete by using water as a migrating agent, plug the pores beneath the surface, and shall not blister or peel off. The material shall be of slurry consistency for efficient application. The Contractor shall submit a detailed methodology of application for the Engineer's approval and coordinate with relevant local authorities as required.

2.08.02 MATERIALS

A. Negative Crystalline Waterproofing

The waterproofing product shall:

- Be a proprietary pre-mixed crystalline waterproofing system.
- Comply with applicable international standards (e.g. ASTM C1202, ASTM C309, or equivalent).
- Be capable of deep penetration using water as a carrier.
- Plug micro-cracks and capillary pores within concrete structures.
- Remain permanently active in the presence of moisture.
- Be slurry-consistency for easy brush or spray application.
- Not blister, peel, or delaminate from the concrete substrate.

The product shall be subject to approval by the Engineer prior to procurement and use.

2.08.03 CONSTRUCTION

A. Surface Preparation

- Clean concrete surfaces to be treated to remove laitance, dust, oil, paint, loose particles, and other contaminants.
- Wet surfaces thoroughly for a minimum of 2 hours prior to application, ensuring a saturated surface-dry condition.

B. Application Methodology

- Submit a detailed method statement for the Engineer's approval before work commencement.
- Apply the crystalline slurry by brush, broom, or low-pressure spray in one or two coats, as per manufacturer's instructions.
- Maintain surfaces moist for at least 7 days following application to ensure effective hydration and penetration.

C. Weather Considerations

- Avoid application during rain, extreme heat, or when temperatures are below 5°C unless proper protection is provided.

D. Protection

- Protect treated surfaces from premature drying, direct sunlight, and mechanical damage during the curing period.

E. Coordination

- Coordinate the works with local authorities for access, safety, and any operational restrictions within the tunnel environment.

2.08.04 MEASUREMENT

Negative crystalline waterproofing shall be measured by the square meter (m^2) of surface area treated, completed, and approved by the Engineer.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Negative crystalline waterproofing to upper tunnel slab	square meter (m^2)

DIVISION 3

SUB-BASE AND BASE COURSES

TABLE OF CONTENTS

SECTION 3.01 GENERAL

3.01.01 SCOPE

This section contains the Materials, Equipment and Construction requirements for Aggregate Sub-Base and Base Courses.

3.01.02 STANDARDS AND CODES

The following standards and codes in their latest edition shall be particularly applied to works covered by this section:

ASTM

C 88	Soundness of Aggregate by Use of Sodium or Magnesium Sulphate
C 131	Tests Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
D 1556	Test Method for Density and Unit Weight of Soil in Place by the Sand- Cone Method
D 1883	Test Method for CBR (California Bearing Ratio) of Laboratory Compacted soils.
D 2167	Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.
D 4318	Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils

AASHTO

T 89	Determining the Liquid Limit of Soils
T 90	Determining the Plastic Limit and Plasticity Index of Soils
T 96	Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine
T 104	Soundness of Aggregate by Use of Sodium Sulphate or Magnesium Sulphate
T 180	Moisture-Density Relations of Soils, Using a 10lb Hammer and an 18in Drop
T 191	Density of Soil in-Place by the Sand-Cone Method
T 193	The California Bearing Ratio
T 205	Density of Soil in-Place by the Rubber-Balloon Method

SECTION 3.02 CONTROL OF MATERIALS FOR SUB-BASE AND BASE COURSES

3.02.01 SOURCES OF MATERIALS

The materials used in the work shall meet all quality requirements of the Contract. All materials shall be tested and approved before use. The Contractor shall notify the Engineer of the sources of materials and the Engineer shall approve the sources prior to delivery of materials to the site. Where a source of material does not meet Specification requirements, the Contractor shall furnish material from other sources. Delivery of materials produced from commercial manufacturing processes shall be accompanied by the manufacturer's certification and test report showing the materials comply with the Specification requirements.

3.02.02 STORAGE AND HANDLING OF MATERIALS

Materials shall be so stored and handled as to assure the preservation of their quality and fitness for the Work. Materials, even though approved before storage or handling, may again be inspected and tested prior to use in the work. Stored material shall be located so as to facilitate their prompt inspection. All storage sites shall be restored to their original condition at the Contractor's expense prior to acceptance of the works.

Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes. Stockpiles shall be kept flat and the formation of high cone-shaped piles shall not be permitted. When conveyor belts are used for stockpiling aggregates, the Engineer may require the use of bafflechutes or perforated chimneys.

When trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. The use of tractors or loaders to push material deposited at one location to another location in the stockpile shall not be allowed during the construction of the stockpile and their use shall be limited to levelling the deposited material only.

The Contractor shall take all necessary protection measures in the storage, handling and stockpiling of materials to prevent contamination of materials. The measures that the Contractor proposes to take shall be subject to the approval of the Engineer.

3.02.03 INSPECTION, TESTING AND CONTROL OF MATERIALS

The Engineer will at all times have access to all portions of the aggregate plant, storage yards, crushers and other facilities used for producing and processing the materials of construction. The Engineer shall have authority to request samples and tests of any material supplied to the site from any source whatsoever in order to establish their compliance with Specifications and to accept or reject as he deems necessary. Samples shall also be taken from completed work to determine compliance with the Specifications. The frequency of all sampling and testing shall be in accordance with these Specifications and / or as directed by the Engineer.

3.02.04 UNACCEPTABLE MATERIALS

Materials that do not conform to the requirements of the Specifications shall be rejected and removed immediately from the site of the works unless otherwise instructed by the Engineer. No rejected materials, the defects of which have been corrected, shall be used until approval has been given by the Engineer.

3.02.05 TEST METHODS

Test methods shall comply with the specified requirements.

3.02.06 WATER

Sea water shall not be used for spreading and compacting operations for aggregate sub-base and base courses.

SECTION 3.03 MAJOR EQUIPMENT USED FOR SUB-BASE AND BASE COURSES

3.03.01 GENERAL REQUIREMENTS

Unless otherwise stipulated herein, all the provisions of these Specifications in respect of specifications for the main machinery and tools utilised in the Earthworks construction, shall be adhered to, all subject to the following modifications and additions:

3.03.02 SPREADERS

Spreaders shall be self-propelled and shall be capable of spreading the sub-base and base materials in one operation so as to make it ready for compaction with minimum shaping. The spreader shall be provided with a screed that strikes off and distributes the material to the required width and level. The width of each spread shall not be less than a traffic lane wide. The screed shall be adjustable to the required cross-section. Screed action includes any practical motion that produces a finished surface texture of uniform appearance.

3.03.03 TRAVEL MIXERS

Travel Mixers shall be of a type which are capable of mixing to the full depth of the layer thickness being processed, by picking up the material, mixing, agitating or otherwise blending into a homogeneous mass which conforms to the required general gradation and other specifications. Mixers shall be equiped with an accurate depth control device to avoid the disturbance of previously accepted layers. After mixing, the material shall be deposited by the mixer in its final position so that prior to compaction no spotting, picking-up or otherwise shifting the material will be required. Mixers may be equiped with pressure spray bars which can supply a uniform distribution of metered water during the mixing process.

3.03.04 CENTRAL MIXERS

A central mixing plant shall be either of an approved drum or pugmill type with a moisture control system so that the material may be spread without further mixing or processing.

3.03.05 ROLLERS

Rolling equipment shall consist of steel wheeled rollers and pneumatic-tyred rollers all as specified in these Specifications. A minimum of three rollers shall be required at all times, one self-propelled pnuematic-tyred and two steel wheeled rollers. As many additional rollers shall be used as necessary to provide the specified density and surface characteristic in an orderly, efficient and continuous manner. Tandem steel wheeled rollers shall be of such weight that, under working conditions, will develop contact pressure adequate to obtain the required density.

3.03.06 UNACCEPTABLE EQUIPMENT

The Engineer shall have the right to stop the use of any equipment or plant which he deems to be inferior to the quality required and to instruct the removal of such equipment and to have it replaced by suitable equipment or to alter the method of operation at any time he so desires.

The Contractor shall immediately comply with such instructions without being entitled to any indemnities or extensions as a result of such instructions. The Contractor shall not be allowed to use any equipment or plant before obtaining the approval of the Engineer and the Contractor shall undertake to follow sound technical methods in operation and to engage skilled and trained operators, mechanics and labour to carry out the works. The Engineer shall have the right to expel any operators, mechanics or labour and to instruct suitable replacement thereof at any time he deems such action is necessary.

SECTION 3.04 AGGREGATE SUB-BASE AND BASE COURSES

3.04.01 GENERAL REQUIREMENTS

A. Description

Aggregate sub-base and base courses shall be in compliance with ASTM D2940 and shall consist of crushed mineral aggregates or natural mineral aggregates of the gradation and thickness indicated in the Specifications and on the Drawings.

B. Natural Aggregate Sub-Base and Base Courses

Shall consist of coarse and fine mineral aggregates which have been screened and blended to the various gradings and constructed to the thickness as indicated on the Drawings and in the Specifications.

C. Crushed Aggregate Sub-Base and Base Courses

Shall consist of crushed coarse aggregate and crushed or natural fine aggregate screened and blended in accordance with the required gradation and constructed to the thicknesses as indicated on the Drawings and in the Specifications.

3.04.02 MATERIALS REQUIREMENTS FOR AGGREGATE SUB-BASE AND BASE COURSES

A. Fine Aggregates Used for Aggregate Sub-Base and Base Courses

Fine aggregate passing the No.4 (4.75mm) sieve shall normally consist of fines from the operation of crushing the coarse aggregate; where available and suitable, natural sand or finer mineral matter, or both, may be added. The fraction of the final mixture that passes the No. 200 (75μm) sieve shall not exceed 60% of the fraction passing the No. 30 (600μm) sieve. The fraction passing the No. 40 (425-μm) sieve shall have a liquid limit no greater than 25 and shall not have a plasticity index greater than 4. The sand equivalent value of the fine aggregate shall be no lower than 35.

B. Coarse Aggregates Used for Aggregate Sub-Base and Base Courses

Coarse aggregate retained on the No.4 (4.75mm) sieve shall consist of durable particles of crushed stone, gravel, or slag capable of withstanding the effects of handling, spreading and compacting without degradation productive of deleterious fines. Of the particles which are retained on a 3/8 –in (9.5 mm) sieve, at least 75% shall have two or more fractured faces.

C. Types of Aggregate Sub-Base and Base Courses

The combined gradation including fine and coarse aggregates shall conform to the gradation for Sub-Base and Base Courses as indicated in the following Table. The continuous smooth gradation of materials used shall be kept within the specified gradation limits and gap grading must be avoided.

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

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

	Design Range (weight percentages passing)		**Job Mix Tolerances** (weight percentages passing)	
Sieve Size: (square openings)	Bases	Sub-bases	Bases	Sub-bases
2 in. (50mm)	100	100	-2	-3
1-1/2 in. (37.5mm)	95-100	90-100	± 5	+5
3/4 in. (19.0mm)	70-92	-	±8	-
3/8 in. (9.5mm)	50-70	-	±8	-
No.4 (4.75 mm)	35 - 55	30 - 60	±8	±10
No.30 (600 μm)	12-25	-	± 5	-
No.200 (75 μm)	0 - 8	0 - 12	± 3	± 5

3.04.03 CONSTRUCTION REQUIREMENTS FOR AGGREGATE SUB-BASE AND BASE COURSES

A. Finished Sub-grade Levels

Prior to commencing the construction of the sub-base and base courses, it is necessary to make sure that the sub-grade conforms to the specifications and is compacted to the maximum Dry Density as indicated in these specifications and that the surface thereof conforms to the levels and slopes indicated in the Drawings. In all cases the approval of the Engineer must be obtained before commencing spreading for the sub-base and bases courses.

B. Screening and Mixing of the Materials

Screening shall be required for the materials used in aggregate sub-base and base courses. Screens shall be of the size and number required to remove oversize aggregate and, if necessary, to separate the materials into two or more fractions so that they may be combined to meet the required gradation. When conveyor belt samples from the end of the screening and/or crushing-screening operation yield a product consistently within the specified gradation, no further mixing shall be required and the material may be loaded and hauled directly to the road. If stockpiled, it shall be stockpiled so as to prevent segregation.

Mixing of material can be achieved through the use of the central mixing plant or travel mixer. Where separate size materials are to be blended to meet the gradation, such blending shall be as directed by the Engineer and shall be accomplished prior to delivery to the roadway. Mixing of separate materials on the roadway by motor grader will not be permitted.

C. Spreading and Compacting

After carrying out the screening and mixing of aggregate material, samples of the approved material shall be taken in order to determine the optimum Moisture Content.

Material shall then be spread on the road surface to thicknesses that would result in layers not more than 250mm thick after compaction.

The natural moisture content of materials constituting the sub-base and base courses shall be determined. If the natural moisture content is less than the optimum moisture content, the necessary amount of water must be added to obtain the optimum content allowing for the quantity which may be lost by evaporation in the process of raking, levelling and compacting, depending on atmospheric temperature, quantity of material and the equipment and plant to be used in this operation, provided that the layer shall be compacted when the moisture content therein is within +/-2% of the optimum moisture content in order to obtain Maximum Dry Density and the moisture content is uniform in all parts of the section where the work is being carried out and in the various depths of the layer thickness.

Compaction shall start immediately thereafter, by means of pneumatic and steel rollers or vibratory rollers and in accordance with the instructions of the Engineer.

Compaction must start with rollers from extreme sides proceeding gradually toward the road axis. Rolling must continue until the in-situ dry density is not less than 100% of the Maximum Dry Density as determined by the Moisture-Density Relationship Test AASHTO T 180.

D. Multi-Layers

During all the above-mentioned operations of mixing, spreading, compacting and levelling of sub-base and base courses material, care must be taken so that layers already compacted under the layer being executed are not affected, or that the finished sub-grade or base surface is also not affected. This aspect must be given special attention in places where equipment makes turns in going back and forth and any such damage resulting in mixing the various layers constituting the different sub-grades and base courses shall be carefully made good by the Contractor at his own expense and to the satisfaction of the Engineer.

If more than one sub-base or base course is required for reaching the required thickness described in the Specifications, each such course will be constructed as hereinbefore described.

Where the finished compacted thickness indicated on the drawings exceeds 200 mm, placing shall be executed in composite layers each layer not exceeding 250 mm in compacted thickness as directed by the Engineer.

E. Protection of Surface

The Contractor shall protect the sub-base or base course so that it shall be maintained sound during work progress, after its completion and prior to receiving the bituminous layers or prior to laying the surface overlay thereon. Any damage caused to the layer if exposed to

traffic or natural conditions resulting in damage to its surface shall be made good at the expense of the Contractor and to the satisfaction of the Engineer.
When the rolling develops irregularities, the irregular surface shall be loosened, then refilled with the same kind of material as used in constructing the course and again rolled according to specifications. Along places inaccessible to rollers, the sub-base and base courses' material shall be tamped thoroughly with mechanical tampers.

Work on the sub-base and base courses shall not be permitted during rainy weather.

Hauling equipment may be routed over the completed portion of the sub-base and base courses provided no damage results and provided that such equipment is routed over the full width of the course to avoid rutting or uneven compaction.

The Engineer has the right to stop all hauling over completed or partially completed sub-base and base courses when in his opinion such hauling is causing damage.

F. Preparing the Surface Before Priming

Following the completion of the courses the Contractor shall perform all maintenance work necessary to keep the course in a condition for priming. The prime coat shall be applied after preparation of the previously compacted surface, all in accordance with these Specifications.

G. Testing and Acceptance of Aggregate Sub-Base and Base Courses

Prior to the application of any prime coat or any other paving course, the aggregate sub-base and/or base course shall have been tested and accepted by the Engineer. The following shall be adhered to in accepting completed aggregate sub-base and base courses:

a. Strength Specification for Compacted Aggregate Sub-Base and base courses - The aggregate sub-base and base courses shall be compacted and tested for acceptance in accordance with the compaction requirements of these Specifications.

b. Requirements for Compaction - Wherever the degree of compaction is found to be less than the 100% specified, the area of sub-base or base course involved shall be satisfactorily corrected so that the specified density is achieved.

c. Requirements for Gradation - Wherever the gradation is found to be outside the limits specified, the area of sub-base and/or base course involved shall be scarified, removed or otherwise reworked as directed by the Engineer to provide a material within specification limit.

d. Requirements for Thickness - Wherever the thickness of compacted aggregate sub-base or base courses is found to vary from the plan thickness by more than 10% the area involved shall be satisfactorily corrected to provide the required thickness constructed to the specified grade level.

e. Requirements for Evenness of Surface and Grade Level - The final surfaces of the sub-base or base course shall be tested by means of a 4 metre long straight edge and no rises or depressions in excess of 10mm shall appear in the surface. Likewise the finished surface shall be constructed to the specified grade levels to within 10mm.

Where these requirements are not met, the Contractor shall determine the full extent of the area which is out of tolerance and shall make good the surface of the course by scarifying to a minimum depth of 75mm or 4 times the maximum particle size, whichever is the greater, reshaping by adding or removing material as necessary and recompacting in accordance with the specifications.

3.04.04 MEASUREMENT

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary works to different payment items.

**** END OF SECTION ****

DIVISION 4

BITUMINOUS CONSTRUCTION

TABLE OF CONTENTS

The following standards and codes in their latest edition shall be particularly applied to works covered by this section.

ASTM

C 88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate
C 127	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
C 128	Standard Test Method for Density, Relative Dens`ity (Specific Gravity), and Absorption of Fine Aggregate
C 131	Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 183	Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 207	Standard Specification for Hydrated Lime for Masonry Purposes
D 5	Standard Test Method for Penetration of Bituminous Materials
D 36	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)
D 75	Standard Practice for Sampling Aggregates
D 92	Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D 113	Standard Test Method for Ductility of Bituminous Materials
D 140	Standard Practice for Sampling Bituminous Materials
D 242	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
D 402	Standard Test Method for Distillation of Cutback Asphaltic (Bituminous) Products
D423	Method of Test for Liquid Limit of Soils
D424	Standard Method of Test for Plastic Limit
D692	Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures
D946	Standard Specification for Penetration Graded Asphalt Cement for Use in Pavement Construction
D 1075	Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures
D 2026	Standard Specification for Cutback Asphalt (Slow-Curing Type)
D 2042	Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene
D 2170	Standard Test Method for Kinematic Viscosity of Asphalts
D 2171	Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer
D 2172	Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
D 2399	Standard Practice for Selection of Cutback Asphalts
D 2419	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate
D 3143	Standard Test Method for Flash Point of Cutback Asphalt with Tag Open-Cup Apparatus
D 3625	Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water
D 4318	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of

	Soils
D 4402	Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
D 5821	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
D 6926	Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus
D 6927	Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures

AASTHO

M 17	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
M 20	Standard Specification for Penetration-Graded Asphalt Cement
M 81	Standard Specification for Cutback Asphalt (Rapid-Curing Type)
M 82	Standard Specification for Cutback Asphalt (Medium-Curing Type)
M 85	Standard Specification for Portland Cement
M 140	Standard Specification for Emulsified Asphalt
M 156	Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
M 208	Standard Specification for Cationic Emulsified Asphalt
M 316	Standard Specification for Polymer-Modified Emulsified Asphalt
M 320	Standard Specification for Performance-Graded Asphalt Binder
M 332	Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
MP 2	Standard Specification for Superpave Volumetric Mix Design
R 28	Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
T 11	Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
T 27	Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates
T 30	Standard Method of Test for Mechanical Analysis of Extracted Aggregate
T 40	Standard Method of Test for Sampling Bituminous Materials
T 44	Standard Method of Test for Solubility of Bituminous Materials
T 48	Standard Method of Test for Flash Point of Asphalt Binder by Cleveland Open Cup
T 96	Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T 104	Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
T 112	Standard Method of Test for Clay Lumps and Friable Particles in Aggregate
T 113	Standard Method of Test for Lightweight Pieces in Aggregate
T 164	Standard Method of Test for Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
T 166	Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
T 182	Standard Method of Test for Coating and Stripping of Bitumen-Aggregate

	Mixtures
T 194	Standard Method of Test for Determination of Organic Matter in Soils by Wet Combustion
T 240	Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
T 245	Standard Method of Test for Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
T 278	Standard Method of Test for Surface Frictional Properties Using the British Pendulum Tester
T 279	Standard Method of Test for Accelerated Polishing of Aggregates Using the British Wheel
T 302	Standard Method of Test for Polymer Content of PolymerModified Emulsified Asphalt Residue and Asphalt Binders
T 304	Standard Method of Test for Uncompacted Void Content of Fine Aggregate
T 313	Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
T 314	Standard Method of Test for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
T 315	Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
T 316	Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer

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 these Specifications - 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 these Specifications - Samples and Approval 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.

401.03 AGGREGATES FOR BITUMINOUS PAVING MIXES

A. General

A.1 Aggregates for use in bituminous base course, leveling course, macadam and cold mix courses shall consist of crushed rock or crushed gravel. Aggregates for use in wearing courses shall consist of 100% crushed rock.

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**
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
Soundness Using Magnesium Sulphate (5 cycles)	ASTM C88	18% maximum, 14% maximum on sites over 1000m above sea level
Degradation (Loss by abrasion)	ASTM C131	30% maximum
Water Absorption	ASTM C127	2% maximum

TEST	STANDARD	LIMIT
Resistance to Stipping	ASTM D3625/3625M	95% minimum
Flakiness and Elongation (5:1 aspect ratio)	ASTM D4791	10% maximum
OR Flakiness Index	BS EN933-3	25% maximum
Polish Stone Value	AASHTO T278 & T279	40 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	2.5% 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 4.1.1.

Table 4.1.1: 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^{o}C to +60^{o}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^{o}C above the maximum application temperature specified nor above 170^{o}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 1^{o}C 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 these specifications: Samples and Approvals.

4.01.06 BITUMEN PRODUCTS

A. Penetration Graded Bitumen

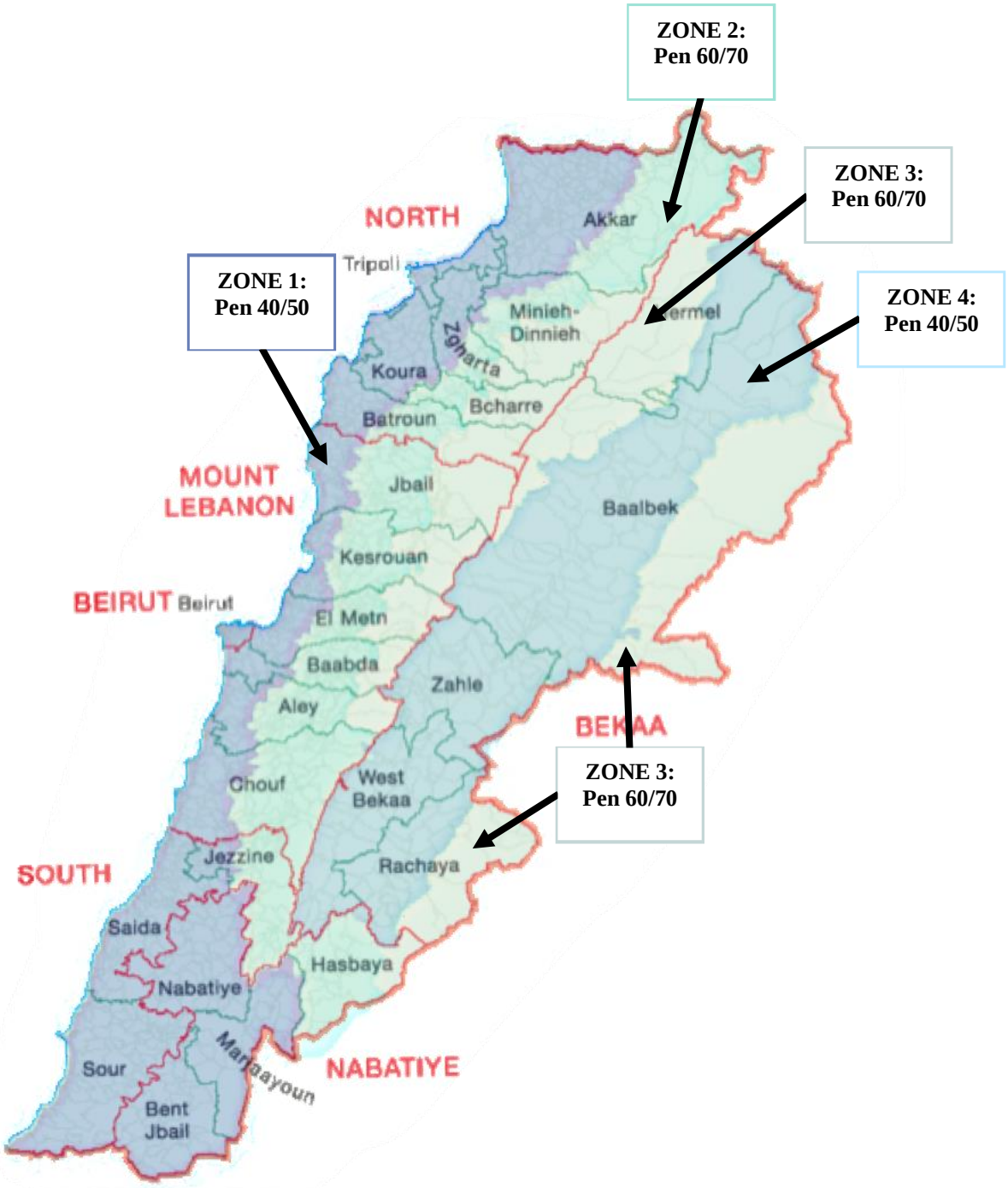
A.1 The binder type shall be classified according to ASTM D946/D946M, as shown in Table 4.1.2.

TABLE 4.1.2: 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.

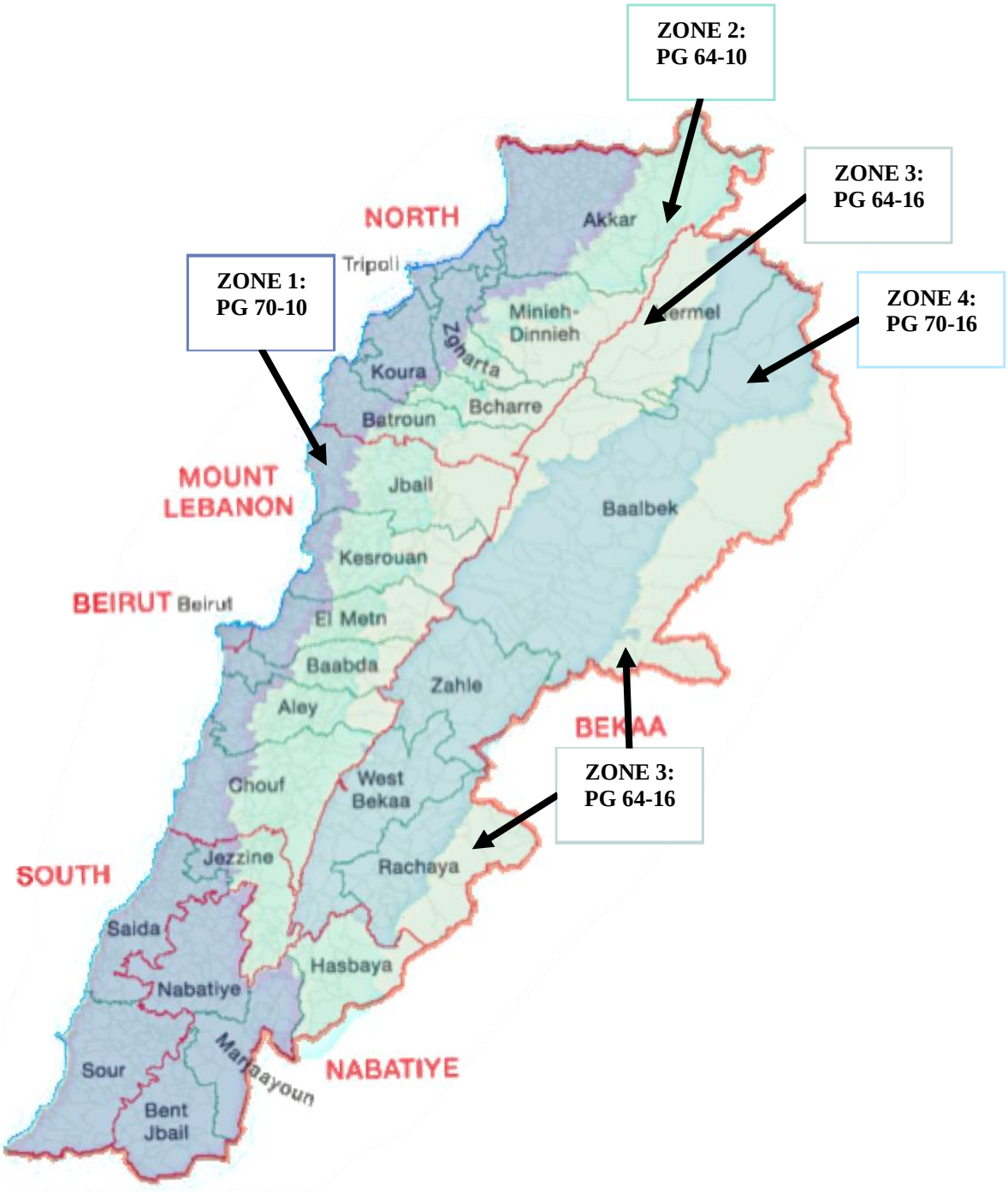
A.3 The binder penetration grade shall conform to the following grading map of Lebanon:


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
Akkar
Tripoli
Minieh-
Dinnieh
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
Sour
NABATIYE
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 4.1.3.

TABLE 4.1.3: 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 4.1.4.

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 ^{o}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 4.1.5.

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 ºC**
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 4.1.6.

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 ºC**
SC – 70	45 - 80
SC -250	70 - 110
SC - 800	95 - 125
SC - 3000	110 – 145

TABLE 4.1.4: 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 4.1.5: 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 4.1.6: 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 4.1.7.

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^{o}C, except for Grade RS-2 where the range shall be 50-75^{o}C. The temperature range for pugmill mixing for medium and slow setting types shall be 15-65^{o}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 4.1.8.

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 ^{o}C (except for Grade CRS-2 where the range shall be 50-75 ^{o}C). The temperature ranges for pugmill mixing for medium and slow setting types shall be 15-65 ^{o}C.

TABLE 4.1.7: 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 4.1.8: 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		

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, highway shoulders, or concrete pavement; and furnishing and applying RC cutback bitumen or emulsified bitumen as a tack coat to a previously constructed bituminous base or wearing 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 these Specifications - 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^{o}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.

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
Bridge wearing surfaces, concrete pavements:	0.3 - 0.6
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^{o}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

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary works to different payment items.

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 various bituminous concrete and other bituminous mixes including the installation of reinforcing fabric when specified, all as and where shown on the Drawings.

B. Requirements with particular application to bituminous base courses, wearing courses, leveling courses, macadam courses, cold mix courses and recycled bituminous base course, are specified in the respective sections relating to such courses.

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 for NMAS 12.5 or 19mm, and 7 to 10 cm thick layers for NMAS 25mm.

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 Wearing Course**			**Bituminous Base Course**		
Traffic Volume*	**Low (< 1M ESAL)**	**Medium (1-5M ESAL)**	**High (>5M ESAL)**	**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	75	75	75
Stability (kg), minimum	1000	1100	1200	800	900	1000
Marshall Flow (mm)	2 – 3.5	2 – 3.5	2 – 3.5	2 – 3.5	2 – 3.5	2 – 3.5
Stiffness (kg/mm), minimum	450	450	550	400	400	500
% Air Voids	3 – 5	4 – 6	4 – 6	4 – 6	4 – 7	4 – 7
% Voids in Mineral Aggregate (VMA)	Minimum 13 (19mm NMAS) Minimum 14 (12.5mm NMAS)			Minimum 12 (25 mm NMAS) Minimum 13 (19mm NMAS)		
% Voids Filled with Asphalt (VFA)	60 – 75	55 – 70	50 – 65	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	25	25	25	30	30	30
% Air Voids at Refusal, minimum	2	2	2	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	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
Million	$N_{initial}$	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 170^{o}C.

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 of the Engineer 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.

4.03.06 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 ^{o}C. If any aggregates contain excess moisture that may cause foaming in the mixture or their temperature is in excess of 170 ^{o}C, 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^{o}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)

4.03.07 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.

4.03.08 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^{o}C below the discharge temperature at the mixing plant. The minimum temperature for the commencement of compaction is 130^{o}C. Mix loads with temperatures less than 130^{o}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^{o}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.

4.03.09 SAMPLING AND TESTING

A. Sampling and testing shall conform to the relevant requirements of these Specifications - 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- Stability 9- Flow	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.

4.03.10 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 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 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.

4.03.11 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. After completion of the final (wearing) course any deficiencies in the thickness of any course which have not been compensated for by increasing the thickness of a subsequent course, shall be considered as deficiencies in the final (wearing) 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.

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. Any deficiencies in the total thickness of bituminous courses shall be subject to a proportional reduction in the final measurements for payment. Alternatively, the Contractor shall construct, at his own expense, a wearing course overlay if practicable in the judgement of the Engineer. Any such overlay shall be a minimum of 40 mm compacted thickness and to the specified standard of the course it is overlaying.

I. 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.

4.03.12 MEASUREMENT

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary works to different payment 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

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary works to different payment items.

SECTION 4.05. BITUMINOUS WEARING COURSE

4.05.01 SCOPE

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

B. Bituminous wearing course material consists of a surface course composed of mineral aggregate, filler and bituminous material mixed in a central mixing plant and placed on a prepared lower asphalt or road base course in accordance with these Specifications and conforming to the lines, grades, thicknesses and typical cross sections shown on the Drawings or as indicated by the Engineer.

4.05.02 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, the bitumen grade for wearing course construction shall be in accordance with the penetration or PG grading map of Lebanon in Section 4.03.03.

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.

4.05.03 JOB MIX AND PROJECT MIX

Wearing course job mixes shall be formulated in accordance with the relevant requirements of Section 4.03 - Bituminous Courses and the following:

A. Air Voids Analysis

A.1 The design range of air voids (Section 4.03.03) shall be the level desired after several years of traffic.

A.2 The laboratory compactive effort shall be selected for the expected traffic demand.

A.3 The overall objective shall be to limit adjustments of the design asphalt content to less than 0.5 percent air voids from the median of the design criteria in Section 4.03.03.

B. Mix Design

B.1 The bituminous mixture shall be designed with the procedures and requirements of Section 4.03 - Bituminous Courses.

B.2 The Contractor shall prepare a series of test specimens with a range of different binder contents so that the test data show a well-defined curve. Tests shall be scheduled on the basis of 0.5% increments of binder content, with at least two binder contents above optimum and at least two below optimum.

B.3 Triplicate test specimens shall be prepared for each binder content mix to be tested.

B.4 Bitumen content shall be calculated by weight of total mixture.

B.5 The compacted thickness of any layer shall be at least twice the nominal maximum aggregate size for wearing course unless otherwise directed by the Engineer.

B.8 The gradations in Section 4.03.03 represent the limits which shall determine the suitability of aggregate for use from the sources of supply. The selection of any of the gradations shall be such that the maximum size aggregate used shall not be more than one-half of the thickness of the layer of the course being constructed. The maximum aggregate size that shall be used in surface course is 25mm unless otherwise directed by the Engineer.

B.9 The aggregate shall have a gradation within the limits designated in Section 4.03.03 and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa, but shall be uniformly graded from coarse to fine.

B.10 The job mix tolerances shall be specified in Section 4.03.04 and shall be applied to the Job Mix Formula to establish a job control grading band.

B.11 The aggregate gradation may be adjusted within the limits designated in Section 4.03.03 without adjustments to the Contract unit prices.

B.12 Should a change in source of materials be made, a new Job Mix Formula shall be established before the new material is used. Deviation from the final approved design for bitumen content and gradation of aggregates shall not be greater than the tolerances permitted and tests for bitumen content and aggregate gradation shall be made at least twice daily. The mixture shall be tested for bitumen content in accordance with ASTM D 2172 and for aggregate gradation in accordance with ASTM C 136.

B.13 If the index of retained strength of the specimens of composite mixture, as determined by ASTM D 1075, is less than 75 the aggregates shall be rejected or the asphalt shall be treated with an approved anti-stripping agent. The amount of anti-stripping agent added to the asphalt shall be sufficient to produce an index of retained strength of not less than 75.

4.05.04 EQUIPMENT

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

4.05.05 CONSTRUCTION OF TRIAL SECTIONS

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

4.05.06 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.

4.05.07 SURFACE PREPARATION

Preparation of the surface upon which the bituminous wearing course mix is to be laid and the use of prime and tack coats shall be appropriate to the type and condition of such surfaces and shall conform with the relevant requirements of Section 4.03 - Bituminous Courses.

4.05.08 DELIVERY, SPREADING AND FINISHING

A. General

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

B. Rollers

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

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

B.3 Final rolling shall be carried out by use of two, 2-axle tandem steel-tired rollers each of minimum weight 10,000 kg, capable of exerting contact pressures of up to 650 kN/m^2.

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

C. Standard of Compaction

The compacted density of the bituminous wearing course shall be 97.5% of the average Bulk Density for each day's production.

4.05.09 SAMPLING AND TESTING

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

4.05.10 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 final bituminous wearing course surface shall not be greater than ± 6mm.

C. When the finished wearing course surface is tested with a 3m 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 6 mm.

D. The combination of the permitted tolerances in the levels of the different pavement layers, excluding aggregate base course, shall not result in a reduction of thickness by more than 10mm from the specified thickness shown on the Drawings or a reduction in the final wearing course thickness by more than 5mm from that specified or shown on the Drawings.

4.05.11 DETERMINATION OF THICKNESS

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

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

4.05.12 MEASUREMENT

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary works to different payment items.

SECTION 4.06. BITUMINOUS SEAL COATS AND SURFACE DRESSINGS

4.06.01 SCOPE

A. The work covered in this section consists of the furnishing of materials for one or more applications of cutback bitumen and stone aggregate material or a single application of emulsified bitumen or spreading emulsified bitumen slurry to a previously prepared base or wearing course surface as and where shown on the Drawings.

B. Bituminous Slurry Seal Coat (**BSSC**) shall consist of spreading and screeding a mixture of emulsified bitumen, sand, aggregate and water.

C. Single Bituminous Surface Dressing (**SBSD**) shall consist of a single application of cutback or straight run bitumen and stone or sand aggregate as specified.

D. Double Bituminous Surface Dressing (**DBSD**) shall consist of an application of cutback or straight run bitumen and (coarse graded) aggregate followed not less than 5 days later by a second application of cutback or straight run bitumen and (medium graded) aggregate as specified.

4.06.02 MATERIALS

A. Bitumen

A.1 Bitumen for SBSD and DBSD applications shall be Rapid-Curing RC-800 Grade conforming to the relevant requirements of Section 4.01 - Materials for Bituminous Construction and AASHTO M-81.

A.2 Bitumen for BSSC (slurry) applications shall be cationic slow setting emulsified bitumen Grade CSS-1 or CSS-1h conforming to the relevant requirements of Section 4.01 - Materials for Bituminous Construction.

B. Aggregates

B.1 Surface dressing aggregates 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 fines. For heavy duty applications slurry aggregate shall consist of 100% crushed fines.

B.2 The properties of cover and slurry seal aggregates and their gradations shall be in accordance with the relevant requirements of Section 4.01 - Materials for Bituminous Construction.

4.06.03 EQUIPMENT

All plant and equipment used for pugmill mixing of slurry mixes, heating and spraying of cutback and emulsified bitumen, spreading, rolling and brooming of cover aggregate and applying and spreading slurry seals shall conform with the requirements of these Specifications - Contractor's Plant and Equipment.

4.06.04 CONSTRUCTION OF TRIAL SECTIONS

A. Before commencement of site seal coat applications, the Contractor shall construct trial sections using varying application rates for bitumen and for aggregates, as selected by the Engineer. Each trial section shall be 2 lanes wide by 50 metres long at locations approved by the Engineer on or close to the Site.

B. Each trial section shall be constructed using the same materials, mixing, spraying, spreading, rolling and brooming equipment and construction procedures proposed for use in the Works. Trial sections for slurry seals shall be along existing bituminous pavements in the vicinity of the Site.

C. The objectives of these trials shall be to determine the adequacy of the Contractor's equipment, the most suitable application rates for cutback bitumen, emulsified bitumen and the various gradations of aggregate and the most suitable consistency of slurry seal to fill cracks and leave a residual coating of 3 mm over the entire bituminous wearing surface.

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

4.06.05 RATES OF APPLICATION

A. Application rates for cutback and emulsified bitumen and for aggregates shall be determined by the Engineer from the trial sections and shall be generally within the ranges given in Table 4.6.1.

Table 4.6.1: TYPICAL SEAL COAT APPLICATION RATES

Types of Seal Coat	**Rate of Application**	
	Aggregate (Kg/m^2)	**Binder (Kg/m^2)**
Coarse aggregate seal coat	12.5- 20.0	1 .00- 1.80
Medium aggregate seal coat	10.0-15.0	0.90- 1.80
Slurry seal	Between 5-6 Kg/m^2 for the mix	

B. The Engineer reserves the right to order additional trial sections and alter the previously established rates of application during progress of the Works.

4.06.06 CONSTRUCTION

A. General

A.1 Applications of bitumen and aggregate and subsequent rolling shall be completed between sunrise and sunset and under favourable weather conditions as determined by the Engineer. The atmospheric temperature shall be above 15 ^{o}C and the weather shall not be foggy, rainy, dusty or unduly windy.

A.2 Where the seal coat is to carry traffic prior to final sweeping, appropriate signs shall be erected to control the speed of traffic.

A.3 When bituminous coatings are applied to sections of road which are to be promptly opened to traffic and the ambient temperature is contributing to slow curing and excessive pickup, the Contractor shall suspend operations until the Engineer approves continuation of sealing works.

A.4 The surface to be treated shall be dry or slightly damp and the moisture content of aggregates at the time of application to the coated surface shall not exceed 3% by weight.

A.5 Unless otherwise directed by the Engineer, the minimum time interval between successive seal coats, in DBSD applications, shall be 5 days.

B. Surface Preparation

B.1 Granular surfaces shall be primed in accordance with the requirements of Section 4.02 - Bituminous Prime and Tack Coats prior to construction of the surface treatment. If there are delays in scheduling the seal coating resulting in deterioration of the surface, the Engineer shall inspect the affected area and order appropriate repairs or corrective treatment prior to the commencement of the seal coat application.

B.2 When coatings are applied to existing pavement surfaces, all pavement repairs shown on the Drawings or instructed by the Engineer shall first be completed. Where applicable, the positions of traffic markings shall be surveyed and recorded to enable their accurate replacement after the seal coats have been applied.

B.3 Immediately before applying any bituminous material, all dirt, dust and other objectionable material shall be removed from the surface and cracks shall be repaired or sealed as directed by the Engineer. If required, the surface shall be slightly dampened with a light application of water immediately prior to the application of bitumen.

B.4 Surfaces to be slurry sealed shall be lightly sprayed immediately prior to spreading the slurry with a slow-curing 3:1 water: emulsion mixture applied at the rate of 0.4 - 0.8 Kg/ m^2

C. Heating of Bitumen

The temperature of cutback bitumen and of emulsified bitumen at the time of application shall be as specified in Section 4.01 - Materials for Bituminous Construction.

D. Spreading Slurry Seal

D.1 Spreading of slurry seals shall be by a spreader box approved by the Engineer, capable of spreading over at least one traffic lane width. It shall have flexible rubber strips fastened on each side

to prevent loss of slurry and shall have baffles incorporated into the box to ensure a uniform application. A rear flexible, adjustable strike-off blade shall also be provided.

D.2 Areas inaccessible to the slurry spreader box shall be slurry scaled using hand or other methods approved by the Engineer.

D.3 The slurry seal coat shall be uniform and homogeneous after spreading and shall not show signs of separation of the emulsion and aggregate after setting.

E. Spraying of Bitumen

E.1 The cutback or emulsified bitumen for seal coats shall be applied by means of a pressure distributor uniformly and continuously over the section to be treated. The rate of application shall be as shown on the Drawings or as designated by the Engineer.

E.2 A strip of building paper or heavy polyethylene sheeting, at least one metre in width and with a length equal to that of the spray bar of the distributor plus 300 mm shall be used at the beginning of each application. If the cut-off is not positive, the paper shall be used at the end of each spread. The paper shall be removed and disposed of after use. The distributor shall move forward at the correct application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected immediately as directed by the Engineer.

E.3 The length of spray run shall not exceed that which can be covered by the aggregate spreading equipment.

E.4 The application width of bitumen shall be not more than 150 mm wider than the width covered by the aggregate spreader. Operations shall not proceed if the bitumen is allowed to chill, dry or otherwise impair retention of the aggregate.

E.5 The Contractor shall keep a complete record of bitumen used based on distributor tank measurements and on areas to which the bitumen has been applied. These records shall be submitted to the Engineer as verification of the accuracy of the tachometer and application rates designated by the Engineer.

E.6 Distribution of bitumen shall be regulated and sufficient material left in the distributor at the end of each application to ensure a uniform distribution across the spray bar. The distributor shall not expel air with the bitumen causing uneven coverage.

E.7 The angle of the spray nozzles and the height of the spray bar shall be adjusted and regularly checked to ensure uniform distribution. The height of the spray bar above the pavement surface should remain constant throughout the spraying process. Distribution shall cease immediately upon any clogging or partial blocking of any nozzle and corrective measures shall be taken before application is resumed.

F. Application of Aggregate

F.1 If directed by the Engineer, aggregates shall be washed prior to use in order to eliminate or reduce any dust coatings or salts before delivery to the spreader.

F.2 Operation of the aggregate spreader at speeds which cause the particles to roll over after striking the bitumen covered surface shall not be permitted.

F.3 Immediately upon application of bitumen, aggregate of the required gradation shall be spread at the rate designated by the Engineer. Spreading shall be accomplished in such a manner that the tyres of the hauling unit or aggregate spreader do not come into contact with the uncovered bitumen surface.

F.4 Where adjacent applications are to be made, the first aggregate application shall not extend closer than 150 mm to the edge of the applied bitumen. The adjacent application of bitumen shall overlap this 150 mm and complete aggregate coverage shall be achieved with the second application.

F.5 Immediately after the aggregate has been applied, deficient areas shall be covered by additional aggregate. Piles, ridges or uneven distributions of aggregate shall be removed and corrected to avoid permanent ridges, bumps or depressions in the completed surface. Additional aggregate shall be carefully spread to prevent pick-up by rollers or traffic; after which the surface shall be rolled as directed by the Engineer.

F.6 The Contractor shall take measures to prevent aggregate from entering ditches or inlets of any type. The Contractor shall be responsible for removal of any such aggregate materials and other accumulated debris arising out of his operations.

G. Rolling and Brooming

G.1 Aggregate shall not be spread more than 150 metres ahead of initial rolling operations.

G.2 Rollers shall not stop, start or turn on the surface being rolled. Any damage to the surface arising out of non-compliance with this requirement shall be made good as directed by the Engineer and at the Contractor's expense.

G.3 Initial breakdown rolling shall proceed behind the spreader (after any adjustments by hand methods to correct for uneven distribution). One complete coverage shall be achieved using 2-axle self-propelled steel-wheeled rollers of 6-8 tons weight and operating at a maximum speed of 5 km/h. Initial rolling shall be completed within 30 minutes of spreading aggregate.

G.4 The Engineer shall order the use of pneumatic-tyred rollers for initial rolling if the achievement of adequate embedment of the aggregate is liable to result in excessive crushing when steel-wheeled rollers are used.

G.5 Immediately following completion of the initial rolling, the surface shall be rolled using self-propelled pneumatic-tyred rollers operated at a maximum speed of 8 Km/h, until at least 3 complete coverages have been achieved.

G.6 If necessary during rolling operations, additional screenings shall be lightly spread by hand methods and re-rolled to make good any small areas visibly deficient in cover material.

G.7 Light drag brooming of the surface shall be carried out 24 hours after completion of rolling to embed aggregate particles. Brooming shall result in a uniform distribution of loose screenings over the surface which shall then be re-rolled using pneumatic-tyred rollers until at least 2 complete coverages have been achieved.

G.8 Light drag brooming and re-rolling shall be repeated 24 hours after the initial brooming, if so directed by the Engineer.

G.9 Excess (surplus) screenings shall be collected and stockpiled or disposed of as directed by the Engineer.

H. Maintenance and Protection of Sealed Surfaces

H.1 BSSC shall be protected from traffic until such time as, in the opinion of the Engineer, the coatings have cured sufficiently and will not be damaged by, adhere to or be picked up by the tyres of vehicles.

H.2 Each coat of SBSD and DBSD shall be maintained and protected from excess traffic speeds for at least 3 days after completion of rolling.

H.3 At the end of the 3-day maintenance period for each seal coat, or earlier if directed by the Engineer, the surface shall be finally swept using a rotary broom to remove loose screenings. Surplus screenings shall be stockpiled or disposed of as directed by the Engineer.

H.4 Adequate traffic control (including speed control measures) shall be taken during the construction of bituminous seal coats and surface dressings.

4.06.07 TOLERANCES AND RECORDS

A. The Contractor shall be responsible for the accurate calibration of pressure distributors and for the correct rates of application of bitumen as designated by the Engineer.

B. Readings shall be taken of the volume and temperature of each bitumen tanker load and temperature immediately prior to and immediately upon completion of each spraying run and the actual application rate in kg/m^2 shall be calculated. Complete records shall be maintained of all such measurements and the specific location, width and length of each the respective run.

C. The tolerances on temperature adjusted application rates of cutback bitumen shall be plus or minus 5% of the designated rate.

D. Applications of cutback bitumen varying by more than 5% but less than 10%, after temperature adjustment, below the specified rate of application shall, if the work is accepted by the Engineer, be subject to a 10% reduction in quantity or area measurements as appropriate.

E. Applications of cutback bitumen varying after temperature adjustment by more than 5% but less than 10% above the specified rate of application shall, if the work is accepted by the Engineer, be measured on the basis of the designated application rate.

F. Applications of cutback bitumen varying by more than 10%, after temperature adjustment, above or below the specified rate of application shall be rejected and the unsatisfactory material replaced or made good as directed by the Engineer, at the Contractor's expense.

G. The Contractor shall maintain on a daily basis complete records of the volumes and tonnages of each type of aggregate delivered to the Site and used in each section of the Works for seal coat and surface dressing applications.

H. All records and calculations of bitumen applications and aggregate delivery and use shall be submitted to the Engineer at the end of each day when seal coat and surface dressing applications have been carried out. No measurements will be accepted of bitumen applications which are not supported by adequate, verifiable records.

SECTION 4.07. BITUMINOUS LEVELLING COURSE

4.07.01 SCOPE

The work covered in this section consists of furnishing materials, mixing at a central mixing plant, spreading and compacting bituminous wearing course on an existing pavement surface as and where shown on the Drawings or as directed by the Engineer.

4.07.02 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, materials shall also conform to the requirements of Section 4.05 - Bituminous Wearing Course.

4.07.03 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 and Section 4.05 - Bituminous Wearing Course.

B. The Job Mix for bituminous levelling courses shall conform to the requirements of Section 4.05 - Bituminous Wearing Course.

4.07.04 EQUIPMENT

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

4.07.05 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.

4.07.06 SURFACE PREPARATION

A. Damaged pavement surfaces shall be repaired by patching prior to receiving the bituminous levelling course in accordance with the relevant requirements of Section 4.08: Pavement Repairs, Trench Excavation and Reinstatement Works. The nature and extent of patching shall be as shown on the Drawings or as directed by the Engineer.

B. In areas where levelling courses are required, either as shown on the Drawings or as directed by the Engineer, the Contractor shall take cross sections of the existing pavement after completing any patching. The cross sections shall be taken at intervals of 10 metres or as directed by the Engineer. When the survey has been approved, the Engineer shall determine and inform the Contractor of the locations, grades and thicknesses of levelling courses required to obtain the desired surface.

C. Prior to placing leveling courses the existing pavement surface shall be prepared in accordance with the relevant requirements of Section 4.03 - Bituminous Courses, including the use of prime and tack coats as appropriate.

4.07.07 DELIVERY, SPREADING AND FINISHING

A. The delivery, spreading and finishing of levelling courses, including compaction, shall conform to the relevant requirements of Section 4.05 - Bituminous Wearing Course.

B. In areas where a specific grade and superelevation are to be achieved by the levelling courses, setting out and level control shall be based on a reference line installed in accordance with the relevant requirements of Section 4.03 - Bituminous Courses. In areas of minor levelling such as filling of potholes or small isolated areas, a mobile reference line or alternative control system may be approved by the Engineer.

4.07.08 SAMPLING AND TESTING

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

B. Where sampling and testing are not feasible due to thickness or other constraints, the Engineer shall determine specification compliance based on an approved rolling pattern or another method.

4.07.09 SURFACE TOLERANCES

Surface Tolerances for levelling courses shall conform to the relevant requirements for Binder Courses in Section 4.04 - Bituminous Base Course.

4.07.10 DETERMINATION OF THICKNESS

The Engineer shall use thickness measurements, spread rates, cross section or other methods as appropriate to verify quantities placed. Thickness measurements shall be in accordance with the relevant requirements of Section 4.03 - Bituminous Courses.

SECTION 4.08. PAVEMENT REPAIR WORKS, PATCHING, CRACK SEALING, TRENCH EXCAVATION AND REINSTATEMENT WORKS

4.08.01 SCOPE

A. The work covered in this section consists of repairs to damaged or defective pavement and the excavation and reinstatement of road openings on existing highways, streets and footpaths as and where shown on the Drawings or as directed by the Engineer.

B. Repairs to existing pavement include:

- Pothole repairs and patching
- Crack sealing
- Removal and replacement of defective pavement layers

C. Road openings include: -

- The breaking up or opening up of a street or other highway for the purpose of: -

  i). Laying, repairing, adjusting, altering or removing any utility or apparatus, or

  ii). Examining subsoil conditions or any existing utility or apparatus:

- Any work which is preparatory or incidental to any works referred to in the paragraphs above, such as the temporary storage of deposition of any building materials, debris, temporary foundation or the placing of any equipment.

4.08.02 MATERIALS

A. All pavement materials shall conform to the relevant requirements of Section III - Sub-Base and Base Courses and Section 4.01 –Materials for Bituminous Construction.

B. Restorations of asphalts including Bituminous Leveling Course, Bituminous Seal Coats, Pavement Repairs, Trench Reinstatement Works and Placing and Finishing of Repair Materials if not specified hereafter, shall confirm with the applicable requirements of these Specifications.

4.08.03 EQUIPMENT

All plant and equipment shall conform to the relevant requirements of these Specifications - Contractor's Plant and Equipment.

4.08.04 GENERAL REQUIREMENTS

A. Full Time Site Supervisor

The Contractor shall nominate from his site staff a full – time site supervisor responsible for road openings and reinstatement works, who shall be contactable by the Engineer and all other affected parties at all times during the period of the reinstatement works including the duration of traffic management. The supervisor shall be capable of responding to any emergency or other situation that arises as a consequence of the rehabilitation and reinstatement work and shall be the Contractor's first point of contact on safety issues arising out of these works.

B. Position, Extent and Protection of Excavation

The Contractor shall take the following into account when preparing method statements for road openings:

- The extent of road opening at any one time shall not exceed 60 metres in length
- The occupation of a carriageway for road opening shall be restricted to one traffic lane width.
- Measures to protect the nearby road surface, existing structures, apparatus and road- related facilities during the course of the road opening and reinstatement work
- A maximum of two trial holes shall be permitted at any one time. No additional trial holes shall be opened until the existing trial holes are properly reinstated to the satisfaction of the Engineer.
- The road surface shall be protected from damage from construction vehicles. Any damage to the surrounding road surface shall be made good to the satisfaction of the Engineer at the Contractor's expense

4.08.05 PREPARATION OF PAVEMENT

A. Cracks in bituminous pavement which, in the opinion of the Engineer, do not require reconstruction shall be prepared by wire brushing and blowing out with compressed air.

B. Defective bituminous pavement which, in the opinion of the Engineer, requires reconstruction shall be cut back to good material using pneumatic cutting tools. The cut edges shall be square or rectangular and in line with the direction of traffic. The depth of cut shall be determined by the Engineer and may include asphalt layers, base and sub – base layers and subgrade layers (in the case of failed pavement, excavation shall include a minimum of 300 mm of subgrade material). All excavated materials shall be removed and disposed of off site. When the bottom of the excavation consists of earth or granular material, it shall be thoroughly compacted using mechanical compactors to the satisfaction of the Engineer. Excavated bituminous surfaces shall be thoroughly cleaned and wire brushed prior to receiving repair materials.

The individual pavement layers shall be cut back to produce steps of a minimum of 200 mm wide between layers of the existing pavement.

Directly before the reinstatement of the aggregate base course, the existing asphalt layer shall be saw cut to additional 500 mm from both sides of the edges the trench. The additional cuts and trench width shall not be less than 2 meters wide in order to allow heavy compactor to operate efficiently unless otherwise directed by the Engineer.

The faces of the layers shall be cut straight and vertical and shall be wire-broomed and painted with bituminous emulsion immediately prior to laying the replacement asphaltic courses.

Asphaltic courses shall be laid in thickness to match the existing pavement layers as specified in this Section or as otherwise directed by the Engineer.

The top asphaltic layer shall be finished level and smooth with the existing pavement. The road shall not be opened to traffic before all backfilling and replacement of asphalt courses have been completed and approved in writing by the Engineer.

C. Utility trench reinstatements in bituminous pavements shall be prepared in the same way as defective bituminous pavement. Excavation shall include a minimum of 300 mm of subgrade material.

4.08.06 PLACING AND FINISHING REPAIR MATERIALS

A. Cracks less than 3 mm wide shall be saturated with a 1:1 diluted emulsified bitumen conforming to the relevant requirements of Section 4.06 – Bituminous Seal Coats and Surface Dressings, unless otherwise directed by the Engineer. Cracks shall be filled to the road surface level. Any excess bitumen shall be removed with a squeegee and the bitumen surface shall be sprinkled liberally with coarse sand.

B. Cracks of 3 mm width or more shall be filled with clean, coarse sand and then saturated with a 1:1 diluted emulsified bitumen conforming to the relevant requirements of Section 4.06 – Bituminous Seal Coats and Surface Dressings, or as directed by the Engineer. Cracks shall be filled to the road surface level. Any excess bitumen shall be removed with a squeegee and the bitumen surface shall be sprinkled liberally with coarse sand.

C. Excavations below subgrade level shall be filled to a level specified by the Engineer with subgrade material in layers not exceeding 150 mm and compacted using mechanical compactors to conform to the requirements of Section III- Subbase & Base Courses and to the satisfaction of the Engineer.

D. Sub-base and/or base course, if required, shall be placed in layers not exceeding 150 mm and compacted using mechanical compactors. They shall conform to the relevant requirements of Section III - Sub – Base & Base Courses and shall be to the grading shown on the Drawings or as specified by the Engineer.

If the existing level of the base course requires additional layer of aggregate base course of less than 100 mm. Then the top 100 mm of the existing base course shall be removed and hauled away, if suitable for reuse, and replaced by new material to the required level and compacted to 100% of maximum dry density.

If the surface of the base course, after the removal of the asphalt layer, is left with rough ridges or other objectional marks that requires skin patching. Then the top 100 mm of the existing base course shall be clarified thoroughly, stockpiled, moistened with enough water necessary for compaction and workability, then re-spread and compact to 100% of maximum dry density of the actual material reinstated.

If the existing pavement structure (Base, Sub-base course and Sub-grade) are to be replaced. then road structure shall be re-evaluated as to the type of road classification and the related CBR vales required for the successive layers of the pavement as specified on the drawings, specifications and as instructed by the Engineer.

E. Prior to receiving bituminous material, the excavations shall be thoroughly cleaned. Subgrade, sub-base or base course material shall be primed with a light coating of MC cutback or emulsified bitumen and existing bitumen surfaces shall be lightly painted with emulsified bitumen, all in accordance with the requirements of Section 4.02 – Bituminous Prime and Tack Coats.

F. The excavation shall be filled with bituminous pavement materials placed in layers not exceeding 70 mm and compacted using vibratory compactors. Unless otherwise ordered by the Engineer, the top layer shall be compacted by a steel wheeled roller, by first compacting the 150 mm strips adjacent to the traffic edges and then rolling in the direction of traffic. Bituminous materials shall conform to the relevant requirements of Section 4.04 – Bituminous Base Course and Section 4.05 –Bituminous Wearing Course and shall be to the gradings shown on the Drawings or as specified by the Engineer.

G. New utility trenches shall be backfilled to the details shown on the Drawings or as instructed by the Engineer and may include surround, haunching or protective materials. Construction of subgrade and pavement shall be as for pavement repairs.

H. No excavated areas shall remain open overnight.

4.08.07 MILLING PROCEDURES FOR ASPHALT OVERLAYS AND CONSTRUCTION OF PAVEMENT

A. Description

This work shall consist of the removal of only the top surface of the existing asphalt pavement using, milling machines at the locations shown on the drawings, to the maximum depth given in the Bill of Quantities and shown on drawings, and the disposal of the milled out material at locations approved by the Engineer.

B. Construction Requirement

The removal of the existing top surface layer at the designated areas shall be carried out by means of cold milling, and form a fresh roughened surface suitable for overlaying with further bituminous layers. The milled surface shall be true to the original pavement profile unless otherwise instructed substantially free from waves, bumps, ridges and any other irregularity, which will adversely affect the overlay.

Rate of removal to be about 45 sq.m. per minute. The loosened material to be placed directly into trucks by a conveyor as the milling machine progresses.

The limits of the areas to be milled should be marked with keel or paint and the depth and number of cuts should be determined.

Milling operations should progress in the direction of traffic and be limited to one lane until that lane is complete. If traffic is to be permitted to use any lane that has been milled, the lane should be swept with a power broom.

The equipment used for pavement milling shall be a power operated planning, grinding or cutting machine capable of removing, without heat the specified layer of the pavement for the width of the machine in one pass. The equipment shall be capable of accurately establishing profile grades by referencing from the existing pavement, gutter, or an independent grade control. Positive means for controlling slope and elevation shall be provided. The operating speed of the machine shall be variable and adequate to leave a textured surface and to produce material with a maximum size of 38 mm. The equipment shall have an effective means of removing the material from the surface.

Work should be scheduled so that there are no hazardous longitudinal drop-offs at the end of each day's operations.

The depth of milling, shall be checked immediately behind the milling machine and if found to be insufficient the machine shall immediately be adjusted accordingly. At no point must the depth of milling exceeds that given in the Bill of Quantities and shown on drawings. Where the specified maximum depth is exceeded the contractor shall replace the over excavation at his own cost and in a manner approved by the Engineer.

After milling, the pavement surface shall be carefully cleaned by means of air jet, which shall be checked to ensure that no oil is carried over from the compressor. The milled material shall be collected and carted off site and disposed of as instructed by the Engineer.
The rate of application of the tack coat on milled surfaces preparatory to an overlay should range between 0.2 and 0.6 kg / Square meter.

The sequence of repair for milling to be as follows:

- Set up work area traffic control devices;
- Mark locations to be milled;
- Cut surface with milling machine;
- Haul material to an approved disposal site;
- Sweep surface with power broom;
- Apply light tack if surface is to be overlaid;
- Place asphalt wearing, surface;
- Roll asphalt wearing surface;
- Pick up all work area traffic control devices.

The Contractor shall submit to the Engineer for his approval a detailed description of the method and equipment, which is proposed for carrying milling of existing surface.

4.08.08 PROCEDURES FOR ASPHALT OVERLAY OR RESURFACING

An overlay is a layer of hot mix of asphalt concrete and aggregates in accordance with this section.

Overlay is used to:

- Cover old asphalt surface, which show extensive cracking, pothole repairs, rutting, etc;
- Cover old asphalt surface which shows a large amount of raveling and pitting;
- Add structural strength where displacement has occurred such as rutting, corrugations and depressions;
- Improve the resistance of the surface to skidding;
- Improve the riding qualities of the surface; and
- Effectively seal an old surface from air and water.

When an old asphalt surface is to receive an overlay, the following preparatory steps must be taken:

- A wide crack more than 3 mm. in width must be filled with an asphalt emulsion slurry or light grade of emulsified asphalt mixed with fine sand.
- Potholes must be cleaned out and patched;
- Catch basins, drop inlets, manhole covers, survey monuments, etc. must be -adjusted to fit the new surface grade; and
- Depressed areas more than 13 mm deep must be brought to grade with a bituminous patch.

After the surface has been swept, a tack coat shall be applied as stated before in this section. Before the thin overlay is placed, the tack coat must be allowed to cure without being disturbed until it feels sticky.

The asphalt mixture is spread and finished true to crown and grade by an automatically controlled paving machine.

The automatically controlled payer should spread the asphalt mixture without tearirig the surface and should strike a finish that is smooth, true to cross section, uniform in density and texture, and free from hollows, transverse corrugations, and other irregularities.

Asphalt mixtures should be delivered to the payer at a temperature high enough as specified to permit compaction. Mixtures delivered to the payer at lower temperatures should be discarded. The mix should be delivered to the payer in time to permit completion of spreading finishing, and compaction of the mixture during daylight hours, unless lighting is provided.

Rolling shall be accomplished by steel wheel vibrating and finished by pneumatic tired rollers. The motion of the roller should be slow enough to avoid displacement of the mixture.
Transverse construction joints in previously laid material should be constructed by cutting the material back vertically for its full depth so as to expose a fresh surface.

The sequence of an overlay is as follows:

- Set up work area traffic control devices;
- Apply asphalt tack coat with distributor;
- Spread asphalt mixture with paving machine;
- Roll asphalt mixture;
- Remove debris from job site;
- Replace centreline and edge stripes; and
- Remove all work area traffic control devices.

4.08.09 MAINTENANCE OF SURFACE RESTORATION

All completed surface restoration works shall be maintained by the Contractor for the period of the Contract including the maintenance period. The Engineer shall instruct when repair work is required and, upon written instructions from the Engineer, the Contractor shall immediately carry out such repairs as are deemed necessary by the Engineer. All repair work shall be subject to written approval for the Engineer.

4.08.10 ADDITIONAL REQUIREMENTS FOR REPAIRS TO EXISTING PAVEMENT

A. Work Programme/ Schedule

A Work Programme / Schedule shall be submitted to the Engineer for approval prior to the start of repair work. The programme may be in the form of bar/ Gantt charts that indicate the areas of work and show the extent and duration of works and the sequence of partial road closures.

B. Temporary Traffic Management Proposals

The proposed traffic control plans for the various stages of work that affects traffic, including pedestrians, shall be submitted. The plans shall include temporary signing details and forms of traffic control to be used. The proposed plans shall comply with the requirements of the Health, Safety and Environmental Regulations in Volume I and current LIBNOR Standards.

4.08.11 ADDITIONAL REQUIREMENTS FOR ROAD OPENINGS

A. Duties and Responsibilities – Road Opening

The Contractor shall be responsible for coordination with the relevant service provider. All trench reinstatement works shall be performed in accordance with these specifications and the regulations of the relevant service provider

B. Application for Road Opening

The Contractor shall submit written proposals to the Engineer for approval prior to carrying out road opening works. The application shall comply with the requirements of the Health, Safety and Environmental Regulations in Volume I and current LIBNOR Standards and include the following:

Detailed Plans

Plans showing details of the opening work including the following: -

- Location of road opening
- Existing and proposed manhole positions
- Lines and levels of other services that may be affected by the works
- Position of trees and road facilities
- Existing road lines and other road markings

Photographs

Photographs of existing conditions

Temporary Traffic Management Proposals

The proposed traffic control plans for the various stages of opening that affect traffic, including pedestrians. The plans shall include temporary signing details and, if necessary, forms of traffic control to be used.

Work Programme/ Schedule

A Work Programme / Schedule shall be submitted to the Engineer prior to commencement of road opening works. The programme may be in the form of bar/ Gantt charts that indicate the different stages of openings and show the duration of works and the extent of road affected.

Statutory Authority Approval

Written confirmation from the relevant service provider that the proposed crossing has been checked and approved.

4.08.12 SAMPLING AND TESTING

Testing of repair materials shall conform to the relevant requirements of Section III - Subbase & Base Courses and Section 4.03 – Bituminous Courses. Sampling shall be as ordered by the Engineer.

4.08.13 SURFACE TOLERANCES

A. Levels shall be checked by straight edge in relation to the adjacent existing pavement.

B. Surface tolerances for bituminous layers shall conform to the relevant requirements of Section 4.04 – Bituminous Base Course and Section 4.05 –Bituminous Wearing Course.

C. Any deficiency in the wearing course surface shall be corrected by cutting out and replacing.

4.08.14 MEASUREMENT AND PAYMENT

Patching works shall be measured by the square metre of repair, prepared, filled, compacted, completed and accepted. Measurement shall be of the areas shown on the Drawings or ordered by the Engineer. The area to be reinstated shall extend to all surfaces broken up or disturbed and in the opinion of the Engineer required to be reinstated.

Sealing of cracks shall be measured by the linear metre for direct payment were specified and upon the approval of the Engineer.

Trench repair shall be measured by the linear metre for both stable trench milling and overlay, and damaged trench reinstatement, for width less than 1 metre, filled, compacted, completed and accepted by the Engineer. Measurements shall be of the areas shown on the Drawings or ordered by the Engineer. The area to be measured shall be limited to the maximum width of trench as requested in the drawings and to the area occupied by any manhole, chamber or other structure below the ground.

No separate payments shall be made for excavation, prime or tack coats or pavement materials.

All other incidental 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**
(4.08.14.1)	Patching works up to *(state depth)* in depth	Square metre (m^2)
(4.08.14.2)	Crack sealing	Linear metre (lm)
(4.08.14.3)	Stable Trench Milling and Overlay (width less than 1 m)	Linear metre (lm)
(4.08.14.4)	Damaged Trench reinstatement (width less than 1 m)	Linear metre (lm)

SECTION 4.09. RECONSTRUCTION OF BASE PAVEMENT LAYERS AND REINSTALLATION OF STONE PAVERS

4.09.01 SCOPE

A. This section covers the removal and reconstruction of pavement foundation layers and the reinstallation of existing stone pavers found to be in good condition, along with the supply and installation of new stone pavers where required, to match the existing paving system in type, size, color, texture, and pattern.

B. The scope includes careful removal, sorting, and reuse of salvaged pavers, reconstruction of the following pavement foundation layers: Sub-base, Base granular layer, Cement-Treated Base (CTB),Sand bedding layer: 5 cm thickness

C. All associated works such as jointing, edge restraints, leveling, compaction, and disposal of unsuitable materials are included.

D. All works shall be executed in accordance with the drawings, technical specifications, and as directed by the Engineer and to the satisfaction of the Consultant.

4.09.02 MATERIALS

A. Stone Pavers

- Shall match the existing pavement in type, size, color, texture, and pattern.
- Only sound, undamaged existing pavers shall be reused.
- New pavers shall be natural quarried stone or approved equivalent, conforming to durability and wear resistance standards and approved by the Engineer.

B. Sub-base Layer

- Crushed aggregate material, well-graded and compacted to a minimum of 98% modified Proctor density.
- Material and placement in accordance with Section III – Sub-base and Base Courses.

C. Base Granular Layer

- Clean, well-graded crushed gravel or crushed stone, compacted to specified density.
- Minimum thickness of 15 cm unless otherwise shown on the drawings.

D. Cement-Treated Base (CTB)

- CTB layer shall be constructed using approved granular material mixed with cement in approved proportions, placed and compacted as per project specifications.
- Minimum 15 cm compacted thickness with proper curing.

E. Sand Bedding

- Clean, well-graded natural sand free from clay and organic matter.
- Bedding layer to be 5 cm thick, leveled and compacted to provide a uniform laying surface.

F. Jointing Materials

- Approved fine sand, polymeric sand, or grout as directed by the Engineer, compatible with the paver system.
- Shall fill joints fully and resist displacement.

G. Edge Restraints and Accessories

- Precast concrete or other approved edge restraints to prevent paver displacement.
- All accessories required for secure installation and durability.

4.09.03 EQUIPMENT

All equipment used shall be suitable for excavation, layer placement, compaction, paver handling, and jointing works. Equipment shall conform to the requirements of Section — Contractor's Plant and Equipment.

4.09.04 GENERAL REQUIREMENTS

A. Site Supervision

- A full-time supervisor shall be assigned to oversee all pavement reconstruction and paver reinstatement works.

B. Salvage and Protection

- Existing pavers shall be removed carefully and stored safely for reuse.
- All surrounding pavement and structures must be protected from damage during execution.

C. Disposal

- All unsuitable or surplus material, debris, and damaged pavers shall be removed from site and disposed of at approved locations.

4.09.05 PREPARATION AND RECONSTRUCTION OF FOUNDATION LAYERS

A. Excavate to the required depth and remove existing bedding and base materials to expose sound subgrade.

B. Compact the subgrade uniformly as per specification to the required density.

C. Place and compact the sub-base layer in two or more layers, if necessary, to achieve uniform compaction and thickness.

D. Place and compact the base granular layer to the required compaction standard.

E. Construct the cement-treated base layer per CTB specifications, including mixing, placing, compaction, and curing.

F. Place a 5 cm thick sand bedding layer, ensuring level surface ready for paver laying.

4.09.06 REINSTALLATION AND INSTALLATION OF STONE PAVERS

A. Reinstall salvaged stone pavers in the original pattern, with accurate alignment and level.

B. Where new pavers are required, install in kind to match existing paving in all respects.

C. Ensure consistent joint widths and alignment.

D. Fill joints with approved jointing material, sweep and compact into joints.

E. Perform final compaction using a plate compactor with protective mat, if required, to seat pavers uniformly.

F. Protect the newly laid surface from traffic and weather until fully set.

4.09.07 TESTING AND ACCEPTANCE

A. All foundation layers and installed pavers shall be subject to inspection and testing for alignment, level, compaction, and pattern consistency.

B. Materials may be sampled for conformity with technical standards.

C. All defects or non-conformities shall be rectified at the Contractor’s expense.

4.09.08 MAINTENANCE

The Contractor shall maintain the reinstated pavement during the maintenance period, promptly repairing any defects, settlement, or damage as directed by the Engineer.

4.09.09 MEASUREMENT AND PAYMENT

A. Measurement shall be by the square metre (m²) of pavement surface reconstructed and stone pavers reinstated, including:

- Removal and reuse of existing pavers
- Supply and installation of new pavers as needed
- Excavation, disposal, and reconstruction of sub-base, base, CTB, and sand bedding layers
- Jointing and all finishing works

B. The unit rate shall be full compensation for all labor, materials, equipment, supervision, and incidentals required to complete the work as specified.

PAY ITEM	UNIT OF MEASUREMENT
Reconstruction of Base Pavement Layers and Reinstallation of Stone Pavers	Square meter (m²)

DIVISION 5

CONCRETE, STEEL AND STRUCTURE (1/3)

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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_2O_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_2O)	
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 (m3) 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.

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. 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) High tensile steel bar reinforcement including chemical anchor adhesive for additional bars	Tonne (T)
(4) Fabric wire mesh reinforcement	Tonne (T)
(5) Fabric bar mesh reinforcement	Tonne (T)
(6) Supply Steel plate cover joint dimensions and thickness (1000mmx1300mmx25mm)	Number (Nr)

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.

DIVISION 5

CONCRETE, STEEL AND STRUCTURE (2/3)

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SECTION 5.05 CONCRETE PAVEMENT

5.05.01 Scope

A. These Works shall consist of furnishing materials and constructing cement concrete pavement, with or without reinforcement, on a prepared base all as and where shown on the Drawings.

5.05.02 Materials

A. Class and strength of concrete for pavement construction shall be as shown on the Drawings.

B. Concrete shall conform with the relevant requirements of Section 5.01 "Concrete and Concrete Mixes and Testing".

C. Chemical admixtures shall conform with the relevant requirements of Section 5.01 "Concrete and Concrete Mix and Testing", sub-section 5.01.2.

D. Steel reinforcing bars and steel wire fabric shall conform with the relevant requirements of Section 5.03 "Steel Reinforcement and Fixing".

E. Dowel bars shall be plain steel bars conforming to AASHTO M 31M (ASTM A 615M) Grade 40 or 60. Sleeves for dowel bars shall be approved types. Tie bars shall be deformed steel bars of approved type and shall conform to AASHTO M 42. (ASTM A996).

F. Water for use in concrete and mortar mixes and for curing purposes shall conform with the relevant requirements of Section 5.01 "Concrete and Concrete Mixes and Testing".

G. Curing membrane materials shall conform with the relevant requirements of Section 5.02 "Concrete Handling. Placing and Curing". Unless otherwise shown on the Drawings, a liquid curing compound conforming to AASHTO M 148. (ASTM C 309) shall be used.

H. Moisture barrier (for spreading on the granular base prior to placing concrete) shall be either PVC plastic film conforming to ASTM D 1593, Type II, or PE plastic film conforming to ASTM D 2103, Type 2000. The film shall be 0.15 mm to 0.20 mm in thickness.

I. Materials for use in expansion joints, construction joints and weakened plane joints shall be approved proprietary sealants, fillers and plastic strips, as shown on the Drawings and conforming with the relevant requirements of Section 5.21 "Joint Sealing and Joint Filler".

J. Poured filler shall conform to AASHTO M 173 (ASTM D 1190). Preformed fillers shall conform to AASHTO M 33, (ASTM D 994) AASHTO M 153, (ASTM D 1752) AASHTO M 213 (ASTM D 1751) or AASHTO M 220. (ASTM D 2628) as appropriate and shall be punched to admit dowels where required. Preformed filler for each joint shall be furnished in a single piece unless otherwise approved.

5.05.03 Equipment

A. Plant and equipment for base course and concrete pavement construction shall conform with the requirements of Section 1.06 "Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

B. At the option of the Contractor unless otherwise shown on the Drawings, stationary side forms or slip-form paving equipment may be utilized for concrete pavement construction.

5.05.04 Base Course Surface Preparation

A. The base course provided immediately beneath the concrete pavement shall have been constructed in accordance with Section 3.03 "Aggregate Base Course" and 3.04 "Stabilized Courses" as applicable.

B. Immediately prior to placing concrete, the base course surface shall be inspected to ensure that it conforms to the compaction and elevation tolerances specified.

C. Moisture barrier material shall be placed over the base course surface prior to placing concrete. All seams shall be lapped a minimum of 150 mm and the barrier material anchored in place by approved methods.

D. Storing or stockpiling of other equipment and materials on the base course will not be permitted.

5.05.05 Preparatory Works

A. Before placing concrete, the Contractor shall provide a sufficient supply of water and ensure that it will remain available throughout the pavement construction period. An inadequate water supply will be considered sufficient cause for delaying or stopping mixing operations. In case of a deficiency of water, the requirements for curing concrete already placed shall take precedence.

B. Slip-form paving and finishing machines shall be in proper adjustment and satisfactory working order. Prior to placing concrete, the Contractor shall demonstrate proper adjustment of all screeds and floats on slip-form pavers by measurements from grade stakes driven to known elevation. Satisfactory operation and adjustment of all propulsion and control equipment, including pre-erected grade and alignment lines, shall be demonstrated by moving slip-form pavers and finishing machines over a 100 m length of prepared base course with all propulsion and control equipment fully operational.

C. The Contractor shall make adequate advance arrangements for preventing delay in delivery and placing of the concrete. An interval of more than 45 minutes between placing of any 2 consecutive batches or loads shall constitute cause for stopping paving operations.

5.05.06 Trial Length

A. General

A.1 At least one month prior to the construction of the trial length of surface slabs the Contractor shall submit for the Engineer's approval a detailed description of the proposed materials, plant, equipment and construction methods. No trials of new materials, plant, equipment or construction methods; nor any development of them shall be permitted either during the construction of the trial length or in any subsequent paving work, unless they form part of further approved trials.

A.2 The Contractor shall demonstrate the materials, plant, equipment and methods of construction that are proposed for concrete paving, by first constructing a trial length of slab, at least 150 m but not more than 300 m long for mechanised construction, and at least 30 m long for hand guided methods.

A.3 The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 75 m constructed each day when mechanised paving plant is used and a minimum of 15 m on each day for hand guided methods. The trial length shall be constructed at a similar rate to that which is proposed for the main Works.

A.4 At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs and jointed reinforced concrete slabs in the main Works shall be constructed and assessed in the trial length. If in the trial length expansion joints are not demonstrated, the first 2 expansion joints and at least the first 150 m of longitudinal construction joint for mechanised paving, or 30 m for hand guided method of construction laid in the main/works, shall be considered the trial length for these joints. One construction joint shall be demonstrated in each trial length.

B. Assessment

B.1 The trial length shall comply with the Specification in all respects.

5.05.07 Construction Generally

A. Concrete shall be handled, placed, compacted and cured in accordance with the relevant requirements of Section 5.02 "Concrete Handling, Placing and Curing".

B. Steel reinforcing bars, steel wire fabric, dowel bars and tie bars, shall be handled and fixed in proper positions in accordance with the relevant requirements of Section 5.03 "Steel Reinforcement and Fixing".

C. All concrete shall be placed while fresh. The use of water for retempering any concrete will not be permitted. Any concrete showing improper proportions of materials, including water, shall not be used in the pavement, and any such unsatisfactory concrete shall be removed and disposed of by the Contractor at his own expense.

D. Unless otherwise shown on the Drawings, concrete pavement shall be constructed in traffic lane widths separated by contact joints, or monolithically in multiples of traffic lane widths with a longitudinal weakened plane joint at each traffic lane line.

E. Concrete shall be spread, shaped, and consolidated so that the completed pavement will conform to the thickness and cross sections shown on the Drawings. Sides of pavement

may be constructed on a batter not exceeding 1:6 (H:V), provided the top of the pavement is maintained at the specified width.

F. When the pavement being constructed is continuous to an existing parallel concrete pavement, the elevation of the new pavement surface shall conform as closely as possible to the elevation of the existing pavement surface and in a manner which will prevent ponding.

G. Pavement shall be constructed using paving equipment which is capable of producing a finished surface meeting straightedge tolerances. Failure of equipment in this respect will constitute cause for stopping placement of concrete until equipment deficiency or malfunction is corrected.

5.05.08 Stationary Side Form Construction

A. Side form sections shall be straight, free from warps, bends, indentations, or other defects. Defective forms shall be removed from the Works. Metal side forms shall be used except at end closures and traverse contact joints where straight forms of other suitable materials may be used.

B. Side forms may be built up by rigidly attaching a section to either top or bottom of forms. If such build-up is attached to the top of metal forms, it shall be made of metal.

C. Side forms shall be of sufficient rigidity, both in the form and in the interlocking connection with adjoining forms, that springing will not occur under the weight of equipment from the pressure of concrete. The Contractor shall provide sufficient forms so that there will be no delay in placing concrete.

D. Before placing side forms, the base course surface shall be at the proper elevation and grade. Side forms shall have full bearing upon the base course throughout their length and width of base and shall be placed to the required grade and alignment of the edge of the finished pavement. They shall be firmly supported during the entire operation of placing, compacting, and finishing the pavement.

E. Immediately in advance of placing concrete, side forms shall be trued and maintained to the required line and grade for a sufficient distance ahead to prevent delay in placing concrete.

F. Side forms shall remain in place for 24 hours after placing the concrete, and in all cases until the edge of the pavement no longer requires the protection of the forms.

G. Side forms shall be thoroughly cleaned and oiled each time they are used and before concrete is placed against them.

H. Concrete shall be spread, screeded. shaped, and consolidated by one or more machines. These machines shall uniformly distribute and consolidate concrete without segregation and so that the completed pavement will conform to the required cross sections with a minimum of handwork, 'the number and capacity of machines furnished shall be adequate to perform the Works required at a rate equal to that of concrete delivery.

I. Concrete shall be effectively consolidated over the full paving width by means of surface vibrators, internal vibrators or by other method of consolidation that produces equivalent results without segregation.

J. When vibrators are used to consolidate concrete, the rate of vibration shall be not less than 3.500 cycles/min for surface vibrators and not less than 5,000 cycles/min for internal vibrators. Amplitude of vibration shall be sufficient to be perceptible on the surface of concrete up to 0.5 m away from the vibrating element. The Contractor shall furnish a tachometer or other suitable device for measuring and indicating frequency of vibrations.

K. Vibrators shall not rest on new pavement or side forms. Power to vibrators shall be connected so that vibration ceases when forward or backward motion of the machine is stopped.

L. When concrete is being placed adjacent to an existing pavement, that part of the equipment supported on existing pavement shall be fitted with protective pads on crawler tracks or rubber-tired wheels with the hearing surface offset to run a sufficient distance from the pavement edge to avoid breaking or cracking such edge.

M. Concrete placed in special situations such as at existing ramp termini, truck weigh stations, ramps, at connectors with steep grades and high rates of super elevation, at short sections of city streets, on sharp curves, and in short lengths or in widths other than multiples of traffic lanes, shall be spread and shaped by any suitable powered finishing machines, supplement by handwork as necessary. Consolidation of such concrete shall be by means of high frequency internal vibrators and completed within 15 minutes after it has been placed.

N. Vibrating of concrete placed in special situations shall be done with care and in such manner as to ensure adequate consolidation adjacent to forms and uniform consolidation across the full paving width. Use of vibrators for shifting masses or piles of concrete will not be permitted. Methods of spreading, shaping and compacting that result in segregation, voids or rock pockets shall be discontinued. and the Contractor shall adopt methods which will produce a dense and homogeneous pavement.

5.05.09 Slip-Form Construction

A. Slip-form pavers shall be equipped with traveling side forms of sufficient dimensions, shape and strength to support the concrete laterally for a sufficient length of time to produce pavement of the required cross section, Slip-form paving equipment shall spread, consolidate and screed freshly placed concrete in such a manner that a minimum of handwork will be required to produce a dense homogeneous pavement.

B. No abrupt changes in longitudinal alignment of the pavement will be permitted. The horizontal deviation shall not exceed 30 mm from the alignment shown on the Drawings.

C. Concrete shall be effectively consolidated over the full paving width by means of high frequency internal vibrators. Vibrators may be mounted with their axes parallel or normal to pavement alignment. When vibrators are mounted with their axes parallel with the pavement alignment, they shall be spaced at intervals not exceeding 750 mm measured center to center. When vibrators are mounted with their axes normal to pavement alignment, they shall be spaced so that lateral clearance between individual vibrating units does not exceed 150 mm.

D. The vibration rate of each vibrating unit shall be not less than 5,000 cycles/min. Amplitude of vibration shall be sufficient to be perceptible on the surface of concrete along the entire length of vibrating units and for a distance up to 0.5 m therefrom. The

Contractor shall furnish a tachometer or other suitable device for measuring and indicating frequency of vibration.

E. When concrete is being placed adjacent to an existing pavement, that part of the equipment supported on existing pavement shall be fitted with protective pads on crawler tracks or rubber-tired wheels with the bearing surface offset to run a sufficient distance from the pavement edge to avoid breaking or cracking such edge.

5.05.10 Construction Of Joints

A. Joints Generally

A.1 Joints in pavement will be designated as longitudinal contact Joints, transverse contact joints, longitudinal weakened plane joints and transverse weakened plane joints. Joints shall be constructed as and where shown on the Drawings and in accordance with the following requirements.

A.2 All transverse joints shall be constructed at the specified angle to centerline of pavement and the faces of all joints, both transverse and longitudinal, shall be normal to the face of the pavement.

A.3 Joints shall be maintained clean and free of all soil, sand, gravel, concrete, or asphalt mix and other foreign material until Joint filler material or sealant has been placed.

A.4 Tie bars in previously placed pavement for longitudinal joints shall not be straightened.

B. Contact Joints

B.1 Contact Joints are those made by placing fresh concrete against hardened concrete.

B.2 Curing compound shall be applied to the face of each contact joint and allowed to dry prior to placing fresh concrete against that joint face. This provision is also applicable to existing concrete pavement not constructed as part of the Works.

C. Weakened Plane Joints

C.1 Longitudinal weakened plane joints; shall be constructed at traffic lane lines in multilane monolithic concrete pavements, by cutting grooves with a power driven saw.

C.2 Transverse weakened plane joints shall he spaced as shown on the Drawings but for unreinforced concrete slabs the spacing of transverse joints shall not exceed 4m and the length / width ratio shall be not greater than 2:1. This spacing may be increased, with the approval of the Engineer, by 20% if limestone coarse aggregate is used throughout the depth of the slab. They shall be constructed by either cutting grooves with a power driven saw of the multiple-bladed span type or by inserting a plastic strip in the fresh concrete.

C.3 Sawed grooves shall be cut to a minimum depth of 50 mm and a maximum width of 6 mm. Every fourth transverse weakened plane joint in the initial lane of concrete and also the first joint immediately after the transverse contact joint shall be sawed within 24 hours after the concrete has been placed and every second transverse weakened plane joint shall be sawed within 48 hours after placing the concrete. Sawing should be undertaken as soon as possible after the concrete has hardened sufficiently to enable a sharp edged groove to be produced without disrupting the concrete and before random

cracks develop in the slab. The minimum and maximum time will depend on site conditions. The exact times for such sawing shall be designated by the engineer.

C.4 Unless otherwise shown on the Drawings, the longitudinal and transverse weakened plane joints in the initial lane of concrete may be sawed at such time. after 24 hours, as the Contractor may elect, except that they shall be completed before placing concrete in succeeding adjacent lanes and before the Contractor's vehicles or public traffic uses the pavement.

C.5 In succeeding lanes of concrete pavement, the transverse joints opposite those which have opened in the initial lane shall be sawed within 24 hours after the concrete has been placed, the exact time to be determined by the Engineer, but in all cases not more than 3 consecutive transverse weakened plane joints shall be omitted.

C.6 The remaining longitudinal and transverse weakened plane joints in succeeding lanes may be sawed at such time. after 24 hours, as the Contractor may elect, except that they shall be completed before placing concrete in the succeeding adjacent lanes and before the Contractor's vehicles or public traffic uses the pavement.

C.7 No sawing shall be done where volunteer transverse cracks exist. If a volunteer transverse crack falls within 2 m of the location of a proposed sawed joint, the sawed joint shall be relocated outside the 2 m zone.

C.8 Unless otherwise shown on the Drawings, insert-type transverse weakened plane joints shall be formed by placing a continuous strip of plastic or other material which shall not react adversely with the chemical constituents of the concrete or bond with the concrete. The strip shall have a minimum thickness of 0.3 mm and a width of 50-55 mm.

C.9 After placement, the vertical axis of the insert-type strip shall be within 13.5 degrees of a plane normal to the surface of the pavement. The top of the strip shall not be above nor more than 10 mm below the finished pavement surface. Final alignment of the strip shall be as shown on the Drawings and shall not vary by more than 30 mm from a 4 in long straightedge.

C.10 Insert-type transverse strips shall be placed by means of a mechanical installation device which shall vibrate the plastic concrete sufficiently to cause an even flow of concrete about the joint material. After installation of the strip, the concrete shall be free of segregation, rock pockets or voids and the finished concrete surface on each side of the joint shall be in the same plane. Splices in the joint strip will not be permitted.

C.11 The Contractor shall maintain a standby multiple-bladed power driven span type joint saw, in proper operating condition, on Site at all times while concrete paving operations are underway, regardless of the type of weakened plane joint being constructed.

C.12 Unless otherwise shown on the Drawings, insert-type longitudinal weakened plane joints at traffic lane lines in multilane monolithic concrete pavement shall be formed by placing a continuous strip of plastic or other material which shall not react adversely with the chemical constituents of the concrete. The joint insert material shall be of such width and type that when placed vertically in the concrete it will not bond with the concrete and will form an effective weakened plane joint to 50 mm depth below the finished surface of the concrete. The joint material shall not be deformed from a vertical position, either in the installation or in subsequent finishing operations performed on the concrete.

C.13 Alignment of the finished longitudinal joint shall be uniformly parallel with the centerline of the pavement and shall be free of any local irregularity which exceeds 12 mm measured by a 4m long straightedge, except for normal curvature of centerline. The mechanical installation devices shall vibrate the concrete during placing of the strip sufficient to cause the concrete to flow evenly about the joint material, producing homogeneous concrete free of segregation and pockets or voids.

5.05.11 Concrete Surface Finishing

A. Preliminary Finishing Generally

A.1 Prior to completion of float finishing and texturing, water shall not be applied to the pavement surface in excess of the amount lost by evaporation.

A.2 Placement of concrete shall cease in sufficient time to enable finishing operations to be completed during daylight hours, unless lighting facilities provided by the Contractor are approved as adequate for allowing later placement and finishing.

A.3 Preliminary Finishing procedures to be adopted will depend on whether side forms or slip-forms are being used.

B. Stationary Side Form Preliminary Finishing

B.1 After spreading and compacting, concrete shall be given a preliminary finish by either machine float or hand methods, as directed. Hand methods shall normally only be permitted in the event of minor breakdown of the machine float or other emergency. A standby machine float shall be made available by the Contractor, if the Engineer deems such provision necessary to avoid undue delays.

B.2 In the case of the machine float method, self-propelled machine floats shall be used to finish the surface smooth and true to grade. The number and capacity of machine floats. furnished shall be adequate to perform all finishing required at a rate equal to that at which concrete is delivered. Any delay exceeding 30 minutes in performing preliminary finishing shall constitute cause for stopping delivery of concrete until machines performing such Work are again in proper position to continue without delay.

B.3 Machine floats shall be capable of running either on side forms or on adjacent lanes of pavement. When machine floats run on adjacent pavement, the concrete surface shall be protected as specified under "Stationary Side Form Construction".

B.4 Floats shall he constructed of hardwood, steel, or steel-shod wood and shall be equipped with devices to permit adjustment of the underside to a true flat surface.

B.5 In the case of hand methods, the surface shall be finished smooth and true to grade with suitable manually operated float" or powered finishing machines. Finishing shall take place as far back from concrete spreading operations as concrete remains workable. The number of finishing passes shall be sufficient to remove all perceptible inequalities.

C. Slip-Form Preliminary Finishing

C.1 The surface shall be given a preliminary float finish by means of devices incorporated in the slip-form paver. These may be supplemented, at the Contractor's option, with suitable machine floats.

C.2 Any edge slump of pavement, exclusive of edge rounding, in excess of 5 mm, shall be corrected before concrete has hardened.

D. Final Finishing

D.1 After preliminary finishing has been completed, edges of initial paving widths shall be rounded to 12 mm radius. Transverse contact joints, expansion joints, and the edge of longitudinal contact joints adjacent to hardened concrete pavement, shall be rounded to 6 mm radius.

D.2 In advance of curing operations, pavement shall be given an initial and a final texturing. Initial texturing shall be performed with a burlap drag or broom device which will produce striations normally parallel with the pavement centerline. Final texturing shall be performed with a spring steel tine device which shall produce grooves parallel with the centerline unless otherwise directed. The steel tine shall not operate closer than 75 mm to the pavement edge.

D.3 Except when texturing areas of pavement finished using hand methods, burlap drags, brooms, and tine devices shall be installed on self-propelled equipment having external alignment control. The installation shall be such that when texturing, the area of burlap in contact with the pavement surface shall be maintained constant at all times.

D.4 Broom and tine devices shall be provided with positive elevation control. Down pressure on pavement surface shall be maintained at all times during texturing so as to achieve uniform texturing without measurable variations in pavement profile. Self-propelled texturing machines shall be operated so that travel speed when texturing is maintained constant.

D.5 Failure of equipment to conform to the above requirements will constitute cause for stopping placement of concrete until the equipment deficiency or malfunction is corrected.

D.6 Spring steel tines of the final texturing device shall be rectangular in cross section, 3-4 mm wide, 20 mm center- to- center and of sufficient length. thickness .and resilience to form grooves approximately 5 mm deep in the fresh concrete surface. Final texture shall be uniform in appearance with all grooves having a depth of 2-5 mm. This texture pattern shall be adopted unless otherwise shown on the Drawings.

D.7 Finished pavement shall be checked by the Engineer not more than 10 days following placement of the concrete, to verify that it conforms to correct lines, grades and cross sections.

D.8 When the finished surface is tested with a 4 m long straightedge, placed parallel to, or at right angles to the centering, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 6 mm.

D.9 All high points which exceed the specified tolerances shall be corrected by grinding as directed.

D.10 The Contractor shall obtain drilled 100mm diameter cores from the completed pavement, at locations selected by the Engineer, to verify compliance with the thickness requirements. The Contractor shall fill all core holes with fresh concrete and finish the surface neatly to match the surrounding concrete.

5.05.12 Curing Procedures

A. Curing Procedures Generally

A.1 Immediately the finishing process is complete, the entire exposed area of the pavement, including edges, shall be cured by the curing compound method unless approval is given for water curing.

A.2 When the side forms are removed before the expiration of 72 hours following the start of curing, the exposed pavement edges shall also be cured. If the pavement is cured by means of the curing compound method, the sawcut and all portions of the curing compound which have been disturbed by sawing operations shall be restored by spraying with additional curing compound.

A.3 When the ambient temperature is above 25 degrees C and whenever deemed necessary by the Engineer, cooling of the concrete with a fine spray of water shall be continued after curing seal is applied, until the Engineer determines that a cooling effect is no longer required.

B. Curing Compound Method

B.1 Surfaces of the concrete which are exposed to the air shall be sprayed uniformly with an approved curing compound as specified in Section 5.02 "Concrete Handling, Placing and Curing".

B.2 Unless otherwise shown on the Drawings, the application rate shall be 0.25 L/sq.m. At any point the application rate shall be within 20% of the specified application rate and the average application rate shall be within 10% of the specified application rate. Runs, sags, thin areas, skips, or gaps in the applied curing compound shall be evidence that the application is unsatisfactory.

B.3 Curing compound shall be applied using approved mechanical sprayers of the fully atomizing type, equipped with a tank agitator which shall provide for continual agitation of the curing compound during application. The power operated spraying equipment shall be equipped with an operational pressure gage and a means of controlling the pressure.

B.4 The spray shall be adequately protected against wind and the nozzles shall be so oriented or moved mechanically transversely as to result in not less than the minimum specified rate of coverage uniformly on all exposed faces.

B.5 Hand spraying of small and irregular areas and areas inaccessible to mechanical spraying equipment will be permitted.

B.6 The curing compound shall be applied before any drying shrinkage or craze cracks begin to appear. In the event of any drying or cracking of the surface- application of water with an atomizing nozzle shall be started immediately and shall be continued until application of the compound is resumed or started. The compound shall not, however, be applied over any resulting free standing water.

B.7 Should the film of compound be damaged from any cause before the expiration of 7 days after the concrete is place, the damaged portion shall be repaired immediately with additional compound.

C. Water Curing Method

C.1 When water curing is permitted. the concrete shall be kept continuously wet by the application of water for a minimum period of 7 days after the concrete has been placed. Cotton mats, rugs, carpets, or earth or sand blankets may be used as a curing medium to retain the moisture during the curing period.

C.2 When cotton mats, rugs, carpets, or earth or sand blankets are to be used as a curing medium to retain moisture, the entire surface of the concrete shall be kept damp by applying water with a nozzle that so atomizes the flow that a mist and not a spray is formed, until the surface of the concrete is covered with the curing medium.

C.3 The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface. At the expiration of the curing period, the concrete surfaces shall be entirely cleared of curing medium.

C.4 When the concrete is to be water cured without the use of a moisture retaining medium, the entire surface of the pavement shall be kept damp by the application of water with the atomizing nozzle, until the concrete has set, after which the entire surface of the concrete shall be sprinkled continuously with water for a period of not less than 7 days.

5.05.13 Determination Of Concrete Thickness

A. Thickness of concrete pavement shall be determined by average calliper measurement of cores, rounded upwards taken to the nearest mm.

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

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

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

E. When the measurement of the core from any pavement 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 m intervals parallel to the centerline 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 thickness will not be used in average thickness determinations.

F. Where the average thickness of concrete pavement is deficient by more than 5 mm but not more than 20 mm adjustments shall be made in the area measurements as shown in Table 5.5.1.

Table 5.5.1: CONCRETE THICKNESS DEFICIENCY

Deficiency in Thickness as Determined by Cores (mm)	Proportion of Area Measured for Payment
0.0 to 5.0	100%
5.1to 10.0	90%
10.1to 15.0	75%
15.1to 20.0	50%

G. When the pavement is more than 20 mm deficient in thickness, the Contractor shall remove such deficient areas and replace them with concrete pavement .of the specified quality and thickness, all at his own expense.

H. When the limits of a deficient area !o he removed and replaced are within 3 m of an expansion, contraction or construction Joint. the entire concrete pavement up to the joint shall be removed and replaced at the Contractor's expense.

I. If approved, and provided the pavement section is not deficient by more than 25 mm, the Contractor may leave the deficient concrete pavement in place, in which case no measurement for payment shall be made of such section.

5.05.14 Measurement

A. Unreinforced concrete (URC), Jointed reinforced concrete (JRC) and Continuously reinforced concrete (CRC) of different thickness pavements shall be measured by sq.m of concrete pavement constructed, including furnishing of all materials, placing, jointing, finishing and curing concrete, completed, and accepted. Measurements shall be of the surface area dimensions as shown on the Drawings, adjusted for thickness deficiencies as specified.

B. Successful trial lengths of URC. JRC or CRC Pavements shall be measured by the square meter and be paid for under the appropriate type of concrete pavement. Unsuccessful trial lengths shall not be measured for payment.

C. Base course surface preparation, furnishing and installing moisture barrier, excavation for thickened portions of pavement, cutting of cores from the finished pavement for testing or measurement purposes, and additional thickness of concrete in excess of the specified thickness, shall not be measured for direct payment, hut 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) Unreinforced Concrete Pavement (State thickness)	Square Meter (m^2)
(2) Jointed reinforced Concrete Pavement (JRCP) (State thickness)	Square Meter (m^2)
(3) Continuously reinforced Concrete Pavement (CRCP) (State thickness)	Square Meter (m^2)

SECTION 5.06 PLAIN AND REINFORCED CONCRETE STRUCTURES

5.06.01 Scope

This Section of these Specifications describes tile construction of plain and reinforced concrete structures.

5.06.02 Materials

A. Concrete

Concrete shall be produced and supplied in accordance with Section 5.01 "Concrete and Concrete Mixes and Testing".

B. Reinforcement

Reinforcement shall conform to Section 5.03 "Steel Reinforcement and Fixing".

C. Formwork and Falseworks

Formwork and falsework shall be designed and supplied in accordance with Section 5.04 "Forms, Formwork and Falsework".

D. Plant and Equipment

Plant and Equipment shall conform with the requirements of specifications Part 1 – Section
4 - 4 and shall be according to the type and number outlined in the Contractor's detailed Program of Work as approved by the Engineer.

5.06.03 Construction

A. General

A.1 The Contractor shall notify the Engineer his intention to concrete at least 24 hours in advance.

A.2 The Engineer shall check and certify that:

- The form and formwork meet the Specifications requirements
- The falsework and support props are in accordance with the approved Drawings.
- The reinforcement conforms to the Drawings and that the concrete covers have been provided
- The forms are free of dirt and other deleterious matter.

B. Concreting

Handling, placing and curing shall be in accordance with Section 5.02 "Concrete Handing, placing and Curing".

C. Slump

Slump shall be within the limits given in Section 5.02 of the Specifications except that the maximum slump of bridge deck shall be 75 mm, unless otherwise agreed by the Engineer.

D. Construction and Expansion Joints

D.1 Whenever the work of placing concrete is delayed until the concrete shall have taken its initial set, the point of stopping shall be deemed a construction joint. So far as possible the location of construction joints shall be as shown on the Drawings, but if not shown on the Drawings, they shall be planned in advance and the placing of concrete carried out continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and in general be located at points of minimum shear.

D.2 Where dowels, reinforcing bars or other adequate ties are not required by the Drawings, keys shall be made by embedding water soaked bevelled timbers in soft concrete. The key shall be sized as shown on the details, or as directed by the Engineer, which shall be removed when the concrete has set. In resuming work the surface of the concrete previously placed shall be thoroughly cleaned of dirt, scum, laitance or other soft material with stiff wire brushes, and if deemed necessary by the Engineer, shall be roughened with a steel tool. The surface shall then be thoroughly washed with clean water and pointed with a thick coat of neat cement mortar, after which the concreting may proceed.

D.3 Expansion joints shall be constructed at the locations, of the materials and to the dimensions shown on the Drawings.

E. Cold Joints

E.1 When the continuous placement of concrete in any structural member is interrupted or delayed for any reason for a period long enough for the previously partially placed concrete to take its initial set the Engineer shall declare such a joint a cold joint in which case the Contractor shall immediately remove the previously partially placed concrete from the forms. No extra payment will be made for the initial placement or the removal of concrete which is wasted because of a cold joint. The Engineer may suspend all or any part of the subsequent concrete work until he deems the Contractor has corrected the cause for the cold joint occurrence.

E.2 The Engineer may with due consideration to the location of the cold joint and/or the importance of the member allow the Contractor to retain the partially placed concrete and complete the concreting by a subsequent pour which for permission the Engineer shall instruct the Contractor to carry out at his own expense some or all of the following measures before completing the pour:

E.2.1 Surface laitance shall be removed from the surface of the partially placed concrete by wire brushing or light tooling or by sand blasting as directed by the Engineer without damage to reinforcement and formwork.

E.2.2 Shear keys shall be cut in the partially placed concrete. The shape size and orientation of the shear keys shall be as directed by the Engineer. The reinforcement and formwork shall not be damaged.

E.2.3 The cleaned surface of the partially placed concrete shall be coated with an approved bonding agent before placing the subsequent pour.

E.2.4 Additives to facilitate bonding shall be added to the concrete used for the subsequent pour.

E.2.5 Dowel bars of a type and length to be approved by the Engineer shall be installed in the partially placed concrete using non-shrink cement grout or resin grout as directed by the Engineer. The size and spacing of the dowel bars shall be approved by the Engineer. Their installation shall not damage the reinforcement or formwork.

E.2.6 The partially placed concrete and the subsequent concrete shall be stressed by prestressing bars of a size and type approved by the Engineer to achieve a level of compressive stress at the interface approved by the Engineer. The method of installing the prestressing bars and type of anchors used shall be approved by the Engineer. Unless otherwise agreed by the Engineer the drill hole shall be grouted with a cement grout containing expanding additive to the manufacturer's recommendations.

F. Finishing

F.1 Unless otherwise noted in the Drawings or provided for in the Special Specifications the following classes of finishes shall be used for formed surfaces:

F.1.1 Pre-cast parapets, cladding panels, New Jersey barriers, wall copings etc, which form architectural features Class F1

F.1.2 Exposed faces of retaining walls, abutments, piers, columns, bridge deck, box culvert etc., which are not in contact with earth and which can be seen Class F2

F.1.3 Backs of retaining walls and solid abutments, outer faces of box culverts, faces of abutment columns and bottom of bank seats for spill-through abutments, plinths for columns, piers, lighting masts and sign gantries etc., which are generally in permanent contact with earth

Class F3

F.1.4 Inner laces of box girders, cellular deck slabs, cellular bases and pile caps etc., which are not in contact with earth and which are not visible Class F3

F.1.5 Sides of bases, footings, pile caps etc., which are to be permanently below final ground level Class F4

F.2 Unless otherwise noted in the Drawings, the following classes of finishes shall be used for unformed surfaces:

F.2.1 Top of bases, footings, pile caps, box culvert roof etc, which are to be backfilled

Class U1

F.2.2 Top of walls, slabs etc, which are to receive coping or tiling, Class U2

F.2.3 Top of box culvert bottom slab, apron slab of box culvert and top of walls and slabs which are to be exposed Class U3

F.3 Finish to bridge decks that are to receive an approved waterproof system shall first be finished to Class U1. Then, when the concrete has sufficiently hardened to prevent laitance being worked to the surface it shall be floated to produce a uniform surface free from screed marks and exposed aggregate. Finally the surface shall be textured by

brushing or otherwise to the waterproofing manufacturer's requirements as agreed by the Engineer. The accuracy of the finished surface shall be such that it does not deviate from the required profile by more than 10 mm over a 3 m gage length or have any abrupt irregularities more than 3 mm.

F.4 Surfaces, other than bridge deck, which are to receive approved waterproofing systems shall be finished to Class U2, unless noted otherwise in the Drawings.

G. Concrete Cover to Reinforcement

G.1 The cover shall be not less than the size of the bar or the maximum aggregate size plus 5 mm. In the case of bundled bars, it shall be equal to or greater than the size of a single bar of equivalent area plus 5 mm.

G.2 Where surface treatment such as grooved finish or bush hammering cuts in to the face of the concrete, the expected depth of the treatment shall be added to the cover.

G.3 The cover to reinforcement should also be determined by considerations of durability under the envisaged conditions of exposure. Minimum cover to reinforcement under particular severe conditions shall be determined by Engineer on site.

H. Tolerances

H.1 In-Situ Construction

H.1.1 Length: The horizontal and vertical dimensions of in-situ concrete members, but not cross-sections, shall be within the following tolerances:

Length (mm)	Tolerance (mm)
Up to 3000	± 3
3001 -4500	± 6
Vertical lines out of plane	± 5 + 1 for every 3000 out of true line

H.1.2 Cross-Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns, piers etc., shall be within the following tolerances:

Member Dimensions (mm)	**Tolerance (mm)**
Up to 500	6
50 l -750	10
Additional for every subsequent 100 mm	± 1 mm

H.2 Pre-cast Construction

H.2.1 Length: The horizontal and vertical dimensions of members, but not cross-sections, shall be within the following tolerances:

Length (mm)	**Tolerance (mm)**
Up to 3000	± 2
3000 and over	± 5

H.2.2 Cross Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns, piers etc., shall be within a tolerances of ± 3 mm.

Member Dimensions (mm)	**Tolerance (mm)**
Up to 500	6
501 - 750	9
Additional for every subsequent 250 mm	± 3 mm

H.3 Squareness

For in-situ and pre-cast construction the tolerance between the short side and the long side shall be wit l the following limits:

Member Dimensions (mm)	**Tolerance (mm)**
Up to 3000	± 3
3000 and over	± 6

H.4 Straightness

For in-situ and precast construction the straightness or bow, defined as deviation form the intended line, shall be within the following tolerances:

Member Length (mm)	**Tolerance (mm)**
Up to 3000	± 3
3000 and over	± 6

H.5 Alignment

The alignment of members shall be within the following tolerances:

Column and piers	1:400 of column or pier length.
Others.	1:600 of length.

H.6 Flatness

The flatness of a surface, measured with a straight edge of 1.5 meter, shall be not greater than 6 mm at any point.

H.7 Twist

Twist, measured as the deviations of any corner from the plane containing the other three corners, shall be within the following limits.

Member Dimensions (mm)	Tolerance (mm)
Up to 6000	6
Above 6000	12

5.06.04 Measurement

The provisions of this Section of the 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 Specifications.

SECTION 5.07 PRESTRESSED CONCRETE CONSTRUCTION

5.07.01 Scope

The Works shall consist of the specifications for prestressing steel, prestressing components, prestressing equipment and plant and construction requirements of prestressed concrete.

5.07.02 Materials

A. Concrete

Concrete for prestressing shall be in accordance with the requirements of Section 5.01 "Concrete and Concrete Mixes and Testing".

B. Prestressing Steel

B.1 Steel Wire: Steel wire shall comply with AASHTO M204 (ASTM A421), or with BS5896.

B.2 Stress-Relieved Seven-Wire Strand: Stress-Relieved Seven-Wire Strand shall comply with AASHTO M203 (A416) or with BS5896.

B.3 High Tensile Steel Bar: High tensile steel bars for prestressed concrete shall comply with AASHTO M275 (ASTM A722) or with BS4486.

B.4 Nineteen-Wire Strand: Nineteen-wire strand shall comply with BS4757.

C. Prestressing Components

Prestressing components, such as cable ducts, anchorages and couplers, shall be of approved types suitable for types of cables and bars used.

D. Grout

Grout shall be water and cement complying with the requirements of Section 5,01 "Concrete and Concrete Mixes and Testing".

E. Epoxy Bonding Agents for Precast Segmental Construction

E.1 Epoxy bonding agents for match cast joints shall be thermosetting 100 percent solid compositions that do not contain solvent or any nonreactive organic ingredient except for pigments required for coloring- Epoxy bonding agents shall be of two components, a resin and a hardener. The two components shall be distinctly pigmented, so that mixing produces a third color similar to the concrete in the segments to be joined, and shall be packaged in preportioned, labeled, ready-to-use containers.

E.2 Epoxy bonding agents shall be insensitive to damp conditions during application and, after curing, shall exhibit high bonding strength to cured concrete, good water resistivity, low creep characteristics, and tensile strength greater than the concrete, in addition, the epoxy bonding agents shall function as a lubricant during the joining of the match cast segments, as a filler to accurately match the surface of the segments being joined, and as a durable, watertight bond at the joint.

E.3 The physical, chemical and mechanical properties of epoxy bonding agents shall satisfy the recommendations of Federation Internationale, de la Precontrainte (FIP) "Proposals for a standard for acceptance tests and verifications of epoxy bonding agents for segmental construction".

5.07.03 Definition

A. Prestressing Steel

Steel wire, strand or bars used for prestressing of concrete.

B. Post-Tensioning

The process when the prestressing steel is tensioned after the concrete has hardened.

C. Pre-Tensioning

The process when the prestressing steel is tensioned against independent anchorages before the concrete is placed round it.

D. Cable and Tendon

Cable and tendon both refer to a bundle of prestressing steel of the same type and size bundled together to be contained within a duct and stressed, individually or collectively, from the same anchorage.

E. Prestressing System

A proprietory system of applying prestress and includes anchorages, couplers and jacks but does not necessarily include prestressing steel and cable ducts.

5.07.04 Construction

A. General

A.1 The Contractor shall submit to the Engineer for his approval full details of the proposed prestressing system and suppliers of the basic materials and components. No system shall be incorporated in the Works until approved by the Engineer.

A.2 Prestressing operations shall be carried out only 'under the direction of an experienced and competent supervisor and all personnel operating the stressing equipment shall have been properly trained in its use. As an addition to the normal precautions against accident for the whole of the work, special precautions shall be taken when working with or near tendons which have been tensioned or are being tensioned.

B. Cable Ducts

B.1 Ducts shall be maintained in their correct positions during placing of the concrete. Where members are made up of precast units stressed together, the ducts in the joints between the units shall be in perfect alignment and joined securely so as to allow unimpeded cable threading and pulling and prevent the ingress of the epoxy mortar used for gluing the several units together before stressing. Details of such joints shall first be approved by the Engineer. The tolerance in the location of the sheath shall be plus or minus 3 mm.

B.2 Joints shall be kept to a practicable minimum and each joint adequately scaled against the ingress of any material. Joints m adjacent sheaths shall be staggered by at least 300 mm.

B.3 Ducts shall be kept free of any matter detrimental to the bond between the sheath and the grout and, except for material sealing a sheath joint, between the sheath and the concrete.

B.4 The ends of all ducts shall be sealed and protected until the tendon is threaded through and the stressing operations are commenced. Where tendons in sheaths or sheath on its own are left exposed to atmosphere, rust inhibitors shall be used as per the maker's specification to prevent rusting and corrosion of the inside of sheaths. They shall be flushed with clean water before the tendons are grouted. The Contractor is responsible for carrying out these measures at his own expense.

C. Prestressing Steel

C.1 All wires or strands stressed at the same time shall be taken from the same parcel. Each cable shall be tagged with its number and the coil number of the steel used.

C.2 Tendons shall not be welded within the length to be tensioned and, unless other methods of cutting are approved by the Engineer, tendons shall be sawn or cropped using an abrasive-disc cutter.

C.3 Tendons shall be built into the work strictly in accordance with the system which is being employed.

C.4 Tendons shall not be kinked or twisted and individual wires or strands shall be readily identifiable at each of the members. No strand which has become unravelled shall be used in the work.

D. Anchorages

D.1 All anchorages shall be approved cast anchorages. Anchor cones, blocks and plates shall be positioned and maintained during concreting so that the centerline of the duct passes axially through the anchorage assembly.

D.2 All bearing surfaces of the anchorages shall he clean prior to concreting and tensioning.

D.3 If proprietary forms of anchorage are used, the anchoring procedure shall be strictly in accordance with the manufacturer's instructions and recommendations.

D.4 Any allowance for draw-in of the tendon during anchoring shall be in accordance with the Engineer's instructions, and the actual slip occurring shall be recorded for each individual anchorage.

E. Jacks for Prestressing

E.1 All jacks used for prestressing shall be of the type applicable to the system adopted. The accuracy of the load metering equipment shall be checked to the satisfaction of the Engineer at the start of the work each day it has to be used and whenever the equipment is moved to a different job.

E.2 Documentary proof shall be provided confirming that all jacks have been fully over-hauled and checked by an agent approved by the manufacturer of the equipment. Each jack shall be accompanied by a test certificate indicating that it has been tested and calibrated by the manufacturer or by an approved testing laboratory up to a load equal to the full capacity of the jack within a period of two years prior to the commencement of prestressing.

E.3 All gages, load cells, dynamometers and other devices used for measuring the stressing force shall have an accuracy of within plus or minus 1.5 percent. Pressure gages shall have a capacity and calibrated cell such that the working pressure required to stress the tendons to the fully slated load lies within the central half of the range of the gage.

E.4 Each gage shall have a calibration certificate issued by an approved test laboratory. All pressure gages shall be so constructed that they may be calibrated, cither directly by an approved testing laboratory, or by compressing with a meter gage which has itself been calibrated by an approved testing laboratory.

E.5 All pressure gages shall be re-calibrated before use and at intervals of 14 days during the prestressing operation. The Engineer will order re-calibration of any pressure gage at any time should he have reason to suspect damage to or faulty operation of the gage.

E.6 The accuracy of all prestressing and load measuring equipment shall be checked whenever required by the Engineer. The Contractor shall provide a rig suitable in the opinion of the Engineer, for all checking and calibration of any jacking system consisting" of jacks and associated load devices, pressure gages and dynamometers.

F. Grout for Ducts

F.1 Unless otherwise directed or agreed as a result of grouting trials, the grout shall consist only of ordinary Portland cement and water. The water cement ratio shall be as low as possible consistent with necessary workability and under no circumstances be higher than 0.45 and not be subject to bleeding in excess of 2 percent after 3 hours, or 4 percent maximum. When measured at 18 degrees C in a covered glass cylinder approximately 100 mm water shall be reabsorbed after 24 hours.

F.2 Grout shall be mixed for a minimum of two minutes and until a uniform consistency is obtained. The pumpability of the grout may be determined in accordance with the US Corps of Engineers Method CRD-C79 in which case the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds.

F.3 Admixture containing chlorides or nitrates shall not be used. Other admixtures may be used only with the written permission of the Engineer and shall be applied strictly in accordance with the manufacturer's instruction.

F.4 The design for grout mix shall be tested in accordance with ASTM C49 for longitudinal change. Each design mix and each batch mix shall be tested for vertical dimensional change:

G. Plant for Grouting

G.1 The grout mixer shall produce a grout of colloidal consistency. The grout injector shall be capable of continuous operation with a sensibly constant pressure up to 0.7 Newtons per square millimeter and shall include a system of circulating or agitating the grout while actual grouting is not in progress. All baffles to the pump shall be fitted with sieve strainers of 1.0 mm nominal aperture size to ASTM E11. The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a nozzle which can be locked off without loss of pressure in the duct.

G.2 The pressure gages shall be calibrated before they are first used in the work and thereafter as required by the Engineer, All equipment shall be thoroughly washed with clean water at least once every 3 hours during the grouting operations and at the end of use each day.

5.07.05 Post-Tension Construction

A. General

A.1 Immediately before tensioning, the Contractor shall prove that all tendons are free to move between jacking points and that members are free to accommodate the horizontal and vertical movements due to the application of prestress.

A.2 Unless otherwise specified, concrete shall not be stressed until it has reached the age at which at least 2 test specimens taken from it attain the specified transfer strength. The test specimens shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast sufficient specimens to demonstrate that the required strength of the concrete at transfer has been reached.

A.3 Where members consist of jointed elements the strength at transfer of the jointing material shall be at least equivalent to the specified transfer strength of the member.

B. Tension Procedures

B.1 The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the Engineer.

B.2 The Contractor shall add to the specified forces and allowance where necessary for anchorage friction, wedge pull-in, jack losses and friction due to duct alignment and curvature. The total forces and calculated extensions shall be submitted to the Engineer's approval before stressing is commenced.

B.3 Immediately after anchoring, the stresses in the tendons shall not exceed 75 percent of their ultimate tensile strength. During stressing the value shall not exceed 80 percent.

B.4 The tendons shall be stressed at a gradual and steady rate until they attain the force and extension specified.

B.5 If the measured extension differs by more than 5 percent from the estimated extension, corrective action shall be taken as directed by the Engineer.

B.6 The force in the tendons shall be obtained from reading on a load cell or pressure gage, and the extension of the tendons measured. Due allowance must be made for taking up slack in the tendons.

B.7 Stressing shall be from both ends unless otherwise specified or agreed by the Engineer.

B.8 Where stressing from one end only, the pull-in at the end remote from the jack shall be accurately measured and the appropriate allowance made in the measured extension at the jacking end.

B.9 When the specified force, including any overload of short duration, has been applied, to the satisfaction of the Engineer, the tendons shall be anchored. The Jack pressures shall then be released in such a way as to avoid shock to the anchorage of tendons.

B.10 If the pull-in of the tendons at completion of anchoring is greater than that stipulated by the Engineer, tensioning shall be carried out afresh.

B.11 If it is necessary to cut the tendons to enable the ducts to be grouted, this shall be delayed as long as practicable up to the time of grouting. In all other cases, unless agreed otherwise by the Engineer, the tendons shall not be cropped less than 3 days after grouting. Grouting and cropping operations shall not proceed prior to the Engineer's written approval of the measured extensions.

B.12 The Contractor shall keep full and detailed records of all tensioning operations, including the measured extensions, pressure gage or load cell readings and the amount of pull-in at each anchorage. Copies of these records shall be supplied to the Engineer within 24 hours of each tensioning operation.

C. Grouting Procedures

C.1 Grouting trials shall be undertaken when required by the Engineer, All anchorages shall be sealed before grouting. Ducts shall not be grouted when the air temperature in the shade is lower than 3 degrees C. Grout shall not be above 32 degrees C during mixing or pumping and, if necessary, the mixing water shall be cooled.

C.2 All ducts shall be thoroughly cleaned by means of compressed air. Ducts formed without sheathing shall be filled with water at least one hour before grouting- Sheathed ducts shall not be filled with water unless required by the Engineer. Where ducts have been filled with water it shall be blown out by compressed air.

C.3 Ducts shall be grouted as soon as practicable after the tendons have been stressed and the Engineer's permission to commence has been obtained- The duels shall be completely filled with grout. Grout shall be injected in one continuous operation and allowed to flow from the vents until the consistency is equivalent to that being injected.

C.4 Vents shall be sealed consecutively in the direction of flow and the injection tube sealed under pressure until the grout has set. The filled ducts shall be protected to the satisfaction of the Engineer to ensure that they are not subjected to shock or vibration for 1 day and that the temperature of the grout in them does not fall below 3 degrees C for three days after its injection. Two days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good if necessary.

C.5 The Contractor shall keep fully detailed records of grouting including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. Copies of these records shall be supplied to the Engineer within three days of grouting.

C.6 Where required by the Engineer, the Contractor shall provide facilities and attendance for the radiographic testing of ducts.

5.07.06 Pre-Tension Construction

A. In pretensioned members where tendons are specified as debonded from the concrete, they shall be covered with sleeves of PVC or other material approved by the Engineer. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

B. Unless otherwise agreed by the Engineer, tendons shall be stressed in accordance with the requirements of this Specification.

C. Members shall be free to accommodate the horizontal and vertical movements due to the application of prestress.

D. When the concrete has attained the specified strength, the load shall be transferred gradually without severance of the tendons. The tendons shall then be trimmed back flush to the face of the concrete and specified protection applied to their ends.

E. All members shall be indelibly marked to show the specified member mark, the production line on which they were manufactured, the date on which the concrete was cast, the load applied and, if they are of symmetrical section, the face which will be uppermost when the member is in its correct position in the Work. The markings shall be so located that they are not exposed to view when the member is in its permanent position.

5.07.07 Testing

A. Prestressing Steel

A.1 Before approval, at least two samples of the prestressing steel shall be tested at an approved independent laboratory for chemical composition, mechanical strength, relaxation and physical characteristics to the following standards:

- Wires - AASHTO M204 (ASTM A421) or BS5896
- Bars - AASHTO M275 (ASTM A722) or BS4486
- Seven-Wire Strands - AASHTO M203 (ASTM A416) or BS5896.
- Nineteen-Wire Strands - BS4757.

A.2 Subsequently, the Engineer may require additional samples, selected at random from materials on site, to be similarly tested.

A.3 When compression grips are used, not less than six, selected at random, shall be tested to failure using strands to be used in the Works. The test will be witnessed by the Engineer or his appointed representative.

B. Anchorages

B.1 Before approval, at least two anchorages shall be tested at an approved laboratory to BS4447. Subsequently, the Engineer may require additional samples, selected at random from materials on site, to be similarly tested.

B.2 For each anchorage type used in (be Works, the characteristic value of anchorage efficiency, determined in accordance with BS4447, shall be not less 90%.

C. Epoxy Bonding Agents

Epoxy bonding agents shall be tested for and satisfy the requirements of all the tests listed in the recommendations of FIP "Proposal for a standard for acceptance tests and verification of epoxy bonding agents for segmental construction".

D. Grout

Where the grouting operation is interrupted or where a blockage or suspected blockage occurs or where leakage of grout occurs at locations other than at grout tubes, the Engineer shall order radiographic tests to be carried out at specific locations. Strict safety precautions shall be taken during radiography, and the storage, transportation and handling of radioactive materials shall meet current World Health recommendations.

5.07.08 Measurements

A. What to Measure

A.1 Prestressing steel shall be measured by the weight in tones for each size and quality of wire, strand or bar installed and accepted.

A.2 In post-tensioning work, the prestressing steel shall be the actual length between the outermost surface of the anchorages except where couplers are used in which case, the prestressing steel shall be assumed to be continuous, without any flares, through the coupler.

A.3 In pre-tension work, the prestressing steel shall be the actual length between the outermost faces of the member.

B. Items not Measured

B.1 Cable ducts, duct couplers, grout tubes and steel chairs for the correct duct/tendon location are not measured for payment.

B.2 Anchor blocks for use in pre-tension work are not measured for payment.

B.3 Prestressing steel used in connection with temporary works are not measured for payment even if such steel is left permanently in the member.

B.4 Epoxy bonding agent used in precast segmental construction shall not be measured for payment.

B.5 Shear keys and location dowels used in precast segmental construction shall not be measured for payment.

B.6 Prestressing steel and anchorages used for applying temporary prestress to glued segments shall not be measured for payment.

B.7 Anchorages and couplers shall not be measured for payment.

C. Inclusion in the Rates

The rates for items entered in the Bill of Quantities shall include for:

- Items not measured.
- Cement, water and additive used in making the grout.
- All prestressing equipment and its calibration.
- Plant, equipment and labour for all stressing and grouting operations, including making good all anchorage pockets as shown on the Drawings or as directed by the Engineer.
- All testing required in the Specifications.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Prestressing wires (state size and type)	Tonne (T)
(2) Prestressing strands (state size and type)	Tonne (T)
(3) Prestressing bars(state size and type)	Tonne (T)

SECTION 5.08 NOT APPLICABLE

SECTION 5.09 CONCRETE BRIDGES & ERECTION PROCEDURES

5.09.01 Scope

This work shall consist of erecting bridge structures and decks in the conformity with the lines, grades and dimensions shown on the Drawings and in accordance with the Specification.

5.09.02 Materials

The materials shall, conform to the requirements of the following sections of the Specification:

Concrete	Sections 5.01 and 5.02
Forms and Falsework	Section 5.04 "Forms, Formwork and Falsework"
Reinforcement	Section 5.03 "Steel Reinforcement and Fixing"
Prestressing	Section 5.07 "Prestressed Concrete Construction"

5.09.03 Construction

A. Balanced Cantilever Construction With in-Situ Concrete

A.1 General

A.1.1 This work consists of installing temporary bearings, casting concrete units in-situ and setting the superstructure on permanent bearings. The Contractor shall submit complete details and descriptions of all methods, arrangements and equipment which he intends to adopt, for approval before construction work is started.

A.1.2 The construction method shall include casting of units, method of the tie-down of superstructure during cantilever construction, method of application of all temporary forces to be used for adjusting horizontal and vertical alignment and to place the structure on permanent bearings, details of work plans and safety measures. This shall also include control methods to ensure the accuracy of alignments of the constructed superstructure. Work equipment shall include all machinery devices, labor and material which are to be used for construction but will not become a permanent part of the completed superstructure. Equipment must not be operated for or placed upon any part of the superstructure at any stage of construction other than that which specifically meets the requirements of total working load per unit, as by the planning and/or has the approval of the Engineer. This includes the post-tensioning, jointing, jacking, grouting equipment and other equipment whatsoever, men and materials of any kind.

A.2 Unbalanced Load

A.2.1 During construction the cantilever can be unbalanced by only one unit at any time and be consistent with the holding-down method adopted. In addition to the unbalanced load due to 1 unit, 0.5 kN/m2 load is permissible anywhere on the cantilever. This load includes men, miscellaneous equipment and stored materials. It is the Contractor's responsibility to take great care to ensure that this allowable load is not exceeded.

A.3 Construction Schedule

A.3.1 The Contractor shall submit a construction schedule showing the chronological order of every phase and stage of erection and construction of the superstructure. The Contractor shall prepare a table of elevations and alignments required at each stage of construction at the check points listed below, or an alternative of his choice and submit the same for the Engineer's approval. The check points are:

One of the lowest corners at the top surface of any temporary bearing pad which is to be used as datum during construction.

All four corners of the top slabs of the pier units to establish grade and top levels. Two points on the longitudinal center line of each pier unit, one on each end to establish alignment.

One point on the longitudinal center line, and at least on one corner of each unit along every joint between cast-in-place units to establish elevations and alignments at every stage of construction.

A.3.2 The alignment and elevations of the cantilever shall be checked by the Contractor and the Engineer independently within 1 hour of sunrise on each day that the units are to be cast. The measurements made by the Engineer and the Contractor shall agree to within 5 mm.

A.3.3 The temporary bearing pads at the piers shall be very carefully placed. The top surface of these pads must have the correct elevations, alignments and slopes as required by the working drawings and as established by the procedure described above, Shims may be used underneath the pads to accomplish accuracy. The Contractor shall check elevations and alignment of the structure at every stage of construction and must maintain a record of all these checks and of all adjustments and corrections made.

A.4 Casting Procedures

A.4.1 Casting of the units shall not begin until approval of the working drawings, calculations and the post-tensioning system has been given.

A.4.2 Sequence. The units shall be match cast beginning with each pier unit. After the pier unit is cast all units on either side of the pier unit may be cast in order so long as match casting is maintained.

A.4.3 Set-up. Care should be exercised in the set-up of each unit- All materials to be encased within the concrete of the segment shall be properly positioned and supported. Before any concrete is placed, the set up will be thoroughly inspected and checked. All ducts shall be located within 5mm of the location given on approval drawings. The top surface of the units shall be free of depressions or high spots.

A.4.4 Forms shall not be removed until the concrete has achieved the compressive strength specified on the working drawings and has been proved by test cylinders made and cured in the same manner as the unit. Care shall be taken in removing the forms to prevent spalling and chipping of the concrete.

A.5 Tolerances

A.5.1 Formwork for box girder segments must satisfy the following tolerances:

- Web thickness. +10 mm or -5 mm.
- Thickness of bottom slab +5 mm, but 0 reduction in depth.
- Thickness of lop slab +5 mm, but 0 reduction in depth.
- Overall width of unit. ±5 mm.
- Overall depth of unit, ±5 mm.
- Length of match cast unit, ± 10 mm.
  but not cumulative and a maximum of 50mm per span.
- Diaphragm dimensions, +10 mm or -5 mm.
- Grade at lop and bottom flanges. ±3.

A.5.2 After erection, final post-tensioning, final corrections and adjustments are completed and the structure has been placed on its permanent hearings, the superstructure shall conform to the grade and alignment shown on the working drawings with due consideration for creep and superimposed load and dead load deflections within a tolerance of ±5.0.mm horizontally and ±10.0mm vertically.

B. Glued Pre-cast Segmental Construction

B.1 General

B.1.1 Where bridge decks are pre-cast in segments and assembled in position for glueing and stressing, the Contractor shall satisfy the Engineer that his proposed construction method will achieve the required standard of workmanship and finish in the time available. The Contractor is required to submit details for approval of all his forms, Falsework, pre-casting factory and his method of lifting, transporting, assembling, supporting, threading cables, glueing and stressing the pre-cast units before commencement of any work-

B.2 Epoxy Adhesive

B.2.1 The epoxy resin adhesive shall be supplied by an approved manufacturer.

B.2.2 It shall be made up and packaged by approved formulators and to specifications agreed by the Engineer.

B.2.3 The material shall be supplied in accurately measured packs with the pack containing the hardener clearly distinguished by both size and labeling. The pack containing the resin shall be large enough to permit the addition of the hardener. Resin and hardener shall be pigmented with dissimilar colours to indicate when even mixing has been completely attained and to produce an even gray colour to match the concrete.

B.2.4 Each batch of resin mixed shall be tested for setting by compression and shear tests as described below. No permanent prestress shall be applied to a joint until the epoxy has achieved the required strength. Should this test show that the resin is not selling the joint shall be broken and the resin removed. Set resin shall be removed by grit blasting. Further tests may be requested by the Engineer at various times 10 ensure that the material as mixed is complying with the Specification.

B.2.5 All the instructions of the manufacturer and/or the formulator shall be submitted to the Engineer for agreement. Such agreed instructions shall be adhered to in all respects.

B.2.6 The supplier shall carry out a programme of testing as described in FIP "Proposal for a standard for acceptance tests and verification of epoxy bonding agents for segmental construction", after consultation with the Engineer on the range of temperatures and work cycles that are to be considered in the tests. The Engineer may require the tests to be witnessed either in person or by an approved independent authority.

B.3 Surface Preparation

B.3.1 The interface of the units shall be lightly grit blasted before erection to remove laitance- Before applying the epoxy the interfaces must be clean and free from laitance or any bond breaking material. Any oil or grease which may be harmful shall be removal. The surface shall have no free moisture.

B.4 Application of Epoxy

Application shall begin immediately a batch has been mixed. Application shall be to both interfaces to a total nominal Thickness of 2 mm with a spatula or by hand. No epoxy may be applied within 25mm of any duct.

B.5 Preliminary Prestress

B.5.1 Immediately the interfaces are coated with epoxy, the unit shall be brought into position and the preliminary prestress applied. This preliminary prestress is to be just sufficient to start squeezing epoxy resin out of the joint. The amount of prestress required will depend on the formulation of resin chosen by the Contractor. If this operation is not completed with the contract time of the First batch of epoxy to be applied the units shall be moved apart. All the epoxy on both interfaces shall he removed with spatulas and an approved solvent. No epoxy may be applied to the joint until 24 hours after a solvent has been used. The contract time shall be reckoned from the end of the pot life unless the manufacturer's instructions direct otherwise. All excess epoxy shall be cleaned off from the outer faces of the webs and the soffit in such away as not to. smear the concrete face.

B.6 Records of Joining

The Contractor shall keep a record of each joint with the following details:

- Joint Number
- Dale and Time of jointing
- Batch number of resin and hardener
- Weather conditions (temperature and humidity) continuously recorded
- Results of tests

B.7 Tolerances

These shall be similar to those prescribed for balanced cantilever construction.

C. Precast Beam and Slab Construction

C.1 Manufacture of Prestressed beams

C.1.1 The details of method of manufacture shall be approved by the Engineer before work is started. No changes shall subsequently be made without the consent of the Engineer.

C.1.2 The Contractor shall inform the Engineer in advance of the date of commencement of manufacture and the dates when tensioning of tendons, casting of members and transfer of stress will be undertaken for the first lime for each type of beam.

C.1.3 The Contractor shall submit to the Engineer, not more than 7 days after the transfer of stress, a certificate showing the force and strain in the tendons immediately after they were anchored, the strength and age of the lest cylinders cast in accordance with this Specification, and the minimum age in hours of the concrete at the lime stress was applied to the members. Copies of all 28 day cylinder test results relating to the work shall be kept so that the identity of those who stressed the tendons, cast the concrete and transferred the stress, on any member or line of members, can be traced.

C.1.4 Where the Engineer requires tests to be carried out on beams, the beams to which these tests relate, shall not be dispatched to Site until the tests have been satisfactorily completed.

C.2 Storage and Handling of Prestressed Members

Members shall be firmly supported at such bearing positions as will ensure that the stresses induced in them are always less than the permissible design stresses. Members shall be lifted or supported only at the points specified and shall be handled and placed without impact.

C.3 Tolerance in Pre-Cast Member

Dimensional Variations shall not exceed the tolerances given below:

- Length	± 12 mm
- Width and depth	± 6 mm
- Bow in the vertical plane	+ 15 mm or 0-mm
- Bow in the horizontal plane	± 12 mm
- Difference between longest and shortest dimensions (check for squareness of beam) in any plane	6 mm
- Twist (measured by the deviation of any corner from the plane containing the other 3 corners)	6 mm
- Flatness (the maximum deviation from a 1.5 meter straight-edge placed in any position on nominally plane surface)	6 mm
- Cover to reinforcement	+ 5 or -0 mm
- Prestressing tendons	3 mm in any direction
- Dowel holes	3 mm in any direction

C.4 Composite Slab Construction

C.4.1 Where in-situ concrete deck is cast to act compositely with pre-cast beams, the beams shall be installed to correct line and level, starting from the outer most beam and working inwards progressively. When the beams are laid side by side just before erection the difference in soffit level between adjacent beams shall nowhere exceed 6 mm. Where permanent soffit shutters are used, they shall be to the approval of the Engineer and they shall be fixed securely so that there is no movement or grout loss during deck concreting.

C.4.2 The in-situ concrete deck over any one span shall be poured in one continuous operation and shall be placed in such a sequence that the advancing edge of the

freshly deposited concrete over the full width of deck or between longitudinal construction joints is approximately parallel to the deck supports. Lateral displacement of beams shall be prevented during the placing of in-situ concrete.

C.4.3 The width of the in-situ deck shall be within +25 mm of that specified. On curved bridge deck, the in-situ deck may be in a series of straights such that the width is within +25 mm of that specified.

D. In-situ Construction

Where bridge decks are constructed in-situ, the details of all forms and falsework shall first be approved by tile Engineer. Dimensional variations shall not exceed the following tolerances:

- Length ± 12 mm
- Width ± 10 mm
- Thickness ± 6 mm
- Levels ± 10 mm or-0 mm
- Void Location 6 mm in any direction
- Cover to reinforcement + 5 mm or -0 mm
- Prestressing tendons 5 mm in any direction

5.09.04 Measurement

The provisions of this Section of the Specification 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 Specifications.

SECTION 5.10 NOT APPLICABLE

SECTION 5.11 NOT APPLICABLE

SECTION 5.12 NOT APPLICABLE

SECTION 5.13 NOT APPLICABLE

SECTION 5.14 DRAINAGE AND UTILITY STRUCTURES

5.14.01 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

5.14.02 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.

5.14.03 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.

5.14.04 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 5

CONCRETE, STEEL AND STRUCTURE (3/3)

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SECTION 5.15 WATERPROOFING FOR STRUCTURES

5.15.01SCOPE

This work shall consist of furnishing and placing approved waterproofing, membrane and damp proofing course to external concrete surfaces in contact with earth and furnishing and placing epoxy coating to internal surfaces of concrete walls, slabs, and beds and furnishing and installing waterstops to waterproof construction and expansion joints. all as shown on the Drawings or as directed by the Engineer.

5.15.02MATERIALS

A. Asphalt

A.1 Waterproofing asphalt shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, AASHTO M 115 (ASTM D449). NOTE: Type I is for use below ground and Type II for use above ground.

A.2 Primer for use with asphalt in waterproofing shall conform to the Specifications for primer for Use With Asphalt in Dampproofing and Waterproofing. AASHTO Ml16 (ASTM D41).

B. Bitumen

B.1 Waterproofing bitumen shall conform to the Specification for Coal-Tar Bitumen for Roofing Dampproofing, and Waterproofing, AASHTO M118 (ASTM D450). Type II shall be furnished unless otherwise specified.

B.2 Primer for use with coal-tar bitumen in dampproofing and waterproofing shall conform to the Specification for Creosote for Priming Coat with Coal-Tar Pitch in Dampproofing and Waterproofing, AASHTO M121 (ASTM D43).

C. Fabric

The fabric shall conform to the Specification for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing, AASHTO M 117(ASTM D173).

C.1 Self-Adhesive Polyethylene Sheet

Flexible, preformed waterproof membrane comprising strong, high density polyethylene film with self-adhesive rubber/bitumen compound, and having the following minimum properties:

- Total thickness : 1.5 mm
- Weight : 1.6 kg/m^2
- Ensile strength : 42 N/mm^2
- Elongation : 210% long.; 160% trans.
- Tear resistance : 340 N/mm long.; 310 N/mm trans.
- Puncture resistance : 220 N 65 mm
- Man: servicised ltd.
- Ref: bitu-thene 1000x hc
- Or other equal and approved.

D. Tar for Absorptive Treatment

Tar for absorptive treatment shall be a liquid water-gas tar that conforms to the following; requirements:

Specific gravity, 25/25°C.....1.030 to 1.100
Specific viscosity at 40°C (Engler), not more than 3.0
Total distillate, percent by weight, to 300°C, not more than 50.0
Bitumen (soluble in carbon disulfide) not less than, percent 98.0
Water, not more than percent 3.0

E. Tar Seal Coat

Tar seal coat shall conform to the Specifications for Tar for Use in Road Construction, AASHTO M52 Grade RTCB-5 (ASTM D490).

F. Joint Fillers

Filler for use in horizontal and vertical joints in waterproofing work shall be a straight refined oil asphalt conforming to the following requirements:

- Flash point: Not less than 232°C.
- Softening point: 48.9°C to 54.4°C.
- Penetration: At 0°C, 200 grams, 1minute, not less than 1 5.AT 25°C, 100 grams, 5 seconds, 50 to 60. At 46°C, 50 grams, 5 seconds, not more than 300.
- Loss on heating: At 163°C, 50 grams, 5 hours, not more than 0.5 percent.
- Ductility: At 25°C, 5 centimeters per minute, not less than 85.
- Total bitumen (soluble in carbon disulfide): not less than 99.5 percent.

G. Waterstops

G.1 PVC Water Bars: Extruded PVC, heavy duty, of the types and sizes shown on the Drawings, and complete with junction pieces.

- Man: Expandite Ltd .
- Man: Greenstreak Plastic Products
- Man: Servicised Ltd
- or other equal and approved.

G.2 Copper Water Stops: Copper water stops shall be copper sheets of the thickness shown on the Drawings and shall conform to the requirements of AASHTO M138 (ASTM B 1 52).

G.3 Rubber Water Stops: Plain rubber water stops shall be formed iron a stock composed of a high grade compound made exclusively from new plantation rubber, reinforcing carbon black, zinc oxide, accelerators, anti-oxidants, and softeners. This compound shall contain not less than 72 percent by volume of new plantation rubber. The tensile strength shall be not less than 246kg per sq.cm, with an elongation at breaking of 550 percent when tested in accordance with ASTM D412. The unit stresses producing 300 percent and 500 percent elongation shall be not less than 77kg. and l98kg. per cm^2, respectively. The Shore Durometer indication (hardness) shall be between 55 and 65 when tested in accordance with ASTM D676. After 7 days in air at 126 degrees (plus or minus 1 degree) C or after 48 hours in oxygen at 126 degrees (plus or minus 1 degree) C both at 21kg per cm^2, the tensile strength and elongation shall not be less than 65 percent of the original when tested in accordance with ASTM D572.

G.4 Synthetic Rubber Water Stops: Synthetic rubber water stops shall be formed from a compound made exclusively from neoprene, or SBR, reinforcing carbon black, zinc oxide, polymerization agents, and softeners. This compound shall contain not less than 70 percent by volume of neoprene or SBR. The tensile strength shall be not less than 175kg per square centimeter with an elongation at breaking of 425 percent when tested in accordance with ASTM D412. The Shore Durometer indication (hardness) shall be between 50 and 70 when tested in accordance with ASTM D676. After 7 days in air at 126 degrees (plus or minus 1 degree) C or after 48 hours in oxygen at 126 degrees (plus or minus 1degree) C, and 21 kg per cm2 pressure, the tensile strength shall be not less than 65 percent of the original when tested in accordance with ASTM D572.

H. Proprietary Waterproofing Systems

Proprietary waterproofing systems shall be bituminous membranes reinforced with layers of suitable reinforcement, bituminous coated polythene sheet, plasticized polyvinyl chloride sheet, other approved membranes or applications of resinous reinforced coatings. The type to be used shall be either defined on the Drawings or shall be chosen by the Engineer on site according to its location and serviceability. The specific system shall be approved after site trials, should the Engineer decide these to be necessary.

I. Epoxy Coating System

An approved epoxy coating system shall be furnished and applied to the internal concrete surfaces of culverts and open channels as shown on the Drawings or as directed by the Engineer. The thickness of the epoxy coating shall be at least 400 (microns) in accordance with the manufacturer's recommendations.

5.15.03SURFACE PREPARATION

A. Waterproofing

A.1 All surfaces which are to be waterproofed shall be reasonably smooth and free from projections or holes which might cause puncture of the membrane. The surface shall be dry, so as to prevent the formation of steam when the hot asphalt or tar is applied, and, immediately before the application of the waterproofing, the surface shall be thoroughly cleaned of dust projecting tying wire and loose material.

A.2 No waterproofing shall be done in wet weather nor when the temperature is below 4 degrees C, without special authorization from the Engineer. Should the surface of the concrete become temporarily damp it shall be covered with a 2-inch (50mm) layer of hot sands, which shall be allowed to remain in place from 1 to 2 hours or long enough to produce a warm and surface-dried condition after which the sand shall be swept back uncovering sufficient surface for beginning work and the operation repeated as the work; progresses.

B. Dampproofing

The surface to which the dampproofing coating is to be applied shall be cleaned of all loose and foreign material and dirt and shall be dry. When necessary, the Engineer may require the surface to be scrubbed with water and a stiff brush, after which the surface shall be allowed to dry before application of the primer.

5.15.04INSTRUCTION DELIVERY AND STORAGE

A. All waterproofing materials shall be tested before shipment. Unless otherwise ordered by the Engineer they shall be tested at the place of manufacture and when so tested a copy of the test results shall be sent to tile Engineer by tile chemist or inspection bureau which has been designated to make the tests and each package shall have affixed to it a label seal or other mark of identification showing that it has been tested and found acceptable and identifying the package with the laboratory tests.

B. Factory inspection is preferred but in lieu thereof, the Engineer may order that representative samples properly identified be sent to him for test prior to shipment of the materials. After delivery of the materials representative check samples shall be taken which shall determine the acceptability of the materials.

C. All materials shall be delivered to the work in original containers plainly marked with the manufacturer's brand or label.

D. Waterproofing and dampproofing material shall be stored in a dry protected place. Rolls of waterproofing fabric and membranes shall not be stored on end

5.15.05CONSTRUCTION

A. Asphalt and Bitumen Waterproofing Membranes

A.1 Asphalt shall be heated to a temperature between 148.7 degrees C and 176.5 degrees C and tar for hot application shall be heated to a temperature between 93.3 degrees C and 121 degrees C with frequent stirring to avoid local overheating. The heating kettles shall be equipped with thermometers.

A.2 In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed, so that water will run over and not against or along the laps.

A.3 The first strip of fabric shall be of half-width; the second shall be full-width, lapped the full-width of the first sheet; and the third and each succeeding strip shall be full-width and lapped so that there will be two layers of fabric at all points with laps not less than 0.051m wide. All end laps shall be at least 0.305m.

A.4 Beginning at the low point of the surface to be waterproofed, a coating of primer shall be applied and allowed to dry before the first coat of asphalt is applied. The waterproofing shall then be applied as follows.

A.5 Beginning at the low point of the surface to be waterproofed, a section about 0.5m wide and the full length of the surface shall be mopped with the hot asphalt or tar, and there shall be rolled into it, immediately following the mopping, the first strip of fabric, or half-width, which shall be carefully pressed into place so as to eliminate all air bubbles and obtain close conformity with the surface. This strip and an adjacent section of the surface of a width equal to slightly more than half of the width of the fabric being used shall then be mopped with hot asphalt or tar, and a full width of the fabric shall be rolled into this, completely covering the first strip, and pressed into place as before. This second strip and an adjacent section of the concrete surface shall then be mopped with hot asphalt or tar and the third strip of fabric "shingled" on so as to lap the first strip not less than 0.051m. This process shall be continued until the entire surface is covered, each strip of fabric lapping at least 0.051m over the last strip. The entire surface shall then be given a final mopping of hot asphalt or tar.

A.6 The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt or tar, together with a coating of primer. Under no circumstances shall one layer of fabric touch another layer at any point or touch the surface, where must be at least three complete moppings of asphalt or tar.

A.7 In all cases the mopping on concrete shall cover the surface so that no gray spots appear and on cloth it shall be sufficiently heavy to completely conceal the weave. On horizontal surfaces not less than 48.9 ltr of asphalt or tar- shall be used for each 10.0 sq.m of finished work and on vertical surfaces not less than 61.12 ltr shall be used. The work shall be so regulated that at the close of a day's work all cloth that is laid shall have received the final mopping of asphalt or tar. Special care shall be taken at all laps to see that they are thoroughly sealed down.

A.8 At the edges of the membrane and at any points where it is punctured by such appurtenances as drains or pipes suitable provisions shall be made to prevent water from getting between the waterproofing and the waterproofed surface.

A.9 All flashing at curbs and against girders spandrel walls etc. shall be done with separate sheets lapping the main membrane not less than 0.305m. Flashing shall be closely sealed either with a metal counter-flashing or by embedding the upper edges of the flashing in a groove poured full of joint filler.

A.10 Joints which are essentially open joints but which are not designed to provide for expansion shall first be caulked with oakum and lead wool and then filled with hot joint filler.

A.11 Expansion joints both horizontal and vertical shall be provided with sheet copper or lead in "U" or "V" form in accordance with the details. After the membrane has been placed the joint shall be filled with hot joint filler. The membrane shall be carried continuously across all expansion joints.

A.12 At the ends of the structure the membrane shall be carried well down on the abutments and suitable provision made for all movement.

B. Proprietary Waterproofing Membranes

Proprietary waterproofing membranes shal1 be installed strictly in accordance with the manufacturer's instructions and shall be laid so that no air is trapped between it and the concrete surface or between successive layers of sheeting. Unless otherwise specified joints between sheets shall be lapped with end laps of at least 150mm and side laps of al least 100mm. The joints shall be arranged so that at no points are there more than three thicknesses of sheeting and as far as possible so that water will drain away from the exposed edge.

C. Damage Patching of waterproofing Membranes

C.1 Care shall be taken to prevent injury to the finished membrane by the passage over it of men or wheelbarrows, or by throwing any material on it. Any damage which may occur shall be repaired by patching. Patches shall extend at least 0.305m beyond the outermost damaged portion and the second ply shall extend at least 0.076m beyond the first.

C.2 Proprietary waterproofing membranes shall be repaired according to the manufacturer's specifications and as directed by the Engineer.

D. Dampproofing

D.1 Concrete, brick, or other surfaces that are to be protected by dampproofing shall be thoroughly clean before the primer is applied. They shall then be brush or spray painted with two or more coats (as indicated on the Drawings) of tar or asphalt for absorptive treatment. Below ground not less than two coats shall be applied, using 0.56 ltr per sq.m. of surface. On the well-primed surface one application of tar or asphalt seal coat shall be applied by brush, using 0.45 ltr per sq.m.

D.2 Care shall be taken to confine all paints to the areas to be waterproofed and to prevent disfigurement of any other parts of the structure by dripping or spreading of the tar or asphalt.

E. Protection of Waterproofing and Dampproofing

E.1 Over the waterproofing membrane and dampproofing course, there shall be constructed a protection course which, unless otherwise specified or shown on the Drawings, shall be a 0.05m course of mortar mixed in the proportion of one part Portland cement and two parts sand. This mortar course shall be reinforced midway between its top and bottom surfaces with wire netting of 0.15m mesh and No. 12 gauge, or its equivalent. The top surface shall be troweled to a smooth, hard finish and, where required, true to grade.

E.2 The construction of the protection course shall follow the waterproofing so closely that the latter will not be exposed without protection for more than 24 hours.

E.3 Unless otherwise shown on the Drawings or directed by the Engineer, vertical faces waterproofed or dampproofed shall be protected by a porous concrete block wall of not less than 225mm thickness. If approved by the Engineer, a proprietary synthetic sheeting may be used as the protective layer in lieu of the porous concrete block wall.

F. Water Stops

F.1 Copper Water Stops: Copper sheets for water stops shall be of the width and shall be bent to the shapes shown or ordered. The sheet copper in each joint shall be continuous, separate pieces being connected by thoroughly workmanlike soldered joints to form a complete watertight unit. The sheet copper shall be placed in such manner as to ensure its embedment in the concrete on each side of the joints in the positions shown on the Drawings.

F.2 Rubber Water Stops: Rubber water stops shall be installed in accordance with the details shown on the Drawings. The water stops shall be formed with an integral cross section which shall be uniform within 3mm in width and the web thickness or bulb diameter, within plus 1.5mm and minus 0.75mm. No splices shall be permitted in straight strips. Strips and special connection pieces shall be well cured in a manner such that any cross section shall be dense, homogenous, and free from all porosity. All junctions in the special connection pieces shall be full molded. During the vulcanizing period the joints shall be securely held by suitable clamps. The material at the splices shall be dense and homogenous throughout the cross section. Field splices shall be either vulcanized, mechanical, using stainless steel parts, or made with a rubber splicing union of the same stock as the water stop, at the option of the Contractor. All finished splices shall demonstrate a tensile strength of not less than 50 percent of the unspliced material.

G. Testing

Unless otherwise agreed by the Engineer in writing, at least one site trial application of the waterproofing system shall be carried out to determine the suitability of the surface preparation, method of application and effectiveness of the protective layer. The size of membrane laid shall be not less than 2.0 meters wide and 5.0 meters long.

5.15.06PROTECTIVE PAINTING TO CONCRETE

The following work covers the furnishing and application of rubber bituminous emulsion coating or (epoxy resin coating system) to buried surfaces of concrete, and external quality emulsion paint to exposed surfaces of concrete as detailed and shown on the Drawings and directed by the Engineer.

The Contractor shall submit to the Engineer for approval three samples in one liter containers of each of the protective paints.

The Contractor shall submit to the Engineer certificates that the materials to be furnished comply with the Specification requirements.

5.15.06.1 Rubber Bitumen Emulsion

A. Materials - The rubber bitumen emulsion shall be a water bound emulsion with a minimum 60% total solids content by volume, comprising bitumen with fine particles of rubber Not less than 10% nor more than 20% of the total solids shall be rubber. The consistency shall be such that it can be applied to the surface by brush at normal temperature.

B. Application - Before the application of rubberized bitumen emulsion the concrete surfaces shall be thoroughly cleaned and made free from dirt, dust, grease and other extraneous matter and lightly brush dampened immediately prior to application of the emulsion.

The priming coat shall be made up by mixing 0.23 kg of approved powder detergent or the equivalent of liquid detergent, with 45 liters of clean water and adding this to 4.5 liters of emulsion. The priming coat shall be applied at the approximate rate of 9 liters per 30 m2. The second coat consisting of undiluted emulsion shall be applied as soon as the priming coat is dry, at the approximate rate of 9 liters per 15 m^2.

The emulsion shall be applied by brush, squeegee or spraying strictly in accordance with the manufacturer's instructions, It shall not be applied during or when rain or dust storms are to be expected.

Backfilling shall not be commenced until the second coat of emulsion is quite dry.

5.15.06.2 Epoxy Resin Coating System

A. Materials - The epoxy resin coating system shall consist of two component solvent free, liquid epoxy resin modified with refined coal tar pitch conforming to ASTM C881:Type III: Grade 2: Class C or to BS 5493. It can be applied to the surface by brush, short hair roller, or by airless spray at normal temperature.

B. Application - Before the application of rubberized bitumen emulsion the concrete surfaces shall be thoroughly cleaned and made free from dirt, dust, greasy and other extraneous matter. Before start of coating application, concrete surface should be allowed to dry for 5 days and physical test to be performed using a moisture-tester to prove that percent moisture in concrete surface does not exceed 5% or the value allowed by the manufacturer of coating.

Primer: shall be used if required by manufacturer's Instructions.

Coating: shall be applied in two coats to achieve a minimum DFT of 300 microns,

Application steps should be made as per product data sheet and manufacturer's instructions.

C. Tests

Adhesion Test: A test certificate from an approved testing agency should be submitted to the engineer proving that when three pull-off tests ASTM D 4541 are performed, all test failures should occur at substrates or binder levels. If only one test, out of three, records a failure within the coating, the pull-off strength value measured should not be lower than 1 N/mm2.

5.15.06.3 External Quality Emulsion Paint

A. Materials: External quality emulsion paint shall be based on acrylic copolymer dispersions and shall provide a highly durable, washable, protective coating suitable for use on external concrete surfaces. The paint shall be resistant to the ill effects of a saline and urban environment, oils. greases and to the alkalinity of concrete. Paint colour shall be selected by the Engineer.

B. Application: Surfaces must be solid, clean and dry, free from oils, greases, salt, dirt and other contaminants prior to the application of the emulsion paint. Blistered or chalky substrates must be cleaned properly and rebonded by a priming coat, All newly laid concrete must be pre-treated with a 5% solution of Muriatic acid and all holes and irregularities must be filled with an approved grouting material. Before start of coating application, concrete surface should he allowed to dry for 5 days and physical test to be performed using a moisture-tester to prove that percent moisture in concrete surface does not exceed 5% or the value allowed by the manufacturer of coating.

All surfaces should be primed with a clear sealer as recommended by the manufacturer and a second undiluted coat of emulsion applied in accordance with the manufacturer's instructions.

Emulsion shall be applied by brush or spray as recommended by the manufacturer but no painting shall be carried out when rain or dust storms are expected,

C. Testing and acceptance Criteria

UV Light Resistance: Since the coating is exposed to UV Light action, Contractor should provide a test certificate, from an approved testing agency, proving that the proposed Acrylic Copolymer coating does not fade or change color when subjected to ASTM G53 at an accelerated exposure cycle of 1000 hours.

5.15.07MEASUREMENT

A. Waterproofing membrane shall be measured by the square meter laid, completed and accepted for different types of waterproofing membranes, irrespective of the shape of member to which membrane will be applied whether curved, sloped flat, etc.

B. Tar or bituminous painting to surfaces permanently in contact with backfilled material shall be measured by the square meter of surface area so painted, irrespective of the number, and thickness of coats of paint specified.

C. Water stops shall not be measured for direct payment but shall be deemed to be included in the rates for concrete.

D. Protection to waterproofing membrane and dampproofing course shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing and dampproofing.

E. Site trials of waterproofing membranes shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing.

F. Unless otherwise indicated, measurement of protective painting or coating of concrete shall be by the meter square of developed surface areas covered by the protective painting.

G. Where protective painting of concrete is included in other items of works for which all inclusive items are prescribed in the Bill of Quantities, protective painting shall not be measured or paid for separately.

H. The amount of completed and accepted Work measured as provided above will be paid at the unit price bid as specified in the Bill of Quantities, which prices shall be full compensation for furnishing all materials, labor, equipment, tools, supplies and all other items necessary for the completion of the Work.

I. Work is deemed to include:

- Primers, bonding compounds, adhesives and keying mixes.
- Applying coatings by brush or spray.
- Sloping and curved work to coatings
- Work of any width, height or girth. Work laid to falls and crossfalls, and intersections on sloping work.
- Extra material for lapping membranes including adhesive tape.
- Internal and external angles, fillets and the like.
- Edges, arrises and turning into grooves or channels and sealing.
- Cutting, notching and bending membranes.
- Holes for pipes and the like, forming collars and sealing.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Tar or bituminous paint (State type, number of coats)	Square meter (m^2)
(2) Membrane waterproofing (State type, thickness)	Square meter (m^2)
(3) Epoxy coating to internal surfaces of concrete (State type, thickness)	Square meter (m^2)
(4) Protective Painting to Concrete (state type, thickness)	Square meter (m^2)

**** END OF SECTION ****

SECTION 5.16 STRUCTURAL STEELWORK AND METAL COMPONENT

5.16.01SCOPE

A. This work shall include all structural steel and castings used in structures and all metals, ferrous and nonferrous, except reinforcing bars which arc specified in Section 5 03 "Steel Reinforcement and Fixing". Fabrication and construction shall be in accordance with the Specification and in conformity with the lines, grades, dimensions and design as shown on the Drawings.

B. For details of parapets, refer to Section 5.20 "Bridge Parapet and Railings"

5.16.02MATERIALS

A. Except as otherwise specified, shown on the Drawings, the grades and qualities shall conform to the applicable standards of AASHTO and ASTM

A.1 Structural carbon steel shall conform to AASHTO M183 (ASTM A36M).

A.2 Structural steel for welding shall conform to AASHTO M 183 (ASTM A36M).

A.3 High-Strength Low-Alloy structural steel shall conform to AASHTO M222 (ASTM A588).

A.4 Rolled, wrought iron shapes and bars shall conform to ASTM A207.

A.5 Wrought iron plates shall conform to ASTM A42.

A.6 Carbon steel forgings shall conform to AASHTO M102 (ASTM A668). Class C1 forgings shall be furnished.

A.7 Carbon steel castings shall conform to AASHTO M103 (ASTM A27) Grade 70-36 shall be furnished, or AASHTO M192 (ASTM A486M). Class 70 shall be furnished.

A.8 Gray-iron castings shall conform to AASHTO M105 (ASTM A48).

A.9 Malleable-iron castings shall conform to AASHTO M105 (ASTM A48).

A.10 Rolled copper-alloy bearing and expansion plates shall conform to AASHTO M108 (ASTM B 100). Alloy No I shall be furnished.

A.11 High-tensile-strength bolts, including nuts and washers shall conform to AASHTO Ml64 (ASTM A325).

A.12 Steel pipe for metal handrail shall conform to ASTM A53, Grade A seamless.

A.13 Aluminum-alloy for metal handrail shall conform to the requirements of Section 5.20 "Bridge parapet and Railings".

A.14 Zinc (hot-galvanized) coatings shall conform to AASHTO M 111 (ASTM A123).

A.15 Shop paint and Field paint: shall be as specified on the Plans and shall conform to the requirements of Section 6.09 " Painting of Structures".

A.16 Frames and grates: gratings, frames, manhole covers and gulley covers shall meet the requirements of Section 5.14 "Drainage and Utility Structures" and Section 5.22 "Drainage of Structures".

5.16.03CONSTRUCTION

A. Fabrication

A.1 Except as otherwise specified or as shown on the Drawings, all details concerning fabrication shall conform to "AASHTO Standard Specifications for Highway Bridges".

A.2 Fabrication of all metal for steel structures and the erection of steel structures shall be in accordance with shop and erection drawings furnished by the Contractor and approved by the Engineer before any fabrication is commenced.

A.3 Fabrication tolerances shall comply with tolerances stated on tile Drawings. The fabrication tolerances for box girder members are shown in Table 5.16.1.

A.4 Compliance with tolerances shall be achieved both during and after fabrication before any surface preparation. Remedial measures to remove imperfections must be approved by the Engineer.

B. Approval of Drawings

B.1 Approval of Contractor's drawings shall in no way release the Contractor from his responsibilities for work under the Contract. Three copies of each shop and erection dl-awing prepared by the Contractor shall be submitted to the Engineer for his approval and further copies of corrected or amended drawings shall be submitted if required before final approval is given. These drawings shall conform to the general drawings, stress sheets, design specifications and fabrication tolerances. Shop drawings shall include a full and clear set of marking drawings.

B.2 The Contractor shall ensure that all steelwork, including any built in ducts, provides for Signs and any other control equipment, prior to submission of such drawings. Detailed dimensions of equipment designed by specialist suppliers shall be taken into account.

B.3 After final approval has been given, the Contractor shall supply to the Engineer a minimum of two further sets of prints and one set of reproducible negatives of his final drawings.

B.4 The cost of preparing and furnishing all shop and erection drawings shall be considered as part of structural steel items in the Bill of Quantities and without further payment Items.

C. Substitutions

C.1 Where sections shown on the Drawings are not easily obtained, substitutions may be allowed. Substitutions of sections having different dimensions or sections of equal or greater value than those shown on the Contractor's drawings may be made only when approved in writing by the Engineer No payment will be made for additional weight resulting from such substitutions.

Table 5.16.1: Steelwork Fabrication Tolerances Box Girder Members

Part	Imperfection	Maximum Tolerances		Length of Gauge Laid on Part
Longitudinal Stiffeners	Lateral departure from line or outstand	2.0 mm		540 mm
Web and Flange Plates	Departure from flatness along line of longitudinal stiffeners	2.0 mm		Center to center distance of diaphragms or transverse stiffeners
		Unstiffened Plate Width Up to 400 mm	Over 400 mm	
Web and Flange Plates	Departure from flatness other than stiffeners. Gage transverse	3.0 mm	3.0 mm	Unstiffened plate width
Web and Flange Plates	Departure from flatness other than at stiffeners. Gage longitudinal	3.0 mm	5.0 mm	Twice unstiffened plate width

C.2 If the Contractor proposes to form individual members or parts Of members from two or more pieces using joints additional to those shown on his drawings then such joints shall be fully detailed on his working drawings and submitted to the Engineer, with supporting calculations, for his approval. Full penetration butt welds shall be provided at such joints, unless otherwise directed.

D. Mill Inspection

D.1 Except as may be otherwise specified, mill inspection will be waived. In lieu of mill inspection, the Contractor shall furnish the Engineer with three certified copies of the mill orders showing heat numbers of the individual members, together with three certified copies of mill heat test reports showing the properties of each heat number.

D.2 When received at the shop, each member shall bear the heat number in legible form for purpose of identification by the shop inspector. Acceptance of the material shall be based on approval of the mill heat test reports by the Engineer.

E. Shop Inspection

E.1 General Requirements

E.1.1 The Contractor shall notify the Engineer at least two weeks in advance of beginning work at the shop so that the Engineer may inspect and approve the facilities. The Contractor shall furnish all facilities for- inspection of material and workmanship in the shop and the Engineer shall be allowed free access to all parts of the shop where and when inspection will be necessary.

E.1.2 Inspection at the shop is intended as a means of facilitating the work and avoiding errors, and it is expressly understood that it will not relieve the Contractor from any responsibility in regard to defective material or doing the work again. The Engineer shall have the authority to reject materials or workmanship which do not comply with the requirements of the Drawings or the Specifications.

E.1.3 Acceptable of any material or furnished member by the Engineer shall not preclude subsequent if later they are found defective. Rejected materials shall be replaced promptly and rejected workmanship shall be made good, all at no additional expense to the Employer.

E.2 Inspection of Welds

E.2.1 Radiographic inspection of welds will be required, as specified in the current edition of the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society. Additional welds to be inspected radiographically will be shown on the Drawings.

E.2.2 When shown on the Drawings other methods of nondestructive inspection will be required.

E.2.3 The Contractor shall secure the services of an approved organization qualified in the inspection of welds and will bear the costs of this inspection service. Inspection of all welds shall be done only by persons skilled in such inspection and who are acceptable to the Engineer. The Engineer shall review and interpret radiographs and other non-destructive or destructive testing and has the sole authority to accept or reject the inspection or work.

E.2.4 All film and/or other records of weld inspection shall become the property of the Employer.

E.2.5 In the inspection of welds, the presence of any of the following defects in excess of the specified limits will result in the rejection of the weld as being defective.

Cracks, regardless of length or location, will not be allowed.

Overlaps, lack of penetration or incomplete fusion will not be allowed.

Inclusions, including slag, porosity and other deleterious materials less than 1.5 mm in the greatest dimension will only be allowed if well-dispersed and such that the sum of the greatest dimensions of the inclusions in any 25 mm of welded joint does not exceed 9.5 mm and there is no inclusion within 25 mm of the edge of a joint or point of restraint.

Inclusions, including slag, porosity and other deleterious materials 1.5 mm or larger in the greatest dimension will only be allowed provided that such defects do not exceed the following limits: (where T is the thickness of the thinner plate being welded, for:

- T up to 19 mm 6.5 mm
- T 19 mm up to 57 mm 1/3 T
- T over 57 mm 19 mm

Any group of inclusions in line that have an aggregate length greater than T in a length of 12T will not be allowed.

E.2.6 Defects shall be removed by mechanical means or by oxygen grooving, after which the joints shall be welded again.

F. Galvanizing

Small structural steel or cast steel articles, such as bolts, nuts, washers and similar articles that are to be galvanized shall be galvanized after fabrication in accordance with the requirements of ASTM A153.

G. Erection

G.1 The Contractor will be deemed to have satisfied himself before tendering as to the safety and suitability of his proposed methods of site erection. Erection procedure, including any temporary or permanent fastenings, shall at all stages be to the approval of the Engineer. The Contractor shall submit for approval such detailed descriptions and drawings of his proposed procedures, together with supporting calculations, as the Engineer may require The Engineer's approval of the Contractor's erection procedure shall in no way relieve the Contractor of his responsibilities for work under the Contract.

G.2 At all stages of erection the structure must be stable and not liable to excessive oscillations in any wind or ground tremor likely to occur.

G.3 The maximum allowable stresses stated in AASHTO Standard Specifications for Highway Bridges shall not be exceeded at any time during erection.

G.4 Before delivery to site trial, erection of the following completed components shall be carried out and the parts connected for inspection, all as described in AASHTO Standard Specifications for Highway Bridges.

- Every pair of adjacent box girder units as completed
- Every box girder leg unit to base steelwork.

H. Welding

H.1 In addition to the welding of structural steel, all welding shown on the Drawings or ordered by the Engineer shall conform to the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society.

H.2 Before assigning any welder to work covered by this Section of the Specifications, the Contractor shall provide the Engineer with the names of the welders to be employed on the work together with certification that each of these welders has passed qualification tests using procedures covered in the American Welding Society Standard B3.0, Part 11, or such other qualification lest acceptable to the Engineer. If required by the Engineer, the Contractor shall submit identifying stencilled test coupons made by any operator whose workmanship is subject to question.

H.3 The Contractor shall require any welder to retake the test when, in the opinion of the Engineer, the work of the welder creates a reasonable doubt as to his proficiency Tests, when required, shall be conducted at no additional expense to the employer Recertification of the welder shall be made to the Engineer only after the welder has taken and passed the required retest. Welders shall have passed the qualification tests within the preceding 12 month period. The Engineer may require coupons to be cut from any location in any joint for testing. All sections of welds found defective shall be chipped or cut out to base metal and properly rewelded before proceeding with the work. Should any 2 coupons cut from the work of any welder show strengths, under test, less than that of the base metal, it will be considered evidence of negligence or incompetence and such welder shall be permanently removed from the work. When

coupons are removed from any part of a structure, the members cut shall be repaired in a neat and workmanlike manner, with joints of proper type to develop the full strength of the members with approved measures taken where necessary to relieve residual stress, all at no additional cost to the Employer.

I. Painting

The number of the paint type and the number of coats of shop paint and field paint shall be as specified on the Drawings. The quality and application shall conform to the requirements of Section 6.09 "Painting of Structures".

J. Metal Handrail

Metal handrail, either aluminum alloy or steel shall comply with Section 5.20 "Bridge Parapets and Railings" and shall be erected in accordance with the Drawings and painted as specified on the Drawings and in accordance with Section 6.09 "Painting of Structures".

K. Sealing Of Box Members

K.1 All box members, including rolled hollow sections, shall be completely sealed with weld metal as shown on the Drawings except where specific openings are required.

K.2 No subsequent drilling of holes etc., either before or after erection, will be allowed for fixing of signs or other purposes. Holes in other members will not be permitted unless approved by the Engineer.

K.3 Unless shown otherwise, ends of members shall be provided with an end plate at least 6 mm thick, sealed all round with weld metal. The duct tubes pass through a box member shall be fully sealed to it with weld metal.

L. Camber

L.1 Steelwork shall be precambered such that the specified geometry shown on the Drawings is achieved at a temperature of 15 degrees C, under full dead load conditions when all signs and other equipment have been installed. Any instructions shown on the Drawings shall be followed unless otherwise directed by the Engineer.

L.2 The following general tolerances shall apply to completed steelwork:

Line and level:	Plus or minus 5 mm
Plumb:	5 mm per 10 m of height.

M. Spares to Cover Loss of Minerals

The Contractor shall provide an adequate number of spares for materials such as bolts, nuts, washers, packings, cover plates etc., to cover for possible losses, bearing in mind the possibility of long transport distances from places of supply. The Contractor shall state on his working drawings the numbers and types of items being ordered in this respect. Payment will only be made on the basis of the net materials specified, and the Contractor shall allow in his tender for provision of all such spares.

N. Frames, Grates and Covers

Frames, grates and covers that are cast or fabricated shall be placed true to line and grade and shall make full and even bearing on the underlying surface. Frames, grates and covers that are warped or otherwise damaged, as determined by the Engineer, will be rejected and removed from the Site.

O. Metal Parapets

O.1 When parapets are erected they shall be securely held in their correct position until all connections and fastenings are complete and post fixings have gained sufficient strength to withstand design holding-down forces. Assessment of strength of the post fixing shall be subject to the Engineer's agreement.

O.2 Finished parapets shall be true to line and level throughout their length.

5.16.04MEASUREMENT

A. Structural Steel

A.1 This Work shall be measured by the kilogram or metric ton as specified in the Bill of Quantities, complete in place as determined from the Engineer's computed weights, made in accordance with the provisions of Part 1 of Specifications Section 2-4 "Bill of Quantities".

A.2 For the purpose of payment, all metal fixings, other than metal reinforcement for concrete, such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and nuts, weld metal, bolts embedded in concrete, shear connectors, plates and shapes for pier protection, water stops and similar metal items shall, unless otherwise specified, be included within the Pay Item for Structural Steel and not be subject to separate measurement.

A.3 The quantity of "Structural Steel" to be paid for shall include the weight of any full-size members which are tested to destruction as ordered by the Engineer and which meet the requirements of the Specifications. Full-size members which fail to meet the requirements and all members rejected as a result of tests will not be paid for. All costs incurred in conducting tests shall be borne by the Contractor, except as otherwise specified.

A.4 If the Contractor elects (with the Engineer's permission) to use equivalent sections of greater weight than those shown on the approved Drawings, he shall bear all additional costs thereof.

A.5 The amount of completed and accepted materials will be paid for at the unit price bid per kilogram or metric ton as specified in the Bill of Quantities for "Structural Steel", which price shall be full compensation for furnishing, fabricating, welding, delivering, erecting, radiographic inspection, painting and placing all materials, for all labor equipment, tools and all other items necessary for the proper completion of the work.

B. Metal Handrail

Metal handrail shall be measured for payment under the provisions of Section 5.20 "Bridge Parapets and Railings".

C. Manhole Cover

Manhole covers shall be measured for payment under the provisions of Section 5.14 "Drainage and Utility Structures".

D. Metal Parapets

Metal Parapets shall be measured for payment under the provisions of Section 5.20 "Bridge Parapets and Railings".

E. Other Metal Work

Other metal work shall be measured as specified on the Drawings.

F. Computed Weight

F.1 The computed weight shall be obtained by the use of the following rules and assumptions:

- Weight of steel shall be assumed at 7,850 kilograms per cubic meter
- Weight of bronze shall be assumed at 8,720 kilograms per cubic meter
- Weight of cast iron shall be assumed at 7,200 kilograms per cubic meter

F.2 Weight of steel, bronze and cast iron shall be computed on the basis of final dimensions at the unit weights as shown above. The net finished dimensions of the parts as shown on the approved shop drawings shall be used, deducting for copes, cuts, clips and all holes including bolt and rust holes.

F.3 Weight of bolts, including washers, heads and nuts shall be attained by scaled weight measurement methods or by accurate volumetric computations and unit weight.

F.4 Weight of weld metal shall be computed on the basis of the theoretical volume from dimensions of the shop drawing welds at the unit weight of 7,850 kilograms per cubic meter. For ease in computations, weld metal deposited in fillets, joint chamfers and bevels will be measured but no measurement will be made for weld metal deposited outside the heat lines of the approved shop drawings. No deductions will be made for material removed by beveling or other cutting and subsequently replaced with weld metal.

F.5 No allowance will be made for erection bolts, temporary laterals, excess field rivets or other similar items.

F.6 At the option of the Engineer, cast steel, cast iron, wrought iron, small structural steel items and bearing devices composed of any single metal or combinations of metals may be measured by the kilogram, complete in place, as determined by weighing on an accurate set of scales.

PAY ITEMS	**UNITS OF MEASUREMENT**
(1) Structural Steel (Grade)	Tonne (T)
(2) Other Metal Works	as defined on drawings

SECTION 5.17 NOT INCLUDED

SECTION 5.18 BRIDGE EXPANSION JOINTS

5.18.01SCOPE

The work covered by this Section of the Specifications consists in furnishing all plants, equipment, materials and labour and in performing all operations in connection with construction and replacement of existing damaged bridge expansion joints complete, subject to the terms and conditions of the Contract and in strict accordance with this section of the Specification, the applicable drawings and the directions of the Engineer's Representative.
The type of joints within the scope of work is mainly Reinforced Elastomeric Joints, commonly known as Mat Expansion Joints.

5.18.02QUALITY SYSTEM REQUIREMENTS

The Contractor is requested to submit a Quality Plan related to the proposed bridge expansion joints as part of their bid documents. The provided Quality Plan will be taken into consideration when the tenders are examined and evaluated.

A.1 This plan should include the specific documentation detailed in the following table:

Table 5.18.1: Joint Quality Plan

No	Description of document
1	Description of the proposed expansion joint, material specifications, and arrangement drawings showing the details of the proposed expansion joint
2	Laboratory test certificates
3	Certification from the manufacturer of the expansion joint:
4	Details and /or procedures for installation

A.2 The expansion joint must be manufactured by a company which has a third party certified quality management system (i.e. ISO or equivalent) for the manufacture and supply of bridge joints. This certification must be submitted to the Engineer for approval.

A.3 Laboratory test certificates must be provided to the Engineer to verify that the material used in the manufacture and the proposed joint has been tested in a laboratory meeting the requirements of this specifications. Testing must be performed by a laboratory which is accredited by an International Certified Laboratory.

A.4 Full details of the proposed suppliers with their technical specifications,maintenance manual, design calculations, covering materials, dimensions and sizes shall be submitted to the Engineer for approval before the Contractor places an order.

A.5 The Contractor shall submit the detailed shop drawings and obtain the Engineer's approval before manufacture is commenced.

A.6 Joint Installation shall be carried out strictly In accordance with manufacturer's recommendations and in the presence of the manufacturers representatives.

5.18.03 DESIGN METHOD

The expansion joint must be designed in accordance with the European Approval Guidelines for expansion joint ETAG 32 or equivalent international design guidelines. The design calculation notes should be submitted for Engineer's approval, providing all necessary checks for the sufficient mechanical resistance of the proposed joint under service loads.

5.18.04STANDARDS FOR COMPONENTS

The expansion joint must be maded up of vulcanized molded elastomeric elements 1 to 2 meters in length bonded to metal inserts designed to accommodate moving loads and distribute stress in the fixing. They must be connected to each other on-site by means of a high-quality adhesive joint to form a continuous, tight and sustainable joint.

Table 5.18.2: Standards for components

Description	**Applicable standards**	**Material**
Steel element	NF EN 1002	S235 JR minimum
Rubber	Refer Table 5.18.4	Refer Table 5.18.4
Thread rod	NF EN 25-136 / DIN 976	Class 10.9
Nut	ISO 4032 / DIN 934	HR Class 10

5.18.05 MATERIALS

A.1 Steel Inserts:

The reinforcing steel plates incorporated into the elastomer shall consist of steel S235-JR minimum characteristics with a manufacturer's certificate and having the following minimum characteristics.

Table 5.18.3: Properties of Steel Insert Materials

	Properties	**Requirement**
1	Yield strength	>235 Mpa
2	Tensile Strength	>360 Mpa
3	Elongation at break	>12%

Exposed steel parts shall be sufficiently protected corrosion

A.2 Elastomer for Expansion Joints

The elastomer shall be with excellent resistance to aging weathering, chemical attack and abrasion all in accordance with the requirements specified in **Table 5.18.4**.

Table 5.18.4: Properties of Elastomer Qualities

Properties	**Requirement**		**Test / Control Method**
1. Shore A Hardness (IRHD)	(SHE)	60+/-5	ISO 48-2; ISO 48-4
2. Tensile strength (Mpa)	(Mpa)	> 17 Minimum	ISO 37
3. Elongation at break	(%)	>450	ISO 37
Adhesion to Metal	N/mm	Min 10	ISO 813
4. Tear propagation strength	(N/cm)	>30	
5. Shock elasticity Abrasion	(m^3)	<170	
a) Residual compressive strain, 24 h R.T.	(%)	10	
b) Residual compressive strain,	(%)	<=30 %	ISO 815-1 (Type B specimen)

Properties	Requirement		Test / Control Method
24 h 70° C and 25 % constant deflection			
6. Durability under ozone influence, 72 h at 70°C: Ozone concentration of 50 pphm under 20% strain.	(step)	No visible cracking	ISO 1431-1
7.Change of Properties by artificial aging for 7 Days at 70°C:			ISO 188 (Method A)
a) Shore A – hardness (SHE)	increase	<+7 units	EN ISO 2039-1; EN ISO 527-2
b) Tensile strength (%)	decrease	≥- 15%	
c) Elongation at break (%)	decrease	≥ -25%	

5.18.06CONSTRUCTION REQUIREMENTS FOR EXPANSION JOINTS

A. General

A.1 The joints are shock and sound absorbing, watertight systems. Their dimensions shall be in conformity with the drawings. All steel parts must be totally encased in the elastomer. Alternative expansion joints may be submitted to the Engineer's Representative for approval. The application shall be accompanied by exact description, detailed drawings and material certificates which shall comply with the requirements given above.

A.2 The joints shall be manufactured in the factory in full length by vulcanized molded elastomeric elements 1 to 2 meters bonded to metal inserts designed to accommodate moving loads and distribute stress in the fixing.

A.3 All joints are to be shaped according to the transverse profile of the roadway.

A.4 The anchorage of the expansion joints shall be obtained by bonding anchors. All bolts, nuts and washers shall be of rustproof material.

A.5 All items of this section must be delivered to the site clearly identified as to their type and place of installation.

A.6 All items if this section are subject to approval by the Engineer's Representative before being placed unless otherwise directed by him in writing.

A.7 The positioning of holding down bolts and anchorage systems shall be checked for accuracy and agreed by the Engineer before the casting of the concrete for the joint and to locate holding down bolts or anchorage pockets. The templates or forms shall only be removed with the Engineer's consent. Threaded parts shall be protected, kept clean and protected from corrosion by a grease coating.

A.8 Where the carriageway surfacing is to be removed to accommodate the bridge joint it shall be cut to a clear straight line for the full depth of the surfacing without damage to the concrete substrate or the waterproofing.

A.9 Before installation of the joint, the concrete surfaces shall be free from laitance, sand, clear and comply strictly with the joint Manufacturer's requirements.

B. Nosings

B.1 Construction of nosings at joints using epoxy mortar and epoxy concrete shall be formed under the direction of a competent supervisor experienced in the use of the material. The work shall be carried out preferably in the warm weather. The air temperature around the joint shall be not less than 10 degrees C which shall be achieved artificially if necessary. Concrete surfaces to which nosings are applied shall be dry, sound and free from laitance. Before application of the primary coat, loose material and dust shall be removed by an air jet tested to ensure that no oil is carried over from the compressor.

B.2 Unless otherwise specified, surfacing shall be carried across the joint and then cut back to accommodate the nosing. The cutting shall be done with a diamond saw to give a clean edge throughout the depth of the material to be removed. Masking material shall be provided to prevent surfacing materials adhering to the deck where nosings are to be formed and shall be adequately located to prevent displacement by the paving machine.

B.3 A primary coat of unfilled epoxy resin composition shall be well worked in by brush to all surfaces with which the nosings will be permanently in contact, at a uniform rate or not less than 300 g/m2. The mortar shall then be applied as quickly as possible while the primary coat is still tacky.

B.4 The epoxy mortar and epoxy concrete composition shall be approved by the Engineer. Aggregate shall be either silica sand; calcined bauxite or other approved synthetic or natural aggregate of suitable grading. The particle size distribution shall be that which produces a mortar with adequate strength and workability and minimum void volume. Aggregate shall be clean and completely dry. Whichever type of aggregate is used, the epoxy mortar or epoxy concrete constituents shall be thoroughly mixed in a suitable mechanical mixer. The sequence, duration and temperature of mixing shall be in accordance with the manufacture’s instructions.

B.5 The mixed constituents shall be placed in position within the time recommended by the manufacturer, well worked against the primed surfaces and trowelled flush with the adjacent road surface to form a dense mortar to the required profiles. Epoxy mortar shall generally be compacted in courses of thickness not exceeding 50 mm. Where an underlying course is more than one hour old it shall, unless otherwise agreed by the Engineer, be primed with an unfilled epoxy resin priming coat before placing the next course.

B.6 The gap width shall be set, in relation to the prevailing deck temperature, with the joint gap sides parallel as described on the Drawings and within the joint manufacturer’s installation instructions. Seals shall remain in compression for the lull range of joint movement.

B.7 Expansion joints shall be of uniform width and shall be accurately set or finished and aligned flush with the finished carriageway surface. Care shall be given to ensure that metallic components are not bent or deformed during handling and installation.

B.8 The installation process shall strictly comply with instruction given on the drawings and by the joint manufacturer.

B.9 The expansion joint and the waterproofing shall be formed so that a watertight seal is provided.

B.10 During the placing and hardening of the bedding and bonding materials, movement between the joint and the substrate shall be prevented.

B.11 A temporary steel plate covers capable of withstanding vehicular loading shall be provided over expansion joints during and after their installation for an approved period.

5.18.07TESTING

At the request of the Engineer's Representative, individual expansion joints shall be tested to determine whether they meet the chemical, physical and/or statical requirements as stipulated in the specifications.

5.18.08MEASUREMENT

A.1 Bridge expansion joints shall be measured by the linear meter of each joint size (measured by movement range) supplied installed and accepted. The measurement shall be made from outside face of parapet to outside face of parapet whether or not the joint types over carriageway, verges and walkways for a particular joint type are similar. No separate measurement shall be made for labors, equipment, tools, anchors, special curb units, cover plates over walkways, epoxy mortar for the transition strips, but shall be deemed subsidiary to bridge expansion joint.

A.2 The amount of completed and accepted work measured will be paid for at the unit prices bid as specified in the Bill of Quantities, which price shall be full compensation for furnishing all materials, labor, equipment, tools, supplies and all other items necessary for the proper completion of the work.

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Buried joint Strip seal Joint, Movement range ( )	Linear Meter (m)
(2) Reinforced Elastomeric Joint Movement range ( )	Linear Meter (m)
(3) Metallic finger joint Movement range ( )	Linear Meter (m)

**** END OF SECTION ****

SECTION 5.19 BRIDGE BEARINGS

5.19.01SCOPE

A. This work shall consist of furnishing testing and installing elastomeric and replaceable metal bridge bearings as shown on the Drawings or as directed by the Engineer.

B. Codes and Standards: Comply with the provisions of following codes: BS 5400 Section 9.1 Code of Practice for Design of Bridge Bearings.

5.19.02DEFINITIONS

A. Elastomeric: A compound containing natural or chloroprene rubber with properties similar to those of rubber.

B. Roller Bearing: A bearing consisting essentially of one or more steel rollers between parallel upper and lower steel plates.

C. Rocker Bearing: A bearing consisting essentially of a curved surface in contact with a flat or curved surface and constrained to prevent relative horizontal movement. The curved surfaces may be cylindrical or spherical. Rocker bearings permit rotation by rolling of one part on another.

D. Knuckle Bearing: A bearing consisting essentially of two or more members with mating curved surfaces. The curved surfaces may be cylindrical or spherical.

E. Leaf Bearing: A bearing consisting essentially of a pin passing through a number of interleaved plates fixed alternately to the upper and lower outer bearing plates.

F. Sliding Bearing: A bearing consisting essentially of two surfaces sliding one on the other.

G. Elastomeric Bearing: A bearing comprising a block of elastomer that may be reinforced internally with steel plates.

H. Laminated Bearing: An elastomeric bearing reinforced with steel plates.

I. Plain Pad Bearing: An unreinforced elastomeric bearing.

J. Strip Bearing: A plain pad bearing for which the length is at least ten times the width.

K. Pot Bearing: A bearing consisting essentially of a metal piston supported by a disc of unreinforced elastomer that is confined within a metal cylinder.

5.19.03MATERIALS

A. Steel

A.1 Weldable structural steel shall comply with AASHTO M270 (ASTM A709) or if specified to BS 4360.

A.2 Steel casting shall comply with AASHTO M192M (ASTM A486M) or if specified to BS 3100.

A.3 Stainless steel shall comply with ASTM A240 Type 304 or if specified to BS 1449.

A.4 Cast iron shall comply with AASHTO M105 (ASTM A48) or if specified to BS 2789.

B. Polytetrafluoroethylene (PTFE)

B.1 Unfilled PTFE shall be pure virgin PTFE without any addition of regenerated materials of fillers and shall meet the requirements of ASTM D1475. The mechanical properties of unfilled PTFE shall comply with:

- Tensile strength: ASTM D1457 (20N/ mm2 minimum)
- Elongation at break: ASTM D1457 (200% minimum).

B.2 The composition of filled PTFE shall be such that its coefficient of friction is not more than twice the coefficient of friction of pure PTFE when measured under the same conditions.

C. Lubrication Cavities

C.1 Lubricant retention cavities in PTFE shall comply with the following requirements:
The plan area of the cavities shall between 10% and 30% of the total PTFE bearing surface including, the area of the dimples or grooves.
The volume of the cavities shall not be less than 3% nor more than 20% of the volume of PTFE including the volume of cavities. Only the volume above the top of the recess shall be considered if the PTFE is confined.

The depth of the cavities shall not exceed half the thickness of the PTFE sheet, or in the case of confined PTFE, the height of its projection from the top of the recess.

C.2 The temperature for hot pressing of cavities shall not exceed 200°C.

C.3 Lubricants

Lubricants for use with PTFE sliding surfaces shall be compounded for long life and to retain their properties within the temperature range to which the bridge is subject and shall not affect the constituent parts of the bearings.

C.4 Adhesives

Adhesives for bonding PTFE to backing plates shall be epoxy resins meeting the requirements of U.S. Federal Specification MMM-A-134. They shall be resistant to the action of lubricants, atmospheric and biological agents and temperatures to which the bearing may be subject.

D. Elastomer

D.1 The elastomer used in the manufacture of bridge bearings shall contain either natural rubber or chloroprene rubber as the raw polymer, and shall have a hardness in the range of 45 IRHD to 75 IRHD. No reclaimed or ground vulcanizate rubber shall be used.

D.2 Elastomeric bridge bearings shall meet the requirements of ASTM D4014 "Standard Specifications for Plain and Steel-Laminated Elastomeric Bearings for Bridges".

E. Other Materials

E.1 Bronze Bearing Plates

Bronze bearing plates shall conform with the Specification for Bronze Castings for Bridges and Turntables, AASHTO M107 (ASTM B22). Alloy 911 shall be furnished unless otherwise specified.

E.2 Rolled Copper-Alloy Bearing Plates

Rolled copper-alloy bearing plates shall conform to the Specification for Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Uses. AASHTO M108 (ASTM Bl00). Alloy No. 510 or No. 511 (previously designated as No. 1) shall be furnished unless otherwise specified.

E.3 Metal Powder Sintered Bearing Plates

Metal powder sintered bearing plates shall conform to the specifications for such material of the ASTM B438, Grade 1. Type II or Grade 2, Type I.

E.4 Phosphor Bronze

Phosphor bronze back plate to porous bronze plate impregnated with PTFE resins shall conform to ASTM B l 00 and the porous plate to ASTM B 103.

5.19.04CONSTRUCTION

A. General

A.1 The Contractor shall submit to the Engineer outline details of all bearings which he proposes to use in the Works. These shall include the name of the bearing manufacturer bearing types and typical drawings which will form the basis for approval in principle.

A.2 On obtaining the Engineer's approval in principle the Contractor shall submit detailed design calculations of each bearing type, which may include Finite Element Analysis of critical parts as determined by the Engineer, detailed drawings of each bearing type, installation drawings, material specification and a method statement giving installation procedure and recommended bedding materials for use immediately under and above the bearings. If the Engineer is satisfied with these submissions, he shall give approval which will be subject to achieving satisfactory manufacturing tolerances and tests, the requirements of which are given in sub-sections 5.19.5 and 5.19.7 respectively.

A.3 The fixing arrangements of all metal bearings shall be such as to enable the bearings to be replaced without the need for cutting into the bridge deck or bridge pier or abutment.

A.4 Bearings shall be installed in accordance witl1 the manufacturer's instructions and as directed by the Engineer, by competent persons who have been trained in, and have experience of, bearing installations.

A.5 Bearings shall not be dismantled. Any transit bolts, straps or other temporary fixing shall not be removed until the bearing is fixed in its final position and the

structure immediately above the bearing is in place. Care shall be taken to ensure that all transit bolts, straps or other temporary fixings are finally removed.

A.6 Bearings which incorporate low friction material, such as PTFE, shall not be opened up to expose the surface of the low friction material. Should this happen accidentally, bearing surfaces are to be cleaned and re-greased and assembled as required by the manufacturer and to the satisfaction of the Engineer.

A.7 All bearings shall be set horizontal in both directions and all bearings shall be positioned so that the inscribed longitudinal axis is parallel to the structure axis at the point of support, unless otherwise noted in the Drawings or directed by the Engineer.

A.8 All metal bearings must have positive fixing such that the bearing is subsequently removable without excessive jacking. Horizontal forces shall be transferred from the superstructure to bearings and from the bearings to supports by means of shear keys or fixing bolts. However, where precast segmental deck construction is used, it may not be possible to use positive fittings for the top bearing plates. In such circumstances, the top bearing plates shall be fixed to the deck by epoxy injection. The epoxy used, the method of injection and strength of the fixing shall be to the approval of the Engineer and will be subjected to laboratory and field tests.

A.9 The longitudinal movements listed for metal bearings may require presetting the top plates with respect to the bottom plates and also variable orientation of the bearings with respect to the pier axis. Such preset and orientation angles shall be marked on each bearing by the manufacturer before shipment to site.

A.10 Any devices such as steel packs used to hold bearings level whilst being fixed, must be removed finally, so that the bearing seats only on its dry pack mortar bedding.

A.11 Metal bearing shall be set in position on steel to within ± 5mm of the specified level. The location of these wedges beneath the bearings shall be agreed with the bearing manufacturer prior to installation.

A.12 The gap between the underside of bearing and sub-structure shall be filled with epoxy mortar as specified by the Engineer which shall have a minimum 28 day cylinder strength of 310 kg/sp.cm and the resulting voids filled with an approved epoxy mortar. Construction of the bridge superstructure may then proceed. The supporting false work and formwork of the bridge superstructure shall not be removed nor permit the transfer of load to the bearings prior to removal of the temporary supporting wedges.

A.13 Bearings shall be maintained in their correct position during placing of the bridge deck. Mating surfaces of bearings shall be kept free from contamination and, after the deck has been completed, each bearing and the area around it shall be left clean and tidy, to the satisfaction of the Engineer.

B. Steel Elements

B.1 Finished Surfaces

Metal-to-metal contact surfaces within bearings shall be prepared either by machining or fine grinding. As far as practicable, machining shall be carried out after welding has been finished. Machining of rolling contact surfaces of roller bearings or sliding contact surfaces shall be carried out only in the principal direction of movement. Care shall be

taken to remove abrasive materials from finished surfaces, which shall also be cleaned with a degreasing agent. Finished surfaces shall be protected from contamination and/or mechanical damage.

Note: Surfaces that are to be in contact with grout or bedded on a suitable material may be left unmachined.

B.2 Bolts and Bolt Holes

Bolt holes shall be drilled or reamed. Where specified by the Engineer, bolts or screws shall be a vibration resistant type Taper washers of the correct angle of taper shall be provided under all and nuts bearing on beveled surfaces.

B.3 Welding

B.3.1 General: Welding procedures shall be such as to minimize distortion or the bearing components and to avoid damage to finished work or bonded materials. Comply with the provisions of the following codes, specifications and standards except as otherwise indicated. AASHTO/AWSD.1.5.88 Bridge welding. Code – 1988.

B.3.2 Stainless Steel: Welding of stainless steel sheet to a mild steel backing plate shall by an inert gas-shielded metal-arc or tungsten inert gas metal-arc process.

B.4 Fixing of Stainless Steel Sheet

B.4.1 Welding: The weld attaching the stainless steel to its backing plate shall be continuous so as to prevent ingress of moisture and shall be clean, sound, smooth, uniform, without overlaps and properly fused.

B.4.2 Mechanical Fixing with Peripheral Seal: Where mechanical fixing is augmented by peripheral sealing, the backing plate shall be completely protected against corrosion by painting prior to the fixing of the stainless steel sheet. A continuous flexible seal shall be provided around the periphery of the stainless steel.

B.4.3 Bonding: The stainless steel sheet shall be bonded over its entire area.

B.4.4 Stainless Steel Mating Surface: Stainless steel mating surfaces when used shall be 20 gage minimum thickness with a surface finish less than 508×10^{-6} mm. Stainless steel mating surfaces shall be polished or rolled as necessary to meet the friction requirements of this Specification.

C. Bonding of PTFE

Where PTFE sheets are to be epoxy bonded, one side of the PTFE sheet shall be factory treated by an approved manufacturer by the sodium naphthalene or sodium ammonia process.

D. Interlocked Bronze and Filled PTFE Structures

An interlocking bronze and filled PTFE structure consisting of a phosphor bronze plate with a 25 mm thick porous bronze surface layer into which is impregnated a lead PTFE compound. There shall be an overlay of compounded PTFE not less than 0.3mm thick.

E. PTFE Metal Composite

PTFE metal composite shall consist of virgin PTFE molded on each side and completely through a 8mm perforated stainless steel sheet.

F. Forming of Elastomeric Bearings

F.1 Plain Pad Bearings and Strip Bearings: Plain pad bearings shall be molded in one piece, or comprise single pieces cut from previously molded strips or slabs. Cutting shall produce a smooth surface without injurious heating of the elastomer.

F.2 Laminated Bearings: A laminated bearing shall be molded as a single unit under pressure and heat.

F.3 Spacers in Molds: When spacers are used in molds to ensure correct cover to outer plates, they shall comply with the following requirements:

- The resulting exposed steel surfaces shall eventually be covered when the bearings are installed in the bridge structure.
- The spacers shall be located with a minimum distance of l0 mm from the reinforcing plate edge to the edge of the spacer.
- The size of the hole left at the surface of the bearing shall not exceed l0 mm diameter.
- The minimum practical number of spacers shall be used to ensure correct location of plates but in no case shall the total area of spacers exceed 3% of the bearing compression area.

G. Final Assembly and Clamping

After final inspection and acceptance of the various parts of the finished bearing, they shall be assembled and clamped together. If specified by the Engineer, sliding and roller bearings shall be preset at the time of fixing the clamping devices. All deleterious materials shall be excluded from sliding and other contact surfaces.

H. Marking

Completed bearings shall have the supplier's name (or trade mark) and a serial number indelibly marked thereon. The serial number shall be unique and such as to enable other bearings manufactured at the same time to be traced through the production control records should the need arise. Where practicable the serial number shall also be visible after installation of the bearing in the structure. The top of each bearing shall be clearly marked and the size and direction of preset, if any, and the direction of installation shall be indicated.

5.19.05TOLERANCES

A. Definition

A.1 Standard Tolerances

Tolerances for flatness, roundness, cylindricity, profile of a surface, parallelism, squareness and position shall be in accordance with the descriptions and illustrations given in BS 308: Part 3.

A.2 Size

Tolerances for size shall be taken to be variations from the nominal dimensions. They shall be used to control the overall dimensions of components with respect to length, thickness height and diameter.

A.3 Fit

Tolerances for fit relate to clearance and shall be taken as the difference between the sizes of an element and the hole in which it fits, where this difference is positive.

A.4 Surface Roughness

Surface roughness shall be taken as the arithmetical mean deviation Ra defined in and measured in accordance with BS 1134: Part 1.

B. Overall Dimensions of Assembled Bearings

B.1 General

Overall dimensions of assembled bearings shall be within the tolerances given in Table 5.19.1

Table 5.19.1 Tolerances on Overall Size

Type of bearing	Tolerance on size	
	overall plan dimensions	overall thickness or height
Elastomeric		
Up to and including 20mm	+ 6	± 1mm
Thickness or height	- 3mm	
Above 20mm	+ 6	± 5%
Thickness or height	- 3mm	
Other than Elastomeric	± 3mm	± 3mm

B.2 Parallelism of Outer Surfaces

When designed to be parallel, the tolerance on parallelism of the upper surface of a bearing with respect to the lower surface of the bearing, as datum shall be 0 2% of the diameter for surfaces circular in plan and 0.2% of the longer side for surfaces rectangular in plan.

C. Dimensions of Bearing Parts

C.1 Roller Bearings

C.1.1 General: The tolerance on flatness for roller plates measured in any direction shall be 0.025mm for lengths up to and including 250mm and 0.01% of the length, in the direction of measurement, for lengths above 250mm. The surface roughness Ra of rolling, surfaces shall not exceed 0.8μ m.

C.1.2 Cylindrical Rollers: The tolerance on cylindricity shall be 0.025mm. The tolerance on size of single rollers with respect to their nominal diameter shall be +0.5mm and -0.0mm. The tolerance on size of multiple rollers with respect to their nominal diameter shall be +0.08mm and -0.0mm.

C.1.3 Non-cylindrical Rollers: Curved surfaces shall have a profile of surface tolerance of 0.3% of the intended radius. The tolerance on size with respect to the height at the center-line of the bearing shall be +0.5 mm and -0.0mm. The tolerance on parallelism between the chord line joining the ends of the top rolling surface with respect to the chord line joining the ends of the bottom rolling surface as datum shall be 1mm. The tolerance on squareness between the plane passing through the centers of the rolling surfaces as datum and the top and bottom chord lines joining the ends of the rolling surfaces shall be 1mm.

C.2 Rocker Bearings

C.2.1 Steels with hardness of 300HB and Over: For steels with a hardness not less than 300HB, determined in accordance with AASHTO T70 (ASTM E10) or BS 240 Part 1, the tolerance on flatness, along the line of contact, for plates mating with rockers shall be 0.075mm for lengths up to and including 250mm, and 0,03% of the length for lengths above 250mm. For rockers, the profile of surface tolerance for the length of the surface over which contact can occur shall be 0.025mm. The surface roughness Ra of rocking surfaces shall not exceed 0.8 μm.

C.2.2 Steels with Hardness Under 300HB: For steels with a hardness less than 300HB, determined in accordance with AASHTO T70 (ASTM E10) or BS 240: Part 1, the tolerance on flatness, along the line of contact, for plates mating with rockers shall be 0.1mm for lengths up to and including 250mm, and 0.04% of the length for lengths above 250mm. For rockers, the profile of surface tolerance for the length of the surface over which contact can occur shall be 0.05mm. The surface roughness Ra of both rocking surfaces shall not exceed 0.5 μm.

C.3 Knuckle Bearings

C.3.1 Pin and Leaf Knuckle Bearings: For pins and seatings, the tolerance on cylindricity shall be 0.25mm. For pins up to and including 250mm diameter, the diameter of the pins shall be within a size tolerance of -0.25mm to -0.40mm and the diameter of the seating shall be within a size tolerance of 0.0mm to +0.15mm. For pins exceeding 250mm diameter, the clearance between the pin and the seating shall be not less than 0.4mm and not more than 0.75mm.

C.3.2 Cylindrical and Spherical Knuckle Bearings: The tolerances on flatness and profile of surface for cylindrical knuckle bearings and tolerance on profile of surface for spherical knuckle bearings shall be 0.0002 X h mm or 0.24mm, whichever is the greater, where X is the length of the chord (in mm) between the ends of the PTFE surface in the direction of rotation, and h is the projection of the PTFE (in mm) above the top of the confining recess, for confined PTFE, or the thickness (in mm) for bonded PTFE. The tolerance on size with respect to the radius of the curved surface on the finished bearing shall be 3% of the intended radius. The surface roughness Ra of metal curved surfaces shall not exceed 0.5 μm. Where PTEE forms one of the contact surfaces it shall comply with the appropriate requirements given in 3.4 below.

C.4 Plane Sliding Bearings

C.4.1 PTFE, Sheet: The tolerance on flatness of PTFE sheet shall be 0.2mm where the diameter or diagonal is less than 800mm and 0.025% of the diameter or diagonal where this dimension is greater than or equal to 800mm. On PTFE surfaces made up of more than one piece of PTFE the above conditions shall apply to the diameter or diagonal dimension of the inscribing circle or rectangle around the PTFE. The dimensional tolerances on PTEE sheet shall be as given in Table 5.19.2. The gap between the edge of the PTFE sheet and the edge of the recess in which it is confined shall not anywhere exceed 0.5mm or 0.1% of the corresponding plan dimensions of the PTFE sheet, in the direction measured, whichever is the greater. The profile tolerance on the specified projection of PTFE above its confining recess shall be as given in Table 5.19.3. All measurements on PTFE sheet shall be made at a temperature of 20°C to 25°C.

Table 5.19.2: Dimensional Tolerances on PTFE Sheet

Diameter or Diagonal	**Tolerance on plan**	**Tolerance on thickness**	
	dimension	**Recessed PTFE**	**bond PTFE**
mm ≤600	mm ± 1.0	mm + 0.5 - 0	mm + 0.1 - 0
600, ≤1200	± 1.5	+ 0.6 - 0	+ 0.2 - 0
Over 1200	± 0.2	+ 0.7 - 0	Not applicable

C.4.2 Mating Surfaces: For planar surfaces mating with PTFE the flatness tolerance in all directions shall be 0.0002Lh mm where L is the length (in mm) of the PTFE surface in the direction measured and h is the projection of the PTFE (in mm) above the top of the confining recess for confined PTFE or the thickness (in mm) for bonded PTFE. The surfaces roughness Ra of metal planar sliding surfaces shall not exceed 0.15 μm.

Table 5.19.3: Profile Tolerance on PTFE Projection

Maximum dimension of PTFE (diameter or diagonal)	Tolerance on specified projection above recess
mm ≤ 600	mm + 0.5 - 0
over 600, ≤ 1200	+ 0.6 - 0
over 1200, ≤ 1500	+ 0.8 - 0

C.5 Elastomeric Bearings

C.5.1 Parallelism: The tolerance on parallelism for the axes of reinforcing plates with respect to the base of the bearing as datum shall be 1% of the diameter for plates circular in plan or 1% of the shorter side for plates rectangular in plan.

C.5.2 Size: The tolerance on size with respect to the plan dimensions of plates for reinforcing elastomeric bearings shall be + 0mm and -3mm. The tolerance on size with respect to the thickness of the top and bottom covers for laminated elastomeric bearings shall be between + 20% and 0% of the nominal thickness or 1mm whichever is the lesser. The tolerance on size with respect to the thickness of an individual inner layer of elastomer in a laminated elastomeric bearing shall be ± 20% of its nominal thickness value or 3mm whichever is the lesser. The tolerance on size with respect to the thickness of the side cover for a laminated elastomeric bearing shall be +3mm and - 0mm.

C.6 Pot Bearings

The tolerance of fit between the piston and the pot shall be +0.75mm to +l.25mm.

C.7 Guides

The surface roughness Ra of metal sliding surfaces shall not exceed 0.5 μm.

C.8 Fixing Holes in Bearing Plates

Where required, tolerances on the position for centres of fixing holes shall be as specified or approved by the Engineer.

5.19.06PROTECTIVE MEASURES

A. Aluminum Alloy Components

Permanently exposed surface of aluminum alloy components shall be degreased and painted as specified or approved by the Engineer. Where aluminum would otherwise be in contact with Portland cement concrete, the former shall be suitably protected.

B. Ferrous Components

Exposed parts of iron and steel shall be protected against corrosion as specified or approved by the Engineer.

C. Dissimilar Materials

Care shall be taken to prevent electrolytic action between dissimilar metals in contact by the use of suitable insulation and prevention of moisture penetration.

D. Damaged Areas

Any damaged areas of protective treatment shall be made good to the satisfaction of the Engineer or the damaged parts replaced.

5.19.07TESTING

A. General

A.1 All testing shall be carried out at approved independent laboratories.

A.2 The Engineer or his nominated representative may attend one or all of the tests. The Contractor shall arrange the dates and times of tests to enable the Engineer or his representative to attend the tests. If the Engineer or his representative cannot attend a test, the Contractor shall, at his own cost, arrange for an independent observer approved by the Engineer to witness the test.

A.3 A test report in English prepared by the independent laboratory shall be submitted in triplicate. The report shall include photographs and descriptions of the test rigs, instrumentation and all factual data with a comparison of test results and the requirements of the Specification.

B. Materials Tests

B.1 The physical and mechanical requirements of all metal components shall be tested for compliance with the Specification.

B.2 PTFE shall be tested for tensile strength and elongation in accordance with ASTM D1457.

B.3 The physical and mechanical properties of elastomers for elastomeric bearings and elastomers used in pot bearings shall be tested according to the standards specified in ASTM D4014 for compliance with the acceptance criteria set out in ASTM 4014.

B.4 The Engineer may, if sufficient and reliable production test certificates exit, waive the requirement for independent tests. The Engineer may reinstitute the requirement for independent testing at any time if he is not satisfied for any reason whatsoever.

C. Load Testing of Metal Bearings

C.1 Vertical Load Test

C.1.1 The vertical load shall be applied in equal increments of not less than five up to the specified working load, which shall be held for 1 to 3 hours. The load shall then be removed in equal decrement. A second cycle of load increment and decrement shall be applied with the maximum (working) load held for 30 minutes. The load-deformation graph shall be plotted for both load cycles. At the end of the second load cycle, the bearing shall be dismantled and the bearing surfaces examined.

C.1.2 If the bearing surfaces show no sign of distress, a further two load cycles as described in 3.1.1 above shall be carried out except that the maximum load in each cycle shall be 1.5 times the specified load.

C.1.3 The period to which the maximum load is to be held shall be decided by the Engineer or his representative or by the independent witness and will depend on the slope of the load-deformation graph.

C.2 Friction Test

This test shall be performed at constant vertical loads of 50 and 80 per cent of specified load. The horizontal load shall be applied to obtain a steady rate of movement of 1 mm per minute to reach a total movement of 30mm or as directed by the Engineer.

C.3 Guide Test

This test shall be carried out at constant vertical loads of 50 and 100 per cent of rated load. The horizontal load shall be applied in ten equal increments to a maximum of designed horizontal load. Two load cycles for each test shall be performed. Where required by the Engineer, electrical strain gauges shall be installed on the base plate at 30 degrees spacing on one quarter of tile base plate to measure the stress occurring at the rim/base junctions.

C.4 Sampling

At least one bearing of each type, selected at random, shall be load tested unless the type of bearing is a part of a standard product with well documented production test data in which case the Engineer may agree to accept the production test results in lieu of independent testing.

C.5 Load Testing of Elastomeric Bearings

D.1 The sampling and load testing of elastomeric bearings shall be in accordance with ASTM D4014.

D.2 The maximum test load for vertical load, without shear deformation of elastomer, shall be 2 times the specified vertical load.

D.3 Shear testing shall be carried out at constant vertical loads of 50 and 100 per cent the specified load.

D.4 The requirements for load testing of elastomeric bearings may be dispensed with if, in the opinion of the Engineer, sufficient production test data exists.

5.19.08MEASUREMENT

A. Measurement of bridge bearings shall be by the number of each type of bearing installed and completed in place and accepted. Bearings of the same type but of different load capacities shall be measured separately.

B. Bearing tests, installation trials, bedding, nuts and bolts and where applicable epoxy injection shall not be measured separately but shall be deemed to be subsidiary to bearing Where temporary restraint of bearing is necessary due to the sequence of deck

construction, it will not be measured separately for payment.

C. The amount of completed and accepted Work measured as provided above, will be paid for at the unit prices bid for each type of "Bridge Bearing" as specified in the Bill Quantities, which prices shall be full compensation for furnishing, all materials, labour, equipment, tools, supplies and all other items necessary for proper completion of the Work.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Steel Bearings (Type and Capacity)	Number (Nr)
(2) Elastomeric Bearing (Type and Capacity)	Number (Nr)
(3) Bearing Strip (Type and Capacity)	Linear Meter (m).

**** END OF SECTION ****

SECTION 5.20 BRIDGE PARAPETS AND RAILINGS

5.20.01SCOPE

This work shall consist of furnishing and installing bridge parapet and railings and noise barriers as and where shown on the Drawings or as directed by the Engineer.

5.20.02MATERIALS

A. Materials of Construction

The materials of construction of the parapet shall be aluminum alloy or structural steel or reinforced concrete.

B. Aluminum Alloy

Aluminum alloys used for bridge parapets, railings, and noise barriers shall conform with the requirements of AASHTO M193 and M 219 or BS 1470, 1474 and 1490.

C. Structural Steel

Structural steel used for bridge parapets and railings shall conform with the requirements of the Section 5.17 “Structural Steelwork and Metal Components”. The anchorage system shall be as shown on the Drawings or of a type approved by the Engineer.

D. Reinforced Concrete

Reinforced concrete used for bridge-parapets shall conform with the requirements of the Section 5.01 “Concrete Mixes and Curing”, Section 5.02 “Concrete Handling, Placing and Curing”, and Section 5.06 “Plain and Reinforced Concrete Structures”. The anchorage system shall be as shown on the Drawings or be of a type approved by the Engineer.

E. Plexiglass Noise Barriers

Plexiglass barriers used for noise control shall conform with the requirements of BS 3638 and BS 2750:3 or German Regulation ZTV – LSW 88.

F. Anchorage System

The anchorage system of parapets and rails, which shall be to the approval of Engineer, shall be such that damaged metal posts and rails can be readily replaced without the need for cutting the bridge deck or copings or edge units into which the anchorages are located

5.20.03CONSTRUCTION

A. During erection the parapet units shall be securely held in their correct positions until all connections and fixings are complete and the post fixings have gained adequate strength to develop the full holding down moment. The assessment of the adequacy of the post fixing shall be subject to the Engineer’s approval. The finished parapets shall

be true to line and level throughout their length.

B. The welding of aluminum shall comply with the requirements of BS3019 Part 1 and BS 3571 Part 1 and all welding shall be carried out in the factory under controlled environment. Welding of steel parapet units shall be carried out in factory or at site in compliance with Section 5.16 "Structural Steelwork and Metal Components".

C. In case of Metal Bridge Parapet the Contractor shall ensure the proper installation of the posts and rails using tools and procedures recommended by the manufacturer, and thereafter by competent persons who have been trained in the proper installation of the type of bridges parapets used.

D. The rail and posts of the parapet shall be closed sections presenting no visible seam welds or exposed bolt heads. The shape and texture of the posts and rails and the protective treatment to be applied shall be as indicated on the Drawings and deviations and / or alternations to these shall not be permitted.

E. The standard of finish of reinforced concrete parapet units shall conform to finish of approved units made before main production commences. Where minor blemishes and discolorations occur on production units making good with an approved epoxy mortar compound will be permitted only with express approval of the Engineer. Units which are considered unacceptable for use in the works by the Engineer will be destroyed. Considerable care will be given during erection of parapet units to avoid cracking or otherwise damaging the concrete unit or its finish.

5.20.04MEASUREMENT

A. Bridge parapets shall be measured by the linear meter of different types of parapets and railings installed, completed and accepted. Bridge noise barrier shall be measured by square meter of different type of plexiglass sound control barrier, completed and accepted. No separate measurement shall be made for full scale dynamic testing or any other testing that may be required under the Special Specification but shall be considered as subsidiary to bridge parapets. Similarly, expansion joints, Aluminum plates to cover the joint between the median New Jersey barriers on bridge deck, specially fabricated units of posts and rails for nosing areas, special requirements at junctions with transition walls, or guard rails, grit blasting to produce the required surface texture, holding down assemblies and stitching concrete will all be considered subsidiary to bridge parapets.

B. Compensation for completed and accepted work shall be considered only in the unit rate per linear meter for the parapet, and square meter for the noise barrier, which price shall be full compensation for furnishing all materials, labour, equipment, tools, tests, records and all other items for completing the works as specified.

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Concrete bridge parapet (state type)	linear meter (m)
(2) Galvanized Steel bridge parapet	linear meter (m)
(3) Aluminum bridge parapet (state type)	linear meter (m)
(4) Steel pedestrian railings	linear meter (m)
(5) Aluminum pedestrian railing	linear meter (m)
(6) Plexiglass Noise Barrier	square meter(m^2)

**** END OF SECTION ****

SECTION 5.21 JOINT SEALING AND JOINT FILLER

5.21.01SCOPE

This work covers joint sealing materials and performed expansion joint filler for use where shown on the Drawings or as directed by the Engineer.

5.21.02MATERIALS: JOINT SEALING COMPOUNDS

A. Hot Type

A.1 Composition

This type shall be a mixture of virgin synthetic rubber or reclaimed rubber, or a combination of the two, with asphalt plasticisers and tactified. Ground cured rubber scrap shall not be used.

A.2 Physical requirements

A.2.1 The joint sealing compound, after heating and application, shall form a resilient and adhesive compound capable of effectively sealing joints in concrete against the infiltration of moisture and foreign material through repeated cycles of expansion and contraction. It shall be capable of being brought, by heating, to a uniform, smooth pouring consistency, free from lumps, and suitable for completely filling the joints and without damage to the material. It shall not flow from the joints or be picked-up and tracked by vehicle tyres at summer temperatures.

A.2.2 **Pour point:** The pour point shall be at least 11 degrees C lower than the safe heating temperature. The safe heating temperature is defined as the highest temperature to which the material can be heated and still meet all requirements of this specification. No sample of the material will be tested until the manufacturer furnishes his recommended safe-heating and pouring temperatures.

A.2.3 **Prolonged heating:** After 6 hours of continuous heating, with constant mixing in the laboratory matter at the manufacturer's recommended pour temperature, the joint sealer shall meet all requirements of this specification. (For initial qualifying tests and subsequently as directed by the Engineer).

A.2.4 **Penetration:** The penetration at 25 degrees C, 150 gm, 5 sec, shall not be less than 50 nor more than 90 mm.

A.2.5 **Flow:** The flow at 60 degrees C and at a 75 degree angle shall not exceed 1cm in 5 hours.

A.2.6 **Ductility:** Ductility at 25 degrees C shall be not less than 35 cm.

A.2.7 **Bond:** The material when tested at minus 17.8 degrees C to 100 percent extension (1.27 cm extended to 2.54 cm) shall, after 5 cycles, show no surface checking, cracking, separation or other opening in the material or between the material and the block. At least 2 test specimens in a set of 3 specimens representing a given sample shall meet this requirement.

A.2.8 **Resilience:** Recovery shall be not less than 25 percent.

A.2.9 Compression recovery: Compression recovery of bond specimens shall be not less than 1 cm within 15 min.

A.2.10 Impact: No failure in cohesion or adhesion shall occur.

A.3 Methods of Sampling and Testing

A.3.1 Sampling: Samples for testing shall consist of not less than a 4.5 kilogram sample from each batch of the joint sealer. A batch shall be considered as all finished material that was manufactured simultaneously or continuously as a unit between the time of compounding and the time of packaging or placing in shipping containers. Each package or container shall be marked properly to indicate clearly the batch of which it forms a part. The material shall be sampled in accordance with the requirements of the "Standard Methods of Sampling Bituminous Materials" (ASTM Designation: D 140) for solid materials in cakes**.**

A.3.2 Testing: Testing shall be in accordance with AASHTO T187 except that the tolerances on dimensions of test specimens Article 6.3 shall be ± 0.13 cm and the temperature tolerances Article 6.4 shall be ± 2.2 degrees C.

B. Cold Type

B.1 Composition

This type shall be homogeneous material of such consistency that it can be applied by means of high-pressure pump through suitable nozzles to completely fill the joints. The compound may be blended with a suitable solvent or solvents by the manufacturer to provide better workability during installation in the joints. The volatility of these solvents must be such that they will evaporate within a short time after installation leaving a material that is adhesive and resilient.

B.2 Physical Requirements

B.2.1 Flow: The flow during a 5 hour period at 60 degrees C shall not exceed 0.5 cm.

B.2.2 Penetration: After evaporation of the solvent the penetration at 25 degrees C 150 gm 5 sec shall not exceed 220 mm.

B.2.3 Bond: When the compound is tested at minus 17.8 degrees C the development at any time during the test procedure of a crack separation or other opening which is at any point over 64 mm deep in the material or between the material and the concrete block shall constitute failure of the test specimen. The failure of more than 1 test specimen in a group of 3 specimens representing a given sample of joint sealing compound shall be cause for rejection of the sample on the basis of this requirement.

B.3 Methods of sampling and testing

Cold-type joint compound shall be tested in accordance with ASTM D 1851 except that the material for test specimens Article 7(c) will be stirred manually rather than mechanically.

B.4 Preformed

Preformed Polychloroprene Elastomeric Joint Seals shall comply with the requirements of AASHT0 M220(ASTM D2628).

C. Joint Sealant for movement joints in water retaining structures is to be polysulphide based compound to BS 4254 or as manufactured by:

Man: Expandite Ltd.
Ref.: Thioflex 600

Man: Servicised Ltd.
Ref.: Paraseal

or other equal and approved.

D. Exposed Joint Sealant for movement joints is to be approved polysulphide rubber based compound unless otherwise specified.

Man: Dunlop Ltd.
Ref.: High butyl mastic 421.8

Man: Expandite Ltd.
Ref.: Thioflex 600

or other equal and approved.

E. Backing Strip: type recommended by joint sealant manufacturer.

5.21.03PREFORMED EXPANSION JOINT FILLER

A. Description

This type of filler shall be a non-extruding and resilient bituminous type and shall have relatively little extrusion and a moderate to high amount of recovery after release from compression.

B. Requirement

Nonextruding and resilient type of expansion joint filler shall conform to all the requirements of the Standard Specification for "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous types)", AASHTO Designation M 213 (ASTM D1751)

C. Movement Joint Sheet Material Filler

For expansion joints in water retaining structures is to be bonded granular cork to ASTM D 1752 or ASTM D 1751 or as manufactured by:

Man: Expandite Ltd.
Ref.: Cork filler

Man: Servicised Ltd.
Ref.: Kork-Pak
or other equal and approved

5.21.04CERTIFICATE OF GUARANTEE

The Contractor shall furnish the Engineer with a Manufacturer's Certificate of Guarantee for each type of joint material delivered to the Site. The certificate shall note compliance to the appropriate specifications and shall state the results of the tests performed on the material as required by the specifications. The Contractor shall when so directed by the Engineer have the joint material tested for conformance to the applicable specifications at an approved testing laboratory. All costs connected with Certificate of Guarantee and any subsequent quality testing shall be at the Contractor's expense.

5.21.05CONSTRUCTION

A. Generally: joints are to be:

- Straight, vertical, horizontal or as detailed or approved
- Formed to accommodate projecting reinforcement

B. Movement Joints are defined as:

- Formed expansion joints
- Formed contraction joints
- Induced contraction joints.

C. Formed Movement Joints: construct rigid stop ends and formwork at formed movement joints to permit separate construction of structurally separate parts of the work.

D. Construction Joints: where not coincident with movement joints submit proposals for positions of construction joints and obtain approval.

E. Construction Joints: lightly roughen face to expose coarse aggregate unless otherwise instructed. Wet and cover with 1:1 cement and sand grout immediately prior to placing fresh concrete. Stop roughening 25 mm from arises to surfaces exposed to view in finished work. Remove small mortar lips from exposed arises with carborundum stone. Face is to be clean and damp before fresh concrete is placed against it.

F. Concrete Floors side and end forms are to be square edged with steel top surface.

G. Waterbars: nail to forms prior to concreting and butt joint in accordance with the manufacturer's instructions.

H. Sealing of Movement Joints: preparation and application is to be strictly as manufacturer's recommendations. Joints are to be thoroughly clean and dry, free from oil and loose material. Vigorously wire brush or grit blast the joint faces and clean out with compressed air. Prime faces of joint and allow to dry. Where exposed to view mask edges of joint with tape before priming and remove immediately after sealing. Apply sealant ensuring maximum adhesion to sides of joint and a neat, smooth and clean finish.

5.21.06MEASUREMENT

A. No part of this Section is a Bid Item and no measurement shall be made.

B. The materials provided for this Section will not be paid for directly, but will be considered subsidiary to other items of work appearing in the Bill of Quantities.

**** END OF SECTION ****

SECTION 5.22 DRAINAGE OF STRUCTURES

5.22.01SCOPE

This work shall consist of furnishing and installing gully and channel grates and frames on bridge decks, subways and underpasses, for collecting surface water from structures. It shall also consist of furnishing and installing hoppers, draining pipes and downpipes which arc connected to the gully and channel grates by hoppers.

The gully and channel grates and frames may be of cast iron or cast steel with or without integral cast hoppers. In the absence of integral cast hoppers, fabricated PVC or GRP hoppers will be necessary. The Contractor shall submit, as early as possible, details of all drainage material and components he proposes to use for the approval of the Engineer. No material or component shall be incorporated in the Works without written approval of the Engineer.

5.22.02MATERIALS

A. Gully and Channel Grates and Frames

Frames and grating shall comply with the following

- AASHTO M105 (ASTM A48) or BS497: Part 1 for cast iron
- AASHTO M192 (ASTM 486M) or BS497: Part 1 for cast steel.

B. Iron and Steel Pipes

Cast iron pipes shall conform to the requirements of BS78 Parts 1 and 2 and spun iron pipes to BS1211. Steel pipes shall conform to the requirements of ASTM A 135, ASTM A139 or BS534.

C. PVC and UPVC Pipes

Pipes of synthetic materials for general drainage use shall be approved pipes of polythene, polypropylene, or polyvinylchloride. Unplasticised polyvinylchloride pipes shall conform to the requirements of Class 2 and Class 3 ASTM D3033.

5.22.03CONSTRUCTION

A. Drainage pipes and gullies shall be laid to the lines and levels and bedded laid, jointed and protected, all as shown on the Drawings, or as established by the Engineer.

B. When drainage pipes are cast into concrete structures, the Contractor shall take adequate precautions to prevent any displacement of the pipes during the concreting operation.

C. Drainage pipes shall be tested for water tightness and the test procedure shall be agreed with the Engineer. Where drainage pipes are located within the cellular parts of a bridge deck where access after completion of the deck is limited, then the installation and testing of the pipes shall be completed and accepted by the Engineer before the deck construction is allowed to proceed to the stage where free access to the pipes will not be possible.

5.22.04MEASUREMENT

A. Gully grates and frames of different types shall be measured by the number installed, completed, and accepted. Hoppers connecting the gully frames to drainage pipes shall not be measured separately but shall be considered subsidiary to gully grates and frames.

B. Different types of channel grates and frames shall be measured by the linear meter installed, completed, and accepted. Hoppers connecting channel frames to drainage pipes shall not be measured separately but shall be considered subsidiary to channel grates and frames.

C. Different types of drainage pipes shall be measured by the linear meter of each diameter and each type of pipe installed, completed and accepted. No separate measurement will be made for pipes cast into concrete or for pipes connecting gully and channel frames to drainage pipes (only if the connection length is greater than 10m) or for pipe supports and joints or for discharge hoppers from drainage pipes to down-stand pipes, but shall be considered subsidiary to drainage pipes.

D. No separate measurement will be made for testing of gully grates and frames gully hoppers, or drainage pipes and their support system but shall be considered subsidiary to the items tested.

E. Compensation for completed and accepted work shall be considered included in the lump sum price of the Contract, which price shall be full compensation for furnishing all materials, labor, equipment, tools, tests, records and all other- items necessary for the proper completion of the works as specified.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Gully Grates and Frames (state type)	Number (Nr)
(2) Channel Grates and Frames (State type)	Linear meter (m)
(3) Iron pipes (state dia)	Linear meter (m)
(4) Steel pipes (state dia)	Linear meter (m)
(5) UPVC pipes (state dia)	Linear meter (m)
(6) PVC pipes (state dia)	Linear meter (m)

**** END OF SECTION ****

SECTION 5.23 NOT INCLUDED

SECTION 5.24 NOT INCLUDED

SECTION 5.25 CONCRETE REPAIR USING FAST-HARDENING MICRO CONCRETE

5.25.01SCOPE

This Section of the Specification describes the repair works for the damaged concrete by using fast hardening micro-concrete Mortar used for repairing the concrete support of expansion joint, the edges of joint gaps, abutment back walls, deck slabs and any other concrete structure suitable for such repairs.

5.25.02MATERIALS

A. Material to be used shall be cement based high strength and fast hardening micro-concrete (Minimum compressive strength in one day 35 MPa) with a maximum aggregate size of 10mm (Sikacrete or equivalent).
The contractor shall submit documentation for the Engineer for the brand and type of structural mortar intended to be used on the job. The Engineer shall approve the materials before any use on site. The documentation shall include other, additional, materials needed for the job, such as priming coats, antirust (zinc rich), and bonding agent. All materials shall be compatible for the whole repairing package.

B. Steel Reinforcement

Steel reinforcement, If needed, shall be High tensile steel reinforcement bars conforming with AASHTO M31 (ASTM A615) Grades 60 and/or 40 produced and supplied in accordance with Section 5.03: Steel reinforcement.

5.25.03CONSTRUCTION

The contractor shall submit a method statement for construction and submit it to the Engineer for approval at least 2 weeks prior site execution. This method statement should align with the approved manufacturer recommendations and the contract drawings.

5.25.04 MEASUREMENT

Measurement shall be by linear metre (m) of bridge expansion joint support repaired with micro concrete, measured along the centerline of the joint support, as directed by the Engineer.

No separate measurement will be made for the following:

- All materials, labour, equipment, and incidental works necessary to complete concrete repair works
- Supply and installation of additional steel reinforcement bars, including drilling, anchoring with approved epoxy resin, and cleaning and brushing of existing reinforcement.
- Resizing the gaps of the expansion joints where necessary, taking into consideration the maximum bridge movements and the new joint capacity pertaining to the maximum allowable gap .
- Supply and application of polymer-modified, non-shrink structural repair mortar in accordance with project specifications.

- Application of anti-corrosion protective coating to exposed steel reinforcement prior to mortar application.
- Surface preparation, formwork, curing, and provisions to achieve proper finishing consistent with the required levels.
- All associated works necessary to complete the repairs in accordance with project specifications and to the satisfaction of the Engineer.

The structural repair mortar shall be fast hardening micro-concrete (Minimum compressive strength in one day 35 MPa) with a maximum aggregate size of 10mm (Sikacrete or equivalent)

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) concrete repair using fast-hardening micro concrete	Linear metre (m)

**** END OF SECTION ****

SECTION 5.26 SHOTCRETING

5.26.01SCOPE

This work shall consist of furnishing, preparing, and applying shotcrete to the soffit of upper tunnel slabs to depths and locations as instructed by the Engineer. The objective is to restore the structural integrity of slabs damaged by reinforcement rust and to provide serviceable structures equivalent to their original condition prior to deterioration.

Work shall be carried out under the close supervision of the Engineer following installation and adjustment of scaffolding capable of safely supporting the load of men and equipment. Work shall be executed precisely, in accordance with the Engineer's instructions and only during periods authorized by the Client to minimize disruption to traffic and adjacent areas.

5.26.02MATERIALS

A. Shotcrete Materials

Materials for shotcrete shall comply with the requirements of ACI 506.2 and shall be subject to the Engineer's approval prior to use.

B. Cement

Shall be Ordinary Portland Cement conforming to relevant project specifications.

C. Aggregates

Aggregates shall be clean, well-graded, and free from clay, silt, organic matter, and other deleterious substances.

D. Admixtures

Only approved shotcrete admixtures shall be used. Admixtures containing alkali hydroxides or other potentially toxic chemicals shall be handled in accordance with approved health and safety practices to prevent skin and respiratory irritation.

E. Water

Clean, potable water shall be used for mixing and curing purposes, provided by the Contractor at no additional cost.

F. Scaffolding

The Contractor shall provide secure, adjustable scaffolding with proper working platforms to allow safe and comfortable access to work areas.

G. Curing Compound (if required)

Approved curing compound shall be used if directed by the Engineer.

5.26.03CONSTRUCTION

A. Preparation

- Verify field conditions and readiness of the substrate.
- Remove loose material, dust, mud, and foreign matter from new and existing surfaces.
- Clean and saturate porous cementitious surfaces with water several hours before shotcreting.

B. Application

- Employ qualified nozzlemen with prior experience on at least two similar projects, supervised by a foreman with a minimum of three years of experience.
- Nozzlemen shall demonstrate satisfactory technique on vertical and overhead test panels before commencing production work.
- Apply shotcrete using continuous, steady nozzle motion, holding the nozzle perpendicular to the surface at the specified distance.
- Apply in multiple passes, allowing each layer to achieve initial set before subsequent layers.
- Cover reinforcement completely with the first layer.
- Suspend shotcrete operations during high winds, rain, or near-freezing temperatures unless protection is provided.
- Maintain dust and noise control measures, with frequent cleaning of surfaces and surrounding areas.

C. Finishing and Curing

- Screed and finish surfaces as directed by the Engineer.
- Maintain surfaces continuously wet for a minimum of 7 days.
- If required, apply curing compounds per manufacturer’s instructions.
- Protect freshly placed shotcrete against premature drying, extreme temperatures, and mechanical damage.

D. Testing and Quality Control

- Prior to work commencement, the Engineer will verify mix design, aggregate gradation, and material sources.
- Provide three test panels per shooting position and side to be protected.
- Test panels to receive core samples (75 mm diameter) for strength, water absorption, and shrinkage testing.
- Rebound material shall be discarded and not reused.
- Expose and repair any voids detected by hammer sounding.
- Independent testing and inspection shall be provided by a firm approved by the Engineer and paid for by the Contractor, with rates deemed included in the shotcreting work rates.

E. Work Coordination

- Coordinate closely with scaffolding contractor to complete shotcreting in areas previously obstructed.
- Prepare shotcrete edges in these areas prior to continuation of work.

5.26.04MEASUREMENT

- Shotcrete shall be measured by the square meter (m^2) of surface area completed and accepted in accordance with the specifications.
- No separate measurement shall be made for test panels, core sampling, scaffolding, water, electric power, dust control, or testing services, as these shall be deemed subsidiary to the shotcrete unit rates.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Shotcreting to tunnel soffit	square meter (m^2)

SECTION 5.27 CONCRETE SURFACE REPAIR

5.27.01SCOPE

This Section specifies the requirements for carrying out surface repairs to deteriorated or damaged concrete surfaces in bridge structures, including but not limited to soffits, abutments, piers, deck slabs, parapets, and concrete joint supports. The work includes removal of unsound concrete, surface preparation, cleaning and treatment of existing reinforcement, application of bonding agents, placement of repair mortar, and curing, as shown on the Drawings or as directed by the Engineer.

5.27.02MATERIALS

A. Repair Mortar

- The material shall be a pre-packed, polymer-modified, non-shrink, cementitious repair mortar suitable for vertical and overhead applications.
- It shall conform to **ASTM C928/C928M**.
- The repair mortar shall have the following minimum performance properties:
  - Compressive Strength: **≥ 35 MPa at 28 days (ASTM C109)**
  - Bond Strength (Pull-Off): **≥ 1.5 MPa (ASTM C1583)**
  - Chloride Ion Permeability: Low (ASTM C1202)
  - Shrinkage Compensated

B. Bonding Agent

- Latex-modified cement slurry or epoxy bonding system conforming to **ASTM C881**.
- Type and grade to suit site conditions and repair mortar type.

C. Curing Compound

- Liquid membrane-forming curing compound conforming to **ASTM C309**.

D. Water

- Clean, fresh, and free from harmful substances, conforming to **ASTM C1602**.

5.27.03SURFACE PREPARATION

- Deteriorated, loose, and unsound concrete shall be removed to sound, dense material using **light pneumatic tools not exceeding 3 kg** in weight, in accordance with **ACI 546R-14**.
- The removal shall be carried out carefully to avoid damage to adjacent sound concrete and reinforcement.
- All exposed reinforcing steel shall be cleaned to bright metal condition by wire brushing, sandblasting, or equivalent, per **ACI 546R-14**.
- The prepared concrete substrate shall be roughened to a profile equivalent to **ICRI CSP 6-9**, as per **ASTM D4259**.
- The prepared area shall be thoroughly cleaned with compressed air or clean water to remove all dust, debris, and contaminants.
- Before placing repair material, the surface shall be brought to a **Saturated Surface Dry (SSD)** condition if using cementitious mortars.

5.27.04APPLICATION OF REPAIR MATERIAL

A. Bonding Agent Application

- Apply approved bonding agent to the prepared substrate in accordance with manufacturer's instructions.
- If epoxy bonding agent is used, it shall comply with **ASTM C881** and be applied to achieve full coverage of the repair area.

B. Repair Mortar Application

- Repair mortar shall be applied in layers not exceeding the manufacturer's recommended thickness for vertical or overhead applications.
- Each layer shall be well compacted, ensuring intimate contact with the prepared substrate and between successive layers.
- The surface shall be finished to match the adjacent concrete.

C. Edging and Finishing

- All repairs shall terminate against clean, straight saw-cut or chiseled edges, with a minimum depth of **10 mm**.

5.27.05CURING

- Immediately after finishing, the repaired surfaces shall be cured by applying a curing compound conforming to **ASTM C309**.
- Curing shall be maintained for a minimum of **7 days** for cementitious repairs, or as recommended by the repair material manufacturer.

5.27.06MEASUREMENT AND PAYMENT

- Measurement shall be made in **square meters (m^2)** of completed and accepted concrete surface repair.
- The unit rate shall include:
  - Removal of deteriorated concrete
  - Surface preparation
  - Cleaning and treatment of existing reinforcement
  - Supply and application of bonding agent
  - Supply and application of repair mortar
  - Finishing and curing
  - Disposal of debris and waste
  - Provision of all necessary labor, materials, equipment, tools, and incidentals to complete the work in accordance with these Specifications and as directed by the Engineer.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Concrete Surface Repair	square meter (m^2)

DIVISION 6

INCIDENTAL CONSTRUCTION

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SECTION 6.01 CURBS, GUTTERS, SIDEWALKS AND PAVED MEDIANS

6.01.01 SCOPE

These Works shall consist of furnishing materials and constructing concrete / limestone curbs, gutters, curb-and-gutter combinations and concrete / limestone paving to sidewalks and medians, using in situ concrete construction or precast concrete units, as and where shown on the Drawings.

6.01.02 Materials And Precast Manufacture

A. Concrete

A.1 All concrete shall conform to the relevant requirements of Section 5.01 “Concrete and Concrete Mixes and Testing”. And shall be produced by an approved commercial ready-mix plant.

Portland cement concrete shall be Class 210/20 for all in situ and precast concrete, except base course and backing concrete, which shall be Class 170/60. All concrete shall conform to the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing" and shall be produced by an approved commercial ready-mix plant.

A.2 Block Paving: Interlocking Concrete Blocks to BS 6717: Part 1, Precast concrete interlocking block pavers, obtained from an approved manufacturer and to the shapes, sizes, colours, finishes and patterns shown on the Drawings.

B. Mortar

Mortar shall consist of cement and fine aggregate having the same proportions as used in the concrete construction and shall conform with all relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

C. Reinforcement

Reinforcing steel shall conform with the requirements of Section 5.03 - "Steel Reinforcement and Fixing".

For sidewalks mesh reinforcement 6 or 8 mm at 200 mm cent to cent.

D. Precast Concrete Units

D.1 All precast units shall be manufactured to the dimensions shown on the Drawings. Manufacturing tolerances shall be 3 mm in any one dimension. End and edge faces shall be perpendicular to the base.

D.2 Each precast curb or gutter unit shall normally be 0.5 m in length and this length shall be reduced to 0.25 m or as directed, where units are to be installed along curves of less than 10 m radius.

D.3 For horizontal curves of radius less than 10 m, curb and gutter units shall be manufactured to the radius shown and in such circumstances where straight elements or

portions of straight elements shall not be used. Bull noses and curved faces shall be of constant radius with a smooth change from radius to plain face.

D.4 Unless shown otherwise on the Drawings, precast concrete tiles (paving slabs) shall be 200 mm by 200 mm by 25 mm thickness with 5 mm edge bevel. The tile face shall be grooved in squares of a size agreed by the Engineer as appropriate to the tile dimensions. Coloring of the top layer, where required, shall be achieved using mineral oxides.

D.5 Surfaces of precast units that will be exposed to view after installation, shall be true and even, with a dense finish of uniform texture and color, free from cracks, holes, fins, staining or other blemishes or defects. Units failing to meet these requirements will be rejected. Surfaces that will not be exposed to view after installation shall have all fins and irregular projections removed and all cavities, minor honeycombing and other defects made good with mortar after the units have been saturated with water for at least 3 hours.

D.6 Precast units shall be cast upside down in approved steel molds under conditions of controlled temperature and humidity. The units shall be steam cured or any other method approved by the Engineer until the concrete attains the full specified 28-day strength.

D.7 The Contractor shall submit for approval, samples of each of the proposed units together with the manufacturer's certificates and details of the method of manufacture and materials to be used. The Engineer's approval of the samples will not be considered final and the Engineer may reject any precast units delivered to the Site, which do not meet the required standards.

D.8 Testing of Tiles

The following tests shall be carried out on sidewalk tiles to ascertain their suitability fro the work.

(i) Flexural Strength
(ii) Abrasion Resistance

The first test shall be carried out on four samples taking as the final result the average of the most homogeneous results of the four. The abrasion resistance test shall be carried out on two samples, the results of which shall be averaged.

(i) Flexural Strength

This test carried out by placing the tile on two knife supports, with edges rounded with a radius of one cm, arranged parallel to the side of the tile and ten cm apart. The load is gradually transmitted to the tile top surface, along the centerline, by a third knife arranged parallel to the other two.

The unit maximum bending stress equals $15Phb^2$ where "P" is the total breaking load in kilograms, "b" is the width of the tile in centimeters, "h" the thickness of the tile in centimeters.

The limit acceptance value for Flexural Strength shall be 30 kg/sq.cm minimum.

(ii) Abrasion Resistance

This test is carried out with a machine composed of a horizontal cast-iron disc rotating about its vertical central axis at uniform speed; a horizontal diametrical cross-piece by means of which two samples are pressed on the disc, at such a distance from the center of the disc, that the relative speed with respect to the disc, is one

meter per second; a second horizontal diametrical cross-piece orthogonal to the first, which carried at either end appropriate devices to let the moistened abrasive flow on the track; two pairs of conveniently arranged brushes to guide the abrasive that tends to escape under the samples.

The samples, pressed against the disc, rotate by means of a special mechanical device, around their own vertical central axis, at the rate of one turn of the specimen for 50 turns of the disc. Carborundum grit sufficiently coated with liquid mineral oil with an Engler viscosity between five and seven at 50 degrees C shall be used as an abrasive. The grit shall pass sieve No. 60 and be retained on sieve No. 100. Consumption of carborundum and oil should be approximately 20 and 12 grams respectively per minute.

The square sample, with a surface area of 50 sq.cm shall be pressed against the disc by a total weight of 15 kg (unit pressure of 0.3 kg/sq.cm). The test is normally carried out with a distance run of the grinding wheel of 500 meters. For materials with a surface wearing layer different from the rest of the tile, the distance run must be such that the disc does not penetrate into the lower layer.

The thickness of the layer abraded in mm with a pressure of 0.3 kg/sq.cm for a distance run of 1000 meters is taken as the abrasion factor. This factor is determined by assuming that the consumption is proportional to the distance run.

The limit acceptance value for the Abrasion Factor shall be 12mm maximum.

E. Preformed Expansion Joint Filler

Preformed expansion joint filler shall conform to AASHTO M33.

F. Epoxy Adhesive

Epoxy adhesive (for use in attaching precast units to existing concrete pavement surfaces) shall conform with the relevant technical specifications.

G. Ducts

Ducts (if required under sidewalks or medians) shall consist of UPVC plastic pipe conforming to ASTM D2750, Type II. If jacking is required, duct shall be approved galvanized steel tube.

H. Bedding

Bedding material shall conform with the relevant requirements of Section 3.02- "Granular Sub-base Courses" for Class A or Class B granular material.

6.01.03 Construction And Installation

A. Cast Situ Curbs and Gutters

A.1 The subgrade shall be excavated to the grades and sections shown on the Drawings. If the section is not indicated, the width to be excavated shall be 300 mm each side of the outside edges of the curb or gutter. The subgrade shall be of approved uniform density The subgrade foundation shall be excavated to a minimum depth of 150mm and the material

replaced with bedding material which shall be compacted to at least 95% AASTHTO T180 maximum density All foundations shall be rolled or compacted to provide a smooth surface and shall be approved before placing concrete.

A.2 For stationary side form construction, forms for curb or gutter shall be of approved steel type. All forms shall be sufficiently strong and rigid and securely staked and braced to obtain a finished product correct to the dimensions, lines and grades required. Forms shall be cleaned and oiled before each use. Forms may be removed as soon as practicable after concreting, provided no damage results to the curb or gutter and in any case not until 24 hours after completion of concreting.

A.3 For slip-form construction, curb or gutter may be constructed by use of approved slip-form or extrusion equipment. The completed curb or gutter shall be true to shape, grade, and line, and the concrete shall be dense and of the required surface texture.

A.4 Concrete shall be placed upon the previously prepared and moistened subgrade and shall be consolidated with an approved type internal vibrator. The surface shall be shaped by use of a steel screed to produce the section shown on the Drawings. The edges shall be rounded with edgers to form the required radius, which if not shown on the Drawings shall be 5 mm.

A.5 Contraction and construction joints of the required types shall be constructed at the intervals and locations shown on the Drawings. Adjacent to flexible base or surface courses, weaker plane contraction joints in curbs or gutters may be constructed by sawing through the curb to a depth of not less than 30 mm below the surface of the gutter, or they may be formed by inserting a suitable removable metal template in the fresh concrete, or by other approved methods. Sealing of the joints will not be required unless shown on the Drawings.

A.6 Exposed surfaces shall be finished full width with a trowel and edge. The top face of curbs or gutters shall receive a light brush finish. Forms for the roadway face of curbs and the top surface of gutters shall be removed 24 hours after concrete has been placed and finishing of the surfaces shall be carried out, provided the alignment tolerances and other requirements have been met.

A.7 Tolerances on tangent sections of curb and gutter shall be tested using a 4 m straightedge. The finished surface of concrete shall not deviate from the straightedge between any 2 contact points by more than 5 mm. Curved sections shall be true to the specified radius plus or minus 5 mm and all joints shall be flush and neat in appearance.

A.8 All fins and irregular projections shall be removed and cavities produced by form ties and all other small holes, honeycomb spots, broken corners or edges and other defects shall be rectified. After saturating with water for a period of not less than 3 hours. the surfaces shall be carefully pointed and made true with mortar. All construction and expansion joints shall be left carefully tooled and free of all mortar and concrete. Joint filler shall be left exposed for its full length with clean and true edges. The resulting surfaces shall be true and uniform.

A.9 A rubbed finish shall then be carried out to surfaces which will be exposed to view after completion of construction. Before rubbing the concrete shall be kept saturated with water for at least 3 hours. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing of holes and defects to set. Surfaces shall by rubbed with a medium carborundum stone using mortar on its face. Rubbing shall remove all remaining form marks projections and irregularities and result in a uniform surface. The final finish shall involve rubbing with a fine carborundum stone and water until the entire surface is of a

smooth texture and uniform color. After the surface has dried loose powder shall be removed and the surface shall be left clean and free from unacceptable flaws or imperfections.

A.10 Curbs and gutters shall be moist cured until stripped and finished and then membrane cured in accordance with the relevant requirements of section 5.02- "Concrete handling placing and Curing". Curing compound shall be applied immediately following completion of rubbed finish.

A.11 The area adjacent to completed and accepted curbs and gutters shall be backfilled with approved material to the top edges of the curbs or gutters or to the elevations shown on the Drawings. Backfill shall be placed and compacted to 95% AASHTO T180 maximum density.

B. Precast Concrete/Limestone Curbs and Gutters

B.1 Subgrade for the concrete base shall be constructed as for in situ curbs and gutters.

B.2 Forms for the concrete base shall be approved wood or steel. All forms shall be sufficiently strong and rigid and securely staked and braced to obtain a finished product correct to the dimensions, lines and grade required. Forms shall be cleaned and oiled before each use. If approved, forms for the concrete base may be omitted and the concrete placed directly against undisturbed excavated faces.

B.3 Base course concrete shall be placed compacted and shaped to the sections shown on the Drawings. Concrete shall be compacted with an approved internal type vibrator or if approved by hand spudding and tamping. Edges shall be rounded if necessary by the use of wood molding or by the use of an edger as applicable. The concrete base shall be finished to a true and even surface with a wood float. Concrete shall be membrane or water cured for at least 7 days before precast units are placed thereon.

B.4 Precast concrete units shall be soaked in water immediately before installation Units shall be set accurately in position in mortar on the concrete base. Joints between precast units shall not be mortared unless otherwise shown on the Drawings. Units shall he closely spaced and every 10 m run shall be provided with an expansion joint.

B.5 After curbs have been installed, steel forms shall be erected and concrete backing, if required, shall be placed as shown on the Drawings. Pavement courses shall not be laid against curbs until the concrete backing has membrane or water cured for at least 14 days.

B.6 The tolerances on alignment of completed precast units shall be as specified for In situ concrete construction.

B.7 Backfilling shall be carried out as specified for in situ curbs and gutters.

C. In Situ Concrete Paving

C.1 Excavation shall be carried out to the required depth and to a width that will permit the installation and bracing of the forms. The foundation shall be shaped and compacted to an even surface conforming to the sections shown on the Drawings. All soft and yielding material shall be removed and replaced with approved material.

C.2 Bedding material shall be placed in layers not exceeding 100 mm in depth and each layer shall be compacted to 95% AASHTO T180 maximum density. The total bedding course thickness shall be as shown on the Drawings, or if not shown, 100 mm minimum thickness.

C.3 Color pigments to BS 1014 and as per manufacturer recommendation Make samples 3 m x 3 m for approval of color.

The pigment similar to 'CHRYSO' color Savane and Ocre.

C.4 Forms shall be of steel, wood, or other approved material and shall extend for the full depth of the concrete. All forms shall be straight, free from warp, and of sufficient strength to resist pressure of the concrete without displacement Bracing and staking of forms shall be such that the forms remain in both horizontal and vertical alignment until their removal. All forms shall be cleaned and oiled before concrete is placed.

C.5 The foundation shall be thoroughly moistened immediately prior to the placing concrete. Concrete shall be deposited in one course in such a manner as to prevent segregation and shall be consolidated by vibrators. The surface shall be finished with a wooden float and light brooming. No plastering of tile surface will be permitted. All outside edges of the concrete tiles and all joints shall be edged with a 5 mm radius edging tool.

C.6 Forms may be removed only when there is no risk of damage to the concrete and in any cast not until at least 24 hours after completion of concreting.

C.7 The smoothness of paved areas shall be tested using a 4 m straightedge. The finished surface of concrete shall not deviate from the straightedge between any two contact points by more than 5 mm. Sections of defective paving shall be removed and replaced as directed at the Contractor’s expense.

C.8 Expansion joints shall be of the dimensions specified and shall be filled with approved premolded expansion joint filler. The area being paved shall be divided into sections by weakened plane joints formed by a jointing tool or other acceptable means as directed. These joints shall extend into the concrete 0.20 to 0.25 times the depth and shall be approximately 3 mm wide. Joints shall match as nearly as possible adjacent joints in curb or pavements. Weakened plane joints may be sawn in lieu of forming with a jointing tool.

C.9 Construction joints shall be formed around all appurtenances such as manholes utility poles etc. extending into and through the side-walk or median. Premolded expansion joint filler of 10 mm thickness shall be installed in these joints. Expansion joint filler of the thickness indicated shall be installed between concrete construction and any adjacent fixed structures such as buildings or bridges etc. The expansion joint material shall extend for the full depth of the concrete.

C.10 Concrete shall be cured by membrane curing in accordance with the requirements of Section 5.02 "Concrete Handling Placing and Curing".

C.11 Generally

a) Quality of Work: conform to the requirements of BS 7263 : Part 2 or BS 6717: Part 3 as applicable, otherwise:

Operatives must be appropriately skilled and experienced in laying the specified finishes

Carry out work and use materials in accordance with manufacturer's recommendations

Ensure that sub-bases are suitably accurate and to specified gradients before laying paving

Do not use damaged or disfigured paving units; cut neatly and accurately with a masonry saw to give neat junctions at edgings, changes in pattern and adjoining finishes

Select blocks and slabs vertically from at least three separate stacks in rotation, or as required to avoid colour banding in the finished paving.

Lines and levels of finished surface are to be smooth and even with regular falls to prevent ponding

Finished paving is to have an even overall appearance with even joint widths and Free of mortar and sand stains.

b) Samples: before placing orders submit for approval representative samples of each type of block and slab paving. Ensure that delivered materials match samples.

c) Control Samples: in approved locations complete sample areas of not less than 10 m^2 of each type of block and slab paving as part of the permanent work. Obtain approval of appearance before proceeding.

d) Inclement Weather: adequately protect paving with mortar joints and/or mortar bedding from rapid drying out and saturation until mortar has hardened.

e) Acceptance of Base: before starting work ensure that:

base is sound, clean and suitably close textured

levels and falls of base are as detailed, within specified tolerance +/-12 mm

drainage outlets are within +0 to -10 mm of required finished level.

f) Levels of Paving: permissible deviation from specified levels is to be +/-6 mm generally. Paving is to be set 6 mm above drainage outlets and 3 mm above kerbs to allow for settlement.

g) Regularity: sudden irregularities not permitted. Where appropriate in relation to geometry of surface, the variation in gap under a 3 m straight edge placed anywhere on surface is to be not more than 10 mm. Difference in level between adjacent paving units is not to be more than 2 mm.

h) Setting Out: Setting Out of paving and related features is to be as shown on the Drawings.

i) Thicknesses: Thicknesses of mortar beds are to be as shown on the Drawings.

C.12 Laying Paving

a) Interlocking Block Paving: unless otherwise specified:

Do not commence paving until adjacent kerbs, edgings and channels have been installed and sufficiently matured.

Lay blocks to required pattern on sand bed and thoroughly compact with a vibrating plate compactor as the work proceeds, but after infilling at restrained edges; apply the same compacting effort over all areas, avoiding damage to edges

and adjacent work.

Do not compact within 1 m of a working face

Do not leave uncompacted areas of paving at the end of working periods, except within 1 m of unrestrained edges

Check compacted paving initially and at frequent intervals to ensure surface levels are correct; lift blocks, adjust bedding and relay paving as necessary.

Brush dry bedding sand into joints, re-vibrate surfaces and repeat as required to completely fill joints.

b) Slab Paving:

Bed on mortar so that rocking of slabs does not occur or develop

When surface of paving is dry, carefully and thoroughly fill joints with semi-dry mortar mix colored to approval using a proper pointing tool; clean any mortar from face of pavings before it sets

Immediately after completing joints, cover paving with polythene sheeting for not less than 3 days.

c) Joint Widths in concrete slab paving are to be nominal 3 mm.

d) Protection from Traffic: pavings bedded on mortar must be kept free from pedestrian traffic for 4 days and vehicular traffic for 10 days after laying.

D. Precast Concrete Tiles (Paving Slabs)

D.1 Excavation and the placing of bedding material shall be as specified for in situ concrete paving. The surface of the completed bedding shall be dampened and base course concrete shall be placed and finished to the thickness as shown on the Drawings or if not shown, 40 mm minimum thickness.

D.2 The base course concrete shall be water or membrane cured as specified for in situ concrete paving, for not less than 7 days before placing precast tiles.

D.3 Immediately prior to tile laying, the concrete base course shall be dampened and the concrete tiles shall be immersed in water. Tiles shall then be laid true to line and grade on a 10 mm to 20 mm thickness of mortar. Joints shall be 3 mm wide.

D.4 The tolerance on smoothness of precast concrete tiled areas and removal and replacement of defective tiling, shall be as specified for in situ concrete paving.

D.5 Tiles shall be cleaned 24 to 36 hours after laying and joints shall be mortared using, if approved, a plasticizer in the mortar to improve workability and to enable the mortar to be readily smoothed and finished. As soon as the mortar has partially set, all mortar material shall be raked from the top 3 mm depth of the joint, using a grooving tool to produce a smooth circular section.

D.6 When the mortar is sufficiently set, the surface shall be sprinkled with water and covered with plastic or nylon sheets during the curing period. The sheets shall be left in place until final hardening of the mortar, or as directed. All foreign matter, wood, concrete, mortar

lumps, etc., shall then be removed and the surface cleaned of staining, discoloration and other blemishes.

D.7 In cases where tiles are required to be cut at the boundaries of tiled areas, or due to the presence of obstacles, poles, hydrants, etc., or in the construction of the driveways or side roads, the Contractor shall cut the tiles or substitute in situ concrete of at least the same quality as the tile concrete. The Engineer will decide, after trials, on the method to be adopted. Cutting of tiles or substitution of in situ concrete shall be kept to a minimum. The Contractor shall complete the areas using uncut precast tiles to the maximum extent practicable.

D.8 The method of construction and sequence of operations, for areas constructing using precast tiles shall be the same as for areas constructed using in situ concrete. The Contractor shall ensure that the final appearance of such surfaces, regardless of the method of construction, is substantially the same for both types of construction.

D.9 Where a sidewalk crosses tile entrance to a shop or a house, etc., which is higher than the sidewalk, the Contractor shall construct steps, formed by a curb and a complete or partial tile. Steps shall be backfilled with concrete of the same quality as specified for concrete base course.

D.10 Steps shall be constructed wherever the difference in elevation between the entrance and tile sidewalk is more than 250 mm. The Contractor shall submit for approval, prior to commencing any sidewalk construction, a list of locations where steps will be required, together with design details for their construction.

6.01.04 Measurement

A. In Situ Concrete Curb, in Situ Concrete Gutter, In Situ Concrete Curb-and-Gutter, precast Concrete Curb, Precast Concrete Gutter, Precast Concrete Curb-and-Gutter and Limestone Curb of any type size or shape, shall be measured by linear meter L.m. of each type furnished, constructed or installed with all mortar, blinding, dowels, concrete backing, completed, and accepted. Measurements shall be of the front face of concrete curb or of the flow line of gutter as appropriate, and shall include measurement of concrete curbs required for steps.

B. Interlocking Concrete Blocks and precast Concrete and Limestone Tiling of any type size or shape shall be measured by sq.m of each type furnished, constructed or installed, completed, and accepted. Measurements shall be of the surface area and no deduction shall be made for minor obstructions such as manholes, poles or similar small unpaved or untiled areas.

C. Concrete Tiled Steps of any type size or shape shall be measured by sq.m furnished, constructed or installed, completed, and accepted. Measurements shall be of the horizontal projection of the steps.

D. Demolition and dismantling of any existing curb, gutter, interlocking concrete blocks, or concrete tiled steps, excavation, backfilling, bedding, concrete base course, concrete backing, construction in and around obstacles, poles, manholes, flower beds, cutting and shaping of tiles on curves, jointing, and finishing at walls and fences, etc., 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)	In Situ Concrete Curb (any type)	Linear meter (m)
(2)	Precast Concrete Curb (any type)	Linear meter (m)
(3)	In Situ Concrete Gutter (any type)	Linear meter (m)
(4)	Precast Concrete Gutter (any type)	Linear meter (m)
(5)	In Situ Concrete Curb-and-Gutter (any type)	Linear meter (m)
(6)	Interlocking Concrete Blocks	Square meter (m^2)
(7)	Precast Concrete or Limestone Tiling	Square meter (m^2)
(8)	Concrete Tiled Steps	Square meter (m^2)
(9)	Natural Stone Basalt Curb (any type)	Linear meter (m)

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^{o} C ± 3^{o} 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^{o} C ± 3^{o} 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^{o} C ± 2^{o} 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^{o} 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^{o} C ± 2^{o} 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^{o} C ± 3^{o} 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^{o} C ± 3^{o} 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 ROADWAY MARKING

6.03.01 Scope

A. The work covered in this Section consists of the furnishing and application of traffic markings to highway pavements for the guidance, control and safety of vehicular and pedestrian traffic.

B. White and yellow markings shall include centrelines, lane lines, border (edge) lines, pedestrian crossing lines, stop lines, chevron striping (at gore areas), directional arrows, lettering and symbols using the following materials as appropriate and as shown on the Drawings.

- Thermoplastic Reflectorized Paint
- Reflectorized Cold Paint
- Preformed Reflectorized Thermoplastic Film
- Preformed Plastic Tape Extended Service Life

C. Cold paint applications shall be used for the following, or as indicated on the Drawings:

- For all markings on roads with slow moving traffic (design speed less than 30 kph).
- On roads in areas over 1200 metres above sea level, that are regularly snow-ploughed in winter.
- For temporary road markings.
- For yellow painted kerbs adjacent to the pavement edge where parking is prohibited.
- On bituminous speed bumps.

D. Preformed, reflectorized, thermoplastic film shall be used where appropriate and as shown on the Drawings or as instructed by the Engineer.

6.03.02 Marking Colors

A. This section covers the daytime and night-time color of retroreflective pavement marking materials used for traffic control lane markings and symbols on road surfaces. It is intended to apply throughout the service life of the material.

B. Pavement marking colors for all types shall conform with ASTM D6628.

C. Daytime color shall be measured in accordance with Test Method E1349, using 45/0 (0/45) geometry, CIE illuminant D65 and the 1931 CIE 2° standard observer. Night-time chromaticity shall be in accordance with Test Method E811 using the geometric tolerance and sample positioning (including angle setting techniques) as described in Test Method D4061.

D. Color coordinates of samples shall lie within the lines drawn between the corner points which specify the chromaticity limits.

Corner Point	Coordinates	Daytime		Night-time	
		White	Yellow	White	Yellow
1	x	0.355	0.560	0.480	0.575
	y	0.355	0.440	0.410	0.425
2	x	0.305	0.490	0.430	0.508
	y	0.305	0.510	0.380	0.415
3	x	0.285	0.420	0.405	0.473
	y	0.325	0.440	0.405	0.453
4	x	0.335	0.460	0.455	0.510
	y	0.375	0.400	0.435	0.490

E. Alternatively, all pavement markings, without drop-on beads and/or media, shall visually match the colors that correspond to the Federal Standard Number 595b for the following colors:
- White: Color No. 17886
- Yellow: Color No. 13538

F. In-service daytime luminance factor limits (tristimulus value Y expressed as a percent) apply when measured with 45˚/0˚ geometry using a standard illuminant D65 and a CIE 2° standard observer (without drop-on beads) in accordance to ASTM D 6628 or ASTM D4960 (for thermoplastics).

Color	Daylight Reflectance at 45˚/0˚
White	75%
Yellow	45%

G. For white markings, the yellowness index shall be 10 maximum when tested in accordance with ASTM D562 or AASHTO T250 (for thermoplastics).

6.03.03 Materials

A. Thermoplastic Reflectorized Paint (TRP)

A.1. General

a. TRP shall consist of a homogenous mixture of thermoplastic binder, white or yellow pigment, glass reflectorizing spheres and filler that is to be applied to the pavement in a molten state by mechanical means. Upon cooling to normal pavement temperature, this material shall produce an adherent, reflectorized paint line of specified thickness capable of resisting deformation.

b. Thermoplastic striping material shall comply with AASHTO M 249 or any other equivalent standard except when specified otherwise.

A.2. Composition

a. The thermoplastic markings composition shall conform to the following requirements. The components shall be thoroughly mixed to ensure that the pigment, glass beads and filler are uniformly dispersed in the resin.

Component	White	Yellow	Test Method
Binder (hydrocarbon or alkyd)	Min. 18%	Min. 18%	
Glass Beads	30% – 40%	30% – 40%	ASTM D467
Titanium Dioxide (TiO_2)	Min. 10%	Manufacturer Specific	AASHTO T250
Calcium carbonate and Inert Filler	Max. 42%	Manufacturer Specific	
Yellow Pigments	-	Min. 4%	

b. The specific gravity of the white or yellow thermoplastic compound shall not exceed 2.15.

A.3. Reflective Glass Beads

a. Glass beads shall be applied on the surface (drop-on) or incorporated into (inter-mix) the traffic marking material.

b. Beads shall be manufactured from glass of a composition designed to be highly resistant to traffic wear and weather. The glass beads shall be transparent, clean, colorless glass, smooth and spherically shaped, and free from milkiness, pits, or excessive air bubbles. The material shall be free from all skin, dirt, and foreign objects.

c. Glass beads shall conform to AASHTO M247.

d. The glass beads of the surface applied beads shall meet the following sieve requirements.

Sieve Gradation		Mass % Passing	
Sieve size (mm)	Sieve No.	Type I: Standard	Type II: Uniform
0.850	20	100	-
0.600	30	75 - 95	100
0.425	40	-	90 - 100
0.300	50	15 - 35	5 - 75
0.180	80	-	0 - 5
0.150	100	0 - 5	-

e. The intermix glass beads when tested in accordance with ASTM D1214 shall have the following graduation.

Sieve size (mm)	Sieve No.	Percentage Passing by Weight
1.700	12	100
0.180	80	0 – 5

f. An 18 kg dead weight for No. 20 to No. 30 mesh spheres shall be the average resistance when tested in accordance with ASTM D-1213.

g. A minimum of 75% shall be true spheres when tested in accordance with ASTM D-1155. Not less than 70% of the spheres of each sieve size shall be free from imperfections of all types, including film, scratches, pits, clusters, and opaqueness.

h. The spheres mixed into the material shall have a minimum index of refraction of 1.65 when tested by the liquid immersion method at 25˚C, and the spheres automatically applied to the surface of the TRP line shall have a minimum index of refraction of 1.5.

i. The silica content (SiO2) of the spheres shall be 60% plus or minus 5% when tested in accordance with Federal Test Method 141a.

j. The glass spheres shall withstand immersion in water and acids without noticeable corrosion or etching, and shall not be darkened or otherwise decomposed by sulphides. A 3 to 5 gm sample shall be placed in each of 3 glass beakers or porcelain dishes, one covered with distilled water, the second with a 3 N solution of sulphuric acid and the third with a solution of 50% sodium sulphide, 48% distilled water and 2% aerosol 1B or similar wetting agent. No darkening, hazing, or other evidence of instability shall be noticeable in the glass spheres when examined microscopically, after one hour of immersion.

k. Moisture Resistance - Flow Characteristics: The beads shall not absorb moisture in storage. They shall remain free of clusters and lumps and shall flow freely from dispensing equipment.

l. Packaging: Glass beads shall be furnished in lots and packaged in moisture- proofed bags. Containers are to be guaranteed to furnish dry and undamaged beads. Each package shall contain the following information: name, and address of manufacturer, shipping point, trademark or name, the wording “glass beads”, the specification number, number of the lot or batch number and the month and year of manufacture.

m. Unless otherwise specified on the Drawings, thermoplastic materials based on alkyd resins shall be used in urban settings with a minimum Shore A hardness at 45^{o}C of 60, a Brookfield thermoseal viscosity of between 45 and 100 and a minimum flash point of 230 ^{o}C. The drying time at an ambient temperature of 32 ^{o}C shall be 5 minutes.

A.4. Physical Requirements

a. In the plastic state, the thermoplastic material shall not exude fumes which are toxic, injurious, or require specialized breathing apparatus when heated as specified for application.

b. Thermoplastic material shall melt uniformly with no evidence of skins or unmelted particles.

c. The material shall provide a stripe that has a uniform color and thickness throughout its cross section and has the density and character to provide a sharp edge of the line.

d. The thermoplastic material shall have a softening point of 102.5 ± 9.5°C after heating for 240 ± 5 min at 218 ± 2 °C in accordance with ASTM D36.

e. The thermoplastic material shall pass without showing cracks when applied on concrete blocks and heated for 240 ± 5 min at 218 ± 2 ℃ then cooled to -9.4 ± 1.7°C in accordance to AASHTO T250.

f. The thermoplastic material shall have an impact resistance not less than 1.13J (10 in-lb) after heating for 240 ± 5 min at 218 ± 2°C when tested in accordance with AASHTO T250.

g. The flowability of the thermoplastic material as tested based on AASHTO T250 after heating for 240 ± 5 min at 218 ± 2°C shall satisfy the following requirements:

- White: Max. 18% residue
- Yellow: Max. 21% residue

h. Flowability tested in accordance to AASHTO T250 upon extended heating for 480 ± 30 min at 218 ± 2 °C shall not exceed a maximum percent residue of 25% regardless of the pigment color.

i. The thermoplastic material shall have a flash point no less than 260°C when tested in accordance with Test Method ASTM D92.

j. The minimum dry retroreflectivity of the markings when tested 180 days or less after installation shall be as follows when tested according to Test Method E1710:

	White	**Yellow**	**Test Method**
Retro-reflectivity (R_L) mcd/m2/lux	Min. 300	Min. 200	ASTM E1710

k. The minimum dry retroreflectivity of the markings of all classes when tested from 181 days after installation through the end of service life of the markings shall be as follows when tested according to Test Method E1710:

- White: 150 mcd/m^2/lux
- Yellow: 125 mcd/m^2/lux

l. The material shall maintain a granular free-flow condition in dry storage for a minimum of one year, providing the temperature does not exceed 40°C.

B. Cold Paint Pavement Marking

B.1. General

a. Pavement marking paint shall be water-based (latex) or solvent-based (alkyd) white or yellow ready mixed one-component type with spraying consistency suitable for use as a retroreflective pavement marking.

b. Traffic Paint shall consist of a ready mixture of binder, white or yellow pigment, and filler specifically compounded for cold application and adhesion to finished paved areas. Paint shall be reflectorized by adding reflective spheres before the film dries or sets, using drop-on or pressurized methods.

c. Reflectorized white and yellow solvent-based traffic paint shall conform to AASHTO M-248, Type F. The surface application of glass spheres shall conform to AASHTO M 247, Type I.

d. Paint markings shall be free of lead and chromium with a limited quantity of volatile organic compounds (VOC).

B.2. Composition

a. Water-based Paint Pavement Marking

The paint markings composition shall be low VOC solvents that conform to the following requirements.

Paint Properties	Test Method	Water-based Paint			
		White		Yellow	
		Min.	Max.	Min.	Max.
Total Non-volatiles, (solids), % by weight	ASTM D2369	75	-	75	-
Pigment Content, % by weight	ASTM D3723	57	62	57	62
Non-volatile Vehicle (NVV), % by weight	ASTM D2369 ASTM D3723	40	-	40	-
Titanium Dioxide, rutile type II, g/L	ASTM D476	120	-	-	-
Volatile Organic Content, (VOC), g/L	ASTM D3960	-	150	-	150

b. Solvent-based Paint Pavement Marking (Type F)

The paint markings composition shall be low VOC solvents that conform to the following requirements.

Paint Properties	Test Method	Solvent-based Paint			
		White		Yellow	
		Min.	Max.	Min.	Max.
Total Non-volatiles, (solids), % by weight	ASTM D2369	65	-	65	-
Pigment Content, % by weight	ASTM D2698	-	53	-	53
Lead Content, %	ASTM D3335	-	0.06	-	0.06
Titanium Dioxide, rutile type II, g/L	ASTM D4563	120	-	-	20
Volatile Organic Content, (VOC), g/L	ASTM D3960	-	150	-	150

B.3. Reflective Glass Beads

The same requirements as drop-on glass beads for Thermoplastic Reflectorized Paints apply (Section 6.09.2.1-C).

B.4. Physical Requirements

a. Water-based paint pavement markings shall conform with the following requirements.

Paint Properties	Test Method	Water-based Paint			
		White		Yellow	
		Min.	Max.	Min.	Max.
Density (kg/L)	ASTM D1475	Within ± 0.024 kg/L of qualification sample			

Paint Properties	**Test Method**	**Water-based Paint**			
		White		**Yellow**	
		Min.	**Max.**	**Min.**	**Max.**
Viscosity at 25°C, KU	ASTM D562	80	95	80	95
Fineness of Grind, HEGMAN	ASTM D1210	3	-	3	-
Dry Opacity/ Contrast Ratio at 0.38 mm WFT	ASTM D2805 (2°, D65)	0.96	-	-	-
Bleed Ratio	ASTM D969	Reflectance measurement of the alkyd resin paint over asphalt paper shall be at least 95 % of the reflectance measurement of the material over a taped (non-bleeding) surface.			
Flexibility	ASTM D522 Method B	Pass	-	-	-
Scrub Resistance	ASTM D2486	800	-	-	-
Freeze-thaw and Heat stability	ASTM D2243 & D562	± 10 KU from the initial viscosity	-	-	-
Flash Point,	ASTM D93	38°C			
Laboratory Dry Time (Minutes)/ Dry time to no pick up	ASTM D711		10		
Dry Through Time, minutes	ASTM D 1640		20		
No-track time (dry to no-pick-up time for pavement marking), minutes	Measure time required for the line to withstand the running of a Standard sedan at a speed of 65 km/hr, simulating a passing procedure without tracking of the reflectorized line when viewed from a distance of 15 m.	3 minutes when applied to a for 0.38 ±0.03 mm film thickness at pavement temperatures 54.4 -65.6 °C.			

b. Solvent-based paint pavement markings shall conform with the following requirements.

Paint Properties	**Test Method**	**Solvent-based Paint**			
		White		**Yellow**	
		Min.	**Max.**	**Min.**	**Max.**
Density (kg/L)	ASTM D1475	1.5		1.5	
Viscosity at 25°C, KU	ASTM D562	75	85	75	85
Settling Properties during Storage, cm	ASTM D1309	-	20	-	30
Skinning	ASTM D154	The paint shall not skin within 48 hours in a ¾ filled, tightly closed container			
Bleed Ratio	ASTM D969	Reflectance measurement of the			

Paint Properties	**Test Method**	**Solvent-based Paint**			
		White		**Yellow**	
		Min.	**Max.**	**Min.**	**Max.**
		alkyd resin paint over asphalt paper shall be at least 90 % of the reflectance measurement of the material over a taped (non-bleeding) surface.			
Flexibility	ASTM D522 Method B	Pass			
Package Stability	ASTM D1849	6	-	6	-
No-track time (dry to no-pick-up time for pavement marking), minutes	Measure time required for the line to withstand the running of a Standard sedan at a speed of 65 km/hr, simulating a passing procedure without tracking of the reflectorized line when viewed from a distance of 15 m.	1.5 minutes when applied to a for 0.38 ±0.03 mm film thickness at pavement temperatures 54.4 -65.6 °C.			

c. After storage for periods up to 6 months from date of packaging, the pigment shall be readily dispersed and viscosity of the paint shall not have changed more than 5 KU from that of the freshly delivered paint.

C. Preformed Thermoplastic Reflectorized Film

C.1. General

a. Thermoplastic shall be used as a preformed (pre-shaped) material for arrows, stop bars, pavement signs and text markings.

b. Preformed thermoplastic reflectorized film shall conform to the requirements of EN 1790.

c. Preformed thermoplastic reflectorized film shall be homogenous, extruded prefabricated white or yellow, of the specified shape and capable of being affixed to bituminous or cement concrete surfaces. It shall contain reflective glass spheres uniformly distributed and bonded to the top surface of the material. The film shall be weather resistant and shall not show any appreciable fading, lifting, shrinkage, significant tearing, roll back or other signs of poor adhesion throughout its design life.

d. All material used in the formulation of the preformed thermoplastic pavement marking shall meet the requirements to the standard thermoplastic in addition to the requirements specified herein.

C.2. Composition

a. The preformed thermoplastic film shall consist of the following:

Component	Minimum % by weight
Resins and Plasticizers	20
Pigments	30
Reflective Glass Beads	20

C.3. Glass Beads

a. The same requirements as drop-on glass beads for Thermoplastic Reflectorized Paints apply (Section 6.09.2.1-C).

b. Glass beads shall be uniformly distributed throughout the entire cross-sectional area. Immediate retroreflectivity can be provided by a pre-applied layer of beads or by scattering surface beads on a molten material during application. The bead adhesion shall be such that beads are not easily removed when the material surface is scratched with a thumbnail.

C.4. Physical Requirements

a. All material used in the formulation of the preformed thermoplastic pavement marking shall meet the requirements to the standard thermoplastic in addition to the requirements specified herein.

b. The film as supplied shall be of good appearance, free from cracks and discolorations and the edges shall be clean cut and well defined. It shall be supplied complete with a precoated factory-applied, pressure sensitive adhesive backing with a protective release paper or with separate adhesives as recommended by the manufacturer.

c. The marking shall be capable of conforming to pavement contours, breaks, and faults under the action of traffic at all pavement temperatures.

d. The film shall have resealing characteristics and shall be capable of fusing with itself or with previously applied marking material.

e. The preformed thermoplastic material shall be resistant to deterioration due to the exposure to sunlight, water, oil, gasoline, salt or adverse weather conditions.

f. The surface of the marking shall provide a minimum skid resistance value of 45 BPN when tested according to ASTM E 303.

g. The plastic film shall be sufficiently flexible so that at a temperature of 26 to 28°C, an unmounted piece of material (without adhesive and paper backing), 75 mm by 150 mm in size, may be bent over a 25 mm mandrel until the end faces are parallel and 25 mm apart without showing any fracture lines in the uppermost surface.

h. The preformed thermoplastic markings shall not be brittle and must be sufficiently cohesive and flexible at temperatures exceeding 10 °C for one person to carry without the danger of fracturing the material prior to application.

D. Preformed Plastic Tapes Extended Service Life

D.1. General

a. A permanent preformed tape is any material that bonds with the pavement surface and has a service life of at least 1 year.

b. Preformed tapes are frequently used for transverse markings but are often used for longitudinal lines in high-traffic areas.

c. Preformed tapes are cold-applied, preformed pavement marking materials that are supplied in continuous rolls of various lengths and widths.

d. Preformed pavement markings shall be a retroreflective film on a suitable backing.

e. White or yellow marking tape shall consist of glass spheres of high optical quality embedded into a binder on a suitable backing that is precoated with a pressure sensitive adhesive.

D.2. Composition

a. The preformed plastic tape composition without adhesive shall conform to the following requirements.

b. requirements.

Component	Minimum % by weight
Resins and Plasticizers	20
Pigments	30
Reflective Glass Beads	20

c. The remaining materials shall comprise the remaining 30% in various proportions, subject to approval of the Engineer.

D.3. Physical Requirements

a. The physical requirements of preformed tape markings shall conform with ASTM D4505.

b. The marking tape shall adhere to roadway surfaces when applied according to the manufacturer’s recommended procedures on pavement surfaces having temperatures down to 10 °C.

d. The marking shall be capable of conforming to pavement contours, breaks, and faults under the action of traffic at all pavement temperatures. The film shall have resealing characteristics and shall be capable of fusing with itself or with previously applied marking material.

e. The tape shall provide a neat, durable marking that will not flow or distort due to temperature and other weather factors. The markings shall provide a cushioned resilient substrate that reduces bead crushing and loss. The markings shall be weather resistant and show no appreciable fading, lifting, tearing, rollback, or other signs of poor adhesion when subject to normal traffic conditions.

f. The surface of the markings shall provide the following minimum skid resistance values when tested according to ASTM E 303.

Type B	45 BPN
Type C	55 BPN

g. The tape shall have the following minimum tensile strength of cross section when tested according to ASTM D 638-76 using a jaw speed of 250 to 300 mm/min.

Marking Type	**Tensile Strength (kPa)**	**Elongation**
Type B	N/A	N/A
Type C	Min. 1033 kPa	Min. 50%

h. No line shall be displaced, be torn or missing.

i. The marking tape shall be retroreflective, reflecting white or yellow, respectively, and shall be readily visible when viewed with automobile headlights at night and shall have minimum initial reflective values as shown in the table below.

	White	**Yellow**	**Test Method**
Retro-reflectivity (R_L) mcd/m^2/lux	300	200	ASTM E1710
	250	175	

j. The marking tape as supplied shall have a minimum shelf life of one year from date of purchase when stored at temperatures under 38 °C.

6.03.04 APPLICATION AND INSTALLATION

A. Ambient and Pavement Application Temperature

A.1. Pavement marking operations shall not take place when temperatures are beyond the following limits.

Material	**Surface Temperature**	**Material Application Temperature**
Thermoplastic	Min.13 ºC Max. 82 ºC	205 – 245 ºC
Paint	Min. 10 ºC Max. 82 ºC	38 ºC (heated to reduce drying time)
Preformed Thermoplastic	Min. 10 ºC Max. 82 ºC	Manufacturer Specific
Preformed Plastic Tapes	Varies with manufacturer and adhesive 15 ºC	65 ºC (Inlay method) 21 ºC (Overlay method)

A.2 Wind chills should always be considered when determining ambient air temperature.

A.3 For elevation changes greater than 300 m, temperature at the highest point shall govern.

A.4 Wind speed also affects the accuracy of the drop-on bead application. Markings using drop-on beads should not be placed on days with excessively high winds.

B. Surface Preparation

B.1 Remove all dirt, dust, grease, oil, or other detrimental material from the road surface by sweeping and the use of high-pressure air spray.

B.2 Primer-sealers shall be applied to existing hot mix asphaltic concrete surfaces prior to application of the thermoplastic material and shall be applied as recommended by the thermoplastic material manufacturer.

B.3 Restriping above existing pavement marking is permitted if the existing marking was 90% worn away or eradicated

B.4 The Contractor shall set out all control points necessary for locating paint lines and markings. On irregular widths of highway, the locations of border (edge) lines shall be adjusted to provide a smooth alignment on the pavement surface. The locations of all painted markings and each location for raised pavement markers and studs shall be accurately established and shall be subject to approval by the Engineer before application and installation commence. Markers and studs shall not be located over longitudinal or transverse pavement joints.

C. Surface Moisture

C.1 The presence of moisture on the pavement surface prior to marking placement will affect the bond formed between the pavement marking and the pavement surface.

C.2 Surface moisture is inspected as follows:

1) A 30x30 cm square plastic wrap is placed in the pavement surface and the edges are affixed using duct tape.
2) The plastic wrap is left on the surface for 15 minutes.
3) The formation of bubble is then inspected. If moisture bubbles on the plastic are larger than a pencil eraser, then the pavement contains too much excess water. In such cases all marking operations are postponed until the surface is dry.

D. Pavement Marking Thickness

D.1 The minimum recommended pavement marking thicknesses are as follows:

Type		**Baseline Thickness**
Standard Thermoplastic	Edge lines, gore lines, diagonals and arrow symbols	New marking – min. 2.3 mm Restriped marking (on thermoplastic) – min. 1.5 mm
	In-lane and shoulder-transverse pavement markings	Min. 6 mm (may be applied in 2 passes)
	Center lines, skip lines, transverse bands, mini-skip lines, characters, bike lane symbols and crosswalk lines	Min. 3 mm
Preformed Thermoplastic	--	3.2 mm
Paint	Standard application	0.38 mm
	Durable high build applications (2 coats)	0.64 mm
Preformed Plastic Tapes Extended Service Life	Long Lines	1.5 mm
	Transverse pavement markings and symbols	2.3 mm

D.2 Random samples shall be taken at maximum intervals of 600 m to measure their thickness. If three or more successive readings meet the thickness criteria, the Engineer may designate an alternative interval.

D.3 The marking thickness is measured using a small metal strip with a known thickness. The metal strip shall be placed immediately ahead of the striping apparatus. The plate shall be removed after the pavement marking material and glass beads have been applied at the normal rate and the sample has cooled sufficiently so that no deformation to the stripe occurs when removing the plate from the roadway.

D.4 A thickness tolerance not exceeding plus 10% will be allowed for thickness or yield in paint and plastic material application.

E. Marking Application Equipment

E.1 Prior permanent application, marking machine shall demonstrate satisfactory operation on a suitable site which is not part of the permanent works.

E.2 Pavement marking machines shall be capable of producing at least two parallel lines simultaneously and producing lines with uniform widths within the tolerances specified without the paint running or splashing. Machine shall be further capable of painting lines of different widths by adjusting the spray jets on the machine or by means of additional equipment attached to the machine and applying the pavement marking material and glass beads to a uniform film thickness at the specified rates of application.

E.3 The equipment used for pavement marking shall consist of truck-mounted units, motorized equipment or manually operated equipment, depending on the type of markings required. The truck-mounted or motorized unit for centrelines, lane lines, and edge lines shall consist of a mobile, self-contained unit carrying its own material. The hand application equipment shall be sufficiently manoeuvrable to install centrelines, lane and edge lines, gore striping, turn lines, crosswalks, stop lines, kerb lines, arrows and legends.

E.4 Spraying equipment shall be capable of satisfactorily applying the paint under pressure with a uniformity of feed through nozzles spraying directly on the pavement. Each paint tank shall be equipped with cut-off valves which will enable broken (skip) lines to be sprayed automatically. Each nozzle shall have a mechanical bead dispenser that will operate simultaneously with the spray nozzle and distribute the beads in a uniform pattern at the rate specified. Each nozzle shall also be equipped with suitable line guides and shall provide a method for cleaning the surface of dust just prior to paint application.

E.5 The spray machine for application of reflectorized paint lines and other markings shall have an attachment to accurately regulate the rate of application and a tachometer or other approved device to ensure uniform paint application at the designated rate. It shall be adjustable to ensure the painting of one or two adjacent lines simultaneously along the centreline. The paint shall be properly agitated while in operation.

E.6 Hand equipment shall be used only for painted markings, including arrows, pedestrian crossings, stop lines symbols, legends, kerb lines and short sections of linear markings where the use of motorised equipment is not practical. The hand equipment shall be capable of holding a minimum of 25 kg and a maximum of 100 kg of molten material unless otherwise agreed with the Engineer.

E.7 Glass beads dispensing equipment which apply glass beads by means of gravity only shall not be used. Glass beads shall be sprayed onto the paint layer by means of a pressure sprayer except that for small areas, such as application of traffic symbols, hand or gravity application of glass beads may be allowed. An automatic glass sphere dispenser with a synchronized automatic cut-off shall be attached to the applicator machine. The dispenser shall utilize pressure type spray guns which will embed the spheres into the surface to at least

0.5 times the sphere diameter. The dispenser shall also be equipped with an automatic cut-off synchronized with the cut-off of the thermoplastic material.

E.8 Thermoplastic Application Equipment shall be capable of:

1) Maintaining the thermoplastic material in a plastic state at all stages from mixing to application;
2) Incorporating functional and calibrated temperature sensing devices during all melting applications.
3) Providing automatic application of glass beads immediately behind the installed line through an automatic glass beads dispenser attached to the striping equipment.
4) Allow Dispensing and distributing drop-on glass beads evenly to the surface of the completed marking
5) Operating at a speed ranging between 3.2 to 12 kph.

E.9 The main components of thermoplastic marking equipment shall include the following:

1) Melting Kettle: Kettle is oil/air jacketed for uniform heating and melting of the thermoplastic material. It is typically equipped with an automatic thermostat control device to provide temperature control and continuous mixing and agitation of the thermoplastic material. The temperature is typically maintained above 205˚C. Pre-melting thermoplastic material shall be avoided in handler type equipment.
2) Mixing and Agitating Equipment: Mixing equipment shall be capable of thoroughly mixing the material at a rate that ensure even disbursement of the material and uniform temperature distribution.
3) Glass Bead Application Equipment: A drop on glass bead system is essential to be used in both mobile and portable thermoplastic applications.

E.10 Preformed Thermoplastic markings are applied using a propane blow torch or any other manufacture recommended equipment capable of heating the thermoplastic in place.

E.11 Paint type pavement markings shall be applied using motorized airless striping machines. Paint may be brushed or rolled into the pavement surface for non-linear or kerb applications.

E.12 Preformed Plastic Tapes are mechanically applied using mobile pavement marking machines specifically designed for use in applying pressure sensitive pavement marking tape of varying widths shall be used. Hand rolling using a tamper cart (roller loaded with at least 90 kg) is permissible for symbols and legends asper the manufacturer's recommendations.

F. Thermoplastic Reflectorized Paint (TRP) Application

F.1 Thermoplastic material shall be applied by spraying, screed extrusion, or ribbon extrusion, as shown in the Contract plans or as directed by the Engineer. The advantage and disadvantages are as follows.

Application Method	Description	Advantages	Disadvantages
Gravity Extrusion	Consists of the thermoplastic material passing through a heated four-sided die, of which three sides are in direct contact with the pavement surface	- Lines are crisp and well defined on smooth surfaces - Easy to control line thickness and width. - Ensures maximum burn in bonding to	- Slow application rate - Hard to maintain good line definition on rough surface

Application Method	Description	Advantages	Disadvantages
	Shall be applied using truck-mounted units.	asphalt surfaces - Shielded from air and wind, thus preventing loss in temperature at the point of application	
Ribbon Application	Consists of the thermoplastic material passing through a heated four-sided die suspended above the road surface, applying a forced extrusion, well-defined thermoplastic line. Shall be applied using truck-mounted units or motorized ride-on equipment.	- Lines are well defined on irregular surfaces - Moderate application rate - Better control of line thickness and width compared to spray application	- Difficult to obtain uniform thickness - Difficult to achieve maximum burn in bonding to asphalt surfaces in marginal ambient temperature as well as in cool windy conditions.
Hot Sprayed	Consists of the thermoplastic material passing through a spray gun under pressure. Shall be applied using truck-mounted units or motorized ride-on equipment.	- Maximum adhesion to pavement surface - Fastest application rate - Provides good thermal and mechanical bond	- Lines can be less crisp and well defined due to the potential of over spraying - Difficult to maintain uniform thickness across the width.

F.2 To ensure optimum adhesion, the thermoplastic paint shall be applied in a molten state within a temperature range of 204 and 227^{o}C or as recommended by the manufacturer.

F.3 Specified temperature requirements shall be maintained at all times during application.

F.4 Total heating time for any batch of material shall not exceed six hours.

F.5 The contractor shall minimize the thermoplastic material remaining in the kettle at the end of the work day and shall blend a minimum of 80 percent fresh material at the start of each day.

F.6 Drop-on glass beads must be mechanically deposited after applying the thermoplastic line at a rate ranging between 0.35 and 0.5 kg/m2 or as recommended by the manufacturer, into the thermoplastic material immediately after the thermoplastic marking is applied.

F.7 Glass beads shall be uniformly applied on the entire pavement markings surface with 50 to 60% embedment.

F.8 The application rate of the thermoplastic material varies with thickness as follows.

Thickness, mm	Maximum Solid Material Yield (m^2/23 kg bag)
1.5	4.7
2.3	3.7
3.0	2.9

F.9 The completed lines shall have a continuous and uniform cross-section, and shall have clean, sharp edges. The width of paint line specified shall be applied in one application.

F.10 After application the road shall be opened to traffic in 2 to 10 minutes if the ambient temperature is 10°C or 32°C respectively.

G. Cold Paint Application

G.1 Typically, the optimal speed of a striping truck applying 0.38 mm markings is 15–30 kph.

G.2 For reflectorized markings, glass beads shall be applied immediately after the pavement marking material has been applied at a rate of 0.85 kg/litre of paint for a thickness of 0.38 mm. The sphere dispenser shall embed at least 65% of the sphere diameter into the surface.

G.3 When two applications of paint are required to complete all paint markings, the second application shall be squarely on top of the first pass. The time period between paint applications will vary depending on the type of pavement and paint.

Type	Time period
Water-Based Paint	4 hrs to 30 days
Solvent-Based Paint	40 min to 30 days

G4. The markings shall be protected for a minimum of 20 minutes (or longer if necessary, according to the manufacturer's recommendations) to allow for drying and curing of the paint.

H. Preformed Thermoplastic Application

H.1 Specific application requirements may vary with manufacturer, and therefore manufacturer specifications shall always be followed.

I. Preformed Plastic Tapes Extended Service Life

I.1 The manufacturer's application procedures for preformed tape must be strictly followed.

I.2 Preformed plastic tapes may be inlaid or overlaid.

I.3 The inlay method is preferred on newly constructed or resurfaced asphalt pavement due to its superior performance and excellent bond. Application usually follows the pavement breakdown roller when the pavement temperature is still warm but has cooled to approximately 65°C. The tape is then rolled into the pavement surface with a steel drum roller during the final rolling of the pavement. The roller fuses the plastic into the hot asphalt surface creating an excellent bond and sealing out moisture.

I.4 The overlay method is used over existing pavements. The tape is applied directly on and bonded to the surface with a pressure sensitive adhesive. Tape shall be initially tamped into place with a light hand roller or vehicle tire with a weight as recommended by the manufacturer.

J. Kerb Paint Application

J.1 The paint shall be sprayed to cover entirely the kerbstone between the pavement edge and tile edge (25 to 35 cm width depending on the existing condition of the kerb). Areas adjacent to those to be painted shall be protected and covered during paint application. The

surface of the kerbstone shall be free of dirt, grease, oil, moisture loose or unsound layers and any other material which could adversely affect the bond or the colour. The area shall be thoroughly cleaned to the satisfaction of the Engineer before proceeding with painting.

K. Protection of Markings

K.1 Immediately following the application of paint lines and other markings on pavements open to traffic, traffic cones or other approved devices shall be placed alongside or over the paint at intervals not exceeding 10 metres and shall remain in place until the paint has dried.

K.2 Traffic shall be prevented from crossing wet paint lines and the Contractor shall use sufficient numbers of flagmen, barricades, or other protection, particularly at crossings, to prevent traffic from crossing wet paint. Sections of paint which have been damaged by traffic before the paint has cured shall be repaired and the pavement outside the painted area cleaned at the Contractor's expense.

K.3 Temporary barricades and signs as specified, or required by the Engineer, shall be erected at the beginning and end of the highway section on which the Contractor proposes to apply paint markings or install markers or studs. On completion, the temporary barricades and cones shall be moved ahead to the next section. Barricades and cones shall not be left in place overnight. The equipment shall be operated so that it will be unnecessary for public traffic to cross the newly placed material behind the equipment in order to safely pass the equipment.

K.4 Protective and traffic warning devices shall be approved by the Engineer before any placement.

L. Tolerances and Finish

L.1 A tolerance of 12 mm over or 3 mm under the specified line width shall be allowed, provided the variation is gradual and does not detract from the general finished appearance of the line. Segments of broken line may vary up to 30 mm from the specified length. Segments shall be square at each end without mist or distortion. Deviations from the control line of up to 25 mm on tangents and 50 mm on curves shall be accepted, provided the deviation does not increase or decrease at a rate of more than 15 mm in 10 m. Lines that do not meet these tolerances shall be removed and replaced at the Contractor's expense.

L.2 When it is necessary to remove paint, this shall be carried out using a method satisfactory to the Engineer and shall not damage the underlying pavement surface. When it is necessary to correct a deviation which exceeds the permissible tolerance in alignment, the affected length of line shall be removed plus an additional 5 metres in each direction, and a new line painted.

L.3 All pavement markings shall maintain a minimum retro-reflectivity of 100 millicandellas up to the end of the defects liability period following completion of the final application of paint.

6.03.05 Sampling And Testing

A. All material shall be shipped to the job site in undamaged, sealed original packaging, clearly identifying each material by name, colour, manufacturer, batch number and date of manufacture. All material shall be accompanied by certified test results verifying compliance with all specified physical and chemical requirements conforming to latest versions of AASHTO M-247, M-248 and M-249. The Contractor shall be fully responsible for providing all materials conforming to the required specifications.

B. All paint products and other materials designated by the Engineer shall be available for testing. Sampling shall be performed by the Contractor in the presence of the Engineer. Materials shall be sampled in their original containers and the containers resealed as approved by the Engineer. All samples shall be packaged for shipment as approved by the Engineer. Samples shall be transported to an independent laboratory as directed and approved by the Engineer. Paint materials shall not be used until approved by the Engineer.

C. If instructed by the Engineer, the Contractor shall install, at his own expense, at a designated test site, strips of samples of materials proposed for all types of pavement markings for verification and testing for compliance with the Specifications.

D. The following road stripe and marking characteristics shall be tested prior to the issue of the Certificate of Completion and again prior to the Issue of the Defects Liability Certificate. The characteristics shall also be assessed at any other time during the period from the application of test markings to the end of the defects liability period, if instructed by the Engineer:

- Reflection in daylight or under road lighting
- Retroreflection under vehicle headlamp illumination
- Colour (luminance and/or chromaticity)
- Skid resistance

E. The Contractor shall provide assistance in terms of traffic management provision and support labour, testing equipment and materials for the duration of testing as and when requested by the Engineer.

6.03.06 Guarantee By Contractor

A. All marking and painting shall be guaranteed by the Contractor against any defect in material, workmanship, performance during the whole defect liability period. If any defect should arise due to material or workmanship, it shall be rectified by the Contractor at his own expense.

B. If such a defect is rectified by other than the Contractor the expense of such rectification shall be deducted from any monies due on this Contract.

C. The Contractor shall furnish copies of manufacturers' warranties and guarantees.

6.03.07 Types Of Pavement Markings

A. Continuous White Line (Type MR1)
A continuous longitudinal white line 20 cm wide

B. Continuous White Line (Type MR1-A)
A continuous longitudinal white line 15 cm wide.

C. Emergency Stop Lane Line (Type MR1´)
A broken longitudinal white line 20cm wide. The broken or "skip" pattern shall be based on 48.0 m units consisting of a 36 m line and a 12 m gap.

D. Continuous Yellow Line (Type MR2 and MR2-A)
A continuous longitudinal yellow line, 20 cm wide.

E. Continuous Double Yellow Line (Type MR2-2)
Two continuous longitudinal yellow lines, each 20 cm wide, separated by a 10 cm space.

F. Broken White Line (Type MR3)
A broken longitudinal white line, 15 cm wide. The broken or "skip" pattern shall be based on 6 m unit consisting of 4m line and 2 m gap.

G. Broken White Line (Type MR3')
A broken longitudinal white line, 25 cm wide. The broken or "skip" pattern shall be based on a 5.33 m unit consisting of 4m line and 1.33 m gap.

H. Broken White Line (Type MR3A)
As MR3 but with a width of 12 cm.

I. Broken White Line (Type MR3'-A)
As MR3 but with a width of 20 cm.

J. Double Broken White Line (Type MR3A – 3A)
Two broken longitudinal yellow lines, each 12 cm wide and 10 cm apart. The broken or "skip" pattern shall be based on 6 m unit consisting of 4m line and 2 m gap.

K. Broken White Line (Type MR3'- B)
A broken longitudinal white line, 20 cm wide. The broken or "skip" pattern shall be based on a 4 m unit consisting of 3 m line and 1 m gap.

L. Broken White Line (Type MR4)
A broken longitudinal white line, 15 cm wide. The broken or "skip" pattern shall be based on a 16 m unit consisting of 4m line and 12 m gap.

M. Broken White Line (Type MR5)
A broken longitudinal white line, 12 cm wide. The broken or "skip" pattern shall be based on a 12 m unit consisting of 3 m line and 9 m gap.

N. Broken White Line (Type MR5-A)
A broken longitudinal white line, 20 cm wide. The broken or "skip" pattern shall be based on a 6 m unit consisting of a 1.5m line and 4.5 m gap.

O. Broken White Line (Type MR5 - 5)
Two broken longitudinal yellow lines, each 12 cm wide. The broken or "skip" pattern shall be based on a 12 m unit consisting of 3 m line and 9 m gap.

P. Broken White Line (Type MR6)
A broken white line, 20 cm wide. The broken or "skip" pattern shall be based on a 6 m unit consisting of 3 m line and 3 m gap.

Q. Broken White Line (Type MR6 - A)
A broken longitudinal white line, 25 cm wide. The broken or "skip" pattern shall be based on an 8 m unit consisting of 4 m line and 4 m gap.

R. White "Stop" Line (Type MR7)
A transverse solid white line, 50 cm wide.

S. Broken White "Give Way" Line (Type MR8)
A transverse broken white line, 40 cm wide. The broken or "skip" pattern shall be based on a 1 m unit, consisting of a 0.5 m line and a 0.5 m gap.

T. Broken White Line (Type MR9)
A transverse broken white line, 15 cm wide used transversely to delineate the stopping point at traffic signals. The broken or "skip" pattern shall be based on a 1 m unit, consisting of a 0.5 m line and a 0.5 m gap.

U. Broken White Line (Type MR9 -A)
A transverse broken white line, 10 cm wide used at junctions, crossroads and roundabouts. The broken or "skip" pattern shall be based on a 1 m unit, consisting of a 0.5 m line and a 0.5 m gap.

V. Continuous White Line (Type MR10)
A continuous longitudinal white line 12 cm wide.

W. Continuous Double Yellow Line (Type MR10 -10)
Two continuous yellow lines, each 12 cm wide, separated by a 10 cm space.

X. Continuous Mixed Yellow Line (Type MR10 – 3A)
Two longitudinal yellow lines, both 12 cm wide, one continuous and the other based on a 4.5 m unit , consisting of a 3 m line and a 1.5 m gap.

Y. Continuous Yellow Line (Type MR11)
A continuous longitudinal yellow line 12 cm wide solid white line, 40 cm wide unless noted otherwise in the Drawings.

Z. Continuous White Line (Type MR12)
A continuous longitudinal white line 25 cm wide.

AA. Traffic Arrow
A white marking conforming to details shown on the Drawings.

BB. Pedestrian Crossing
50 cm x 300 or 400 cm white lines, with 50 cm gaps between them, as shown on the Drawings.

CC. Gore Stripes {Chevrons}
A solid white line, 50 cm wide, used to delineate turn lanes from through lanes, for traffic islands, and for hash marks, and shall be as shown on the Drawings.

6.03.08 Measurement

A. Painted Pavement Lines and Painted Pavement Markings shall be measured by the sq.m of reflectorized paint of each type, furnished, applied, cured, and accepted.

B. Preformed Marking Film shall be measured by the sq.m of preformed, reflectorized, thermoplastic film furnished, applied, cured, and accepted.

C. Pavement Markers and Pavement Studs shall be measured by the number of each type, furnished, installed, completed, and accepted.

D. Painted Kerbstones shall be measured by the linear meter of kerb painted, cured and accepted.

PAY ITEMS		**UNIT OF MEASUREMENT**
(1)	Painted Pavement Lines (each type of paint/Colour)	Square meter (m^2)
(2)	Painted Pavement Markings (each type of paint//Colour)	Square meter (m^2)
(3)	Preformed Film Markings	Square meter (m^2)
(4)	Ceramic Non-Reflective Pavement Markers	Nr
(5)	Painted Kerbstones (each colour)	Linear meter (m)
(6)	Plastic Non-Reflective Raised Pavement Markers	Nr
(7)	Plain Prismatic Reflective Pavement Markers	Nr
(8)	Aluminum Encased Prismatic Reflective Pavement Markers	Nr
(9)	Catseye Pavement Studs (3-cluster type)	Nr
(10)	Catseye Pavement Studs (5-cluster type)	Nr

SECTION 6.04 NOT INCLUDED

SECTION 6.05 DELINEATORS, MARKER POSTS AND MONUMENTS

6.05.01 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.

6.05.02 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 ".

6.05.03 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.

6.05.04 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

SECTION 6.06 STEEL GUARDRAIL AND CONCRETE SAFETY BARRIER

6.06.01 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.

6.06.02 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.

6.06.03 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. 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.

6.06.04 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.

6.06.05 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, and all complementary works (i.e. galvanized steel tubes, etc,) completed all as specified and as shown on drawings.

C. Concrete terminal unit free-standing or on top of retaining walls. Concrete class 360/20, including steel reinforcement, blinding concrete and all complementary works (i.e. galvanized steel tubes, etc,) completed all as specified and as shown on drawings.

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)	Concrete Terminal Unit (specify type)	Nr

SECTION 6.07 NOT INCLUDED

SECTION 6.08 NOT INCLUDED.

SECTION 6.09 TEMPORARY SAFETY DEVICES USED IN THE TTCP.

6.09.01 Scope

These Works shall consist of temporary measures taken during the construction works to protect workers and manage the risks from civilian traffic within close proximity to maintenance activities on the highways bridges. These works include but limited to providing signs, barriers, warning lights, etc..

6.09.02 References

All materials, color code, locations, sizes etc.. shall be in accordance with the drawings, Lebanese standards (Libnor) and the Manual of Uniform Control Device for Streets and Highways. U.S. Department of Transportation (MUTCD); In case of any contracdition, Libnor will be the final and only reference, while the drawings are only for guidance.

6.09.03 Road Safety Devices And Equipment

The road safety devices and equipment used in this section are as listed below but not necessary limited to the following:

A. Temporary Signs: Warning, Regulatory and Mandatory.

Temporary Warning signs, regulatory signs and mandatory signs of any type shall be furnished with all relevant fixation. Ismanteled and relocated for each temporary job and as directed. All Temporary Signs shall be reflectorized by the application of retro-reflective materials.

B. Measurement

Temporaray Warning signs, regulatory signs and mandatory signs of any type shall be measured by the number of signs intalled and accepted by the Engineer, including posts, supports and all related temporary fixation.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Temporary Warning signs with a demensions of 1mx1m.	Number
(2) Temporaray Warning Signs with a size greater than or equal to 1x1.2m dimensions	Number
(3) Temporary Warning signs with a demensions of 1.8mx0.6m.	Number
(4) Temporary Regulatory and Mandatory signs with a Diameter between 0.85 and 1m.	Number

6.09.04 Plastic New Jersey Barrier

Plastic water-filled New Jersey Barrier must be linked together in an approved manner in accordance with the manufacturer's guidance to form a continouous delineation boundary. The plastic NewJersey barrier shall be used in accordance with the related Traffic Management Plan (TMP) and subject to the Engineer's approval.

A. Measurement

PAY ITEMS	UNIT OF MEASUREMENT
(1) Plastic Barrier 180cm long, 80cm height and 40cm wide installed and accepted on site with reflective taps.	Number

6.09.05 Solar Flashing Beacon

A. **Scope**

The work covered in this section consists of purchasing and installing solar flashlight as shown on the Drawings (TTC) and /or as directed by the Engineer.

B. **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℃
M. Working hours: can working continuously more than 120 hours(exceed 5days) in cloudy and rainy days.
N. Wind load resistance: ≥1.5KN/m2

C. **Measurement**

The Solar Flashlight shall be measured by the number of flash lights installed/ Solar flashing Beacons, functioning and accepted by the Engineer as per the details Drawings and the material specifications.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Solar Flash Light Ø 300 mm installed and accepted on site.	Number

6.09.06 Flashing Arrow or Chevron Boards

A. **Scope**

The work covered in this section consists of purchasing and installing Flashing Arrow Boards (FAB) as shown on the Drawings (TTCP) and/ or as directed by the Engineer.

B. **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)
180 cm x 60 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.

C. **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.

D. **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

**** END OF SECTION ****

DIVISION 10

ENVIRONMENTAL WORKS

TABLE OF CONTENTS

SECTION 10.00 ENVIRONMENTAL WORKS

A. Environmental works shall comprise:

- Water distribution and related works
- Wastewater collection
- Storm water drainage
- Landscape irrigation works

B. Works shall consist of finishing all materials and the construction installation and completion in all respects of works as described in this Specification and as shown on the Drawings.

C. Special Requirements

C.1 Manufacturer's certificate: Materials shall be supplied with a certificate, in respect of each delivery, stating that products comply with and have been factory tested in accordance with specified Standards.

C.2 Marking: Unless otherwise specified in the relevant Standard, products shall have legibly cast, stamped or indelibly painted on, the following marks, as appropriate:

- Manufacturer's name, initials and identification mark.
- Nominal diameter.
- Class designation.
- Initials and number of relevant Standard.
- Length of pipe if shorter than standard length.
- Angle of bends in degrees.
- Date of manufacture.

C.3 Special tests: Whenever required by the Engineer, the Contractor must supply and transport to an approval testing laboratory samples of materials selected by the Engineer. Number of samples shall not be less than 0.5% of total supplied, with at least one from each class, diameter and manufacturer. Failure of any sample shall be followed by a second and if necessary a third test from the same batch. A third test failure will result in all material from that manufacturer being rejected and replaced by material from a different manufacturer, subject to approval and satisfactory tests. Laboratory test reports in an approved form must be provided.

D. Workmanship: Operations

D.1 Manufacturer's recommendations on handling, repairing, laying, jointing, anchoring, testing and other works for pipes and fittings shall be strictly followed.

D.2 Loading and unloading: The Contractor shall use cranes, hoists or skidways as directed by the Engineer. The Contractor shall use hooks, spreader beams, ropes, band or wire slings etc. as recommended by manufacturer for each type of pipe and as approved by the Engineer.

D.3 The Contractor shall stack pipes on level surface. The Contractor shall not rest pipes on sockets or jointing fairlings and shall securely chock end pipes in bottom row. Height of stacks shall be to manufacturer's instructions.

D.4 The Contractor shall handle material with care to avoid damage whether moved by hand, skidways or hoists.

D.5 Storing: The Contractor shall provide safe storage for material. Interior of pipes, fittings etc. shall be kept free from dirt and foreign matter. The Contractor shall provide shade for materials as required by manufacturer's instructions and to the Engineer's approval.

D.6 Cutting: The Contractor shall use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. If, in the opinion of the Engineer, special precautions shall be taken to eliminate airborne particles, the Contractor shall use methods and equipment as directed by the Engineer. The Contractor shall prepare ends according to type of joint used and follow manufacturer's recommendations. The Contractor shall take care not to damage lining, if any. The Contractor shall repair on site, minor damage, if permitted.

D.7 The Contractor shall repair damaged coating, sheathing or lining in accordance with the Specification and manufacturer's instructions. The Contractor shall use material compatible with that originally used. Repair shall be approved by the Engineer before incorporating materials into the work.

SECTION 10.01 PIPING AND APPURTENANCES

10.01.01 GENERAL

A. Special requirements

A.1 Manufacturer's certificate: materials are to be supplied with a certificate, in respect of each delivery, stating that products comply with and have been factory tested in accordance with specified Standards.

A.2 Marking: unless otherwise specified in the relevant Standard products are to have legibly cast, stamped or indelibly painted on, the following marks, as appropriate:

- Manufacturer's name, initials and identification mark,
- Nominal diameter,
- Class designation,
- Initials and number of relevant standard,
- Length of pipe if shorter than standard length,
- Angle of bends in degrees,
- Date of manufacture,

A.3 Special tests: whenever required by the Engineer, supply and transport to a testing laboratory samples of materials selected by the Engineer. Number of samples is not to be more than 0.5% of total supplied, with at least one from each class, diameter and manufacturer. Failure of any sample is to be followed by a second and if necessary a third test from the same batch. A third test failure will result in all material from that manufacturer being rejected and replaced by material from a different manufacturer, subject to approval and satisfactory tests. Provide laboratory test report in an approved form.

B. Workmanship: Operations

B.1 Manufacturer's recommendations on handling, repairing, laying, jointing, anchoring, testing and other works for pipes and fittings are to be strictly followed.

B.2 Loading and unloading: use cranes, hoists or skidways as directed by the Engineer. Use hooks, spreader beams, ropes, band or wire slings etc. as recommended by manufacturer for each type of pipe and as approved by the Engineer.

B.3 Stack pipes on level surface. Do not rest pipes on sockets or jointing fairlings. Securely chock end pipes in bottom row. Height of stack is to be to manufacturer's instructions.

B.4 Handle material with care to avoid damage whether moved by hand, skidways or hoists.

B.5 Storing: provide safe storage for material. Interior of pipes, fittings etc. are to be kept free from dirt and foreign matter. Provide shade for materials as required by manufacturer's instructions and to the Engineer's approval.

B.6 Cutting: use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. If, in the opinion of the Engineer, special precautions are to be taken to eliminate airborne particles, use methods and equipment as directed by the Engineer. Prepare ends according to type of joint used and follow manufacturer's recommendations. Take care not to damage lining, if any. Repair on site, minor damage, if permitted.

B.7 Repair damaged coating, sheathing or lining in accordance with the Specification and manufacturer's instructions. Use material compatible with that originally used. Repair is to be approved by the Engineer before incorporating materials into the work.

10.01.02 PIPES, FITTINGS AND ACCESSORIES

10.01.02.1 MATERIALS

A. Concrete pipes (for Sewage and Drainage)

A.1 Pipe to BS 5911 Part 100 1988 Class H or ASTM C76-95A Class IV or DIN 4032 Class KW. Cement used in manufacture is to be ordinary Portland cement to BS 12.

A.2 Joints: to be of gasket type with flexible spigots and sockets. The shape of the joint must be designed to prevent any movement of the gasket during assembly and as such produce full watertightness. Rubber gasket shall be to BS 2494.

A.3 Factory protection for pipes

For drainage networks internal and external lining not required.

For sewage networks:

- Internally: pipes smaller than 900 mm diameter, use coal tar epoxy coat 70% minimum epoxy content. Coat minimum thickness 40 mils. For pipes 900 mm and larger use Polyethylene liner.
- Externally: unless otherwise specified external coating not required.

B. Ductile iron pipe (for Water Supply)

B.1 Pipe to EN 545 or equivalent. Unless otherwise indicated in the Bill of Quantities. Class K9 for diameters up to 500 mm, Class K8 for diameters from 500 to 800 mm and Class K7 for diameter greater than 800 mm.

B.2 Joints: spigot and socket ended pipes shall be used for straight runs and adjacent to elbows or fittings. These joints shall be provided with rubber gaskets, and an external thrust block is required at elbows or fittings. Anchored or self-restrained joints shall be used for sections on the 1000 mm pipe adjacent to elbows. Anchored joints are to be push-in, self anchored type able to take up the axial forces thus allowing concrete thrust blocks to be dispensed with. The Contractor shall submit calculations verifying the number of restrained joints required noting that pipe pressure testing will be made when pipes are partially backfilled.

B.3 Joints: flanged pipes wherever specified are to have screwed-on or cast-on flanges to sustain working pressure of NP 16 minimum.

B.4 Flanges to BS 4504.

B.5 Factory protection for pipes:

- Internally: cement lined to EN 545 or BS 4772 Appendix C with ordinary Portland cement to BS 12 to specified thicknesses,

- Externally: metallic zinc to EN 545 or BS 4772 and either hot applied material to BS 4164 or bitumen to BS 3416, minimum thickness 6 mils.

B.6 Factory protection for fittings:

Coated internally and externally by dipping, or other method, using hot applied coal tar based material to BS 4164 or hot applied bitumen to BS 3416, Type 1, grade d, minimum thickness 10 mil.

C. UPVC pipes

C.1 Pipes to DIN 8061/8062, Series 4 and 5 or ISO R161 Class 10 and & 16. Use concrete encasement if cover is less than 1 meter.

C.2 Fittings to DIN 8063 part 1 fabricated from pipe.

C.3 Joints to DIN 8063 Part 1, socket spigot with rubber sealing rings to BS 2494.

D. Polyethylene (PE) pressure pipe for water supply

D.1 Pipe and fittings to DIN 8074/8075 or AWWA C906-90. Straight with straight ends suitable for heat fusion. Class 10 and 16 kg/cm2.

D.2 Materials used shall have a standard PE code designation 3408 and a minimum hydrostatic design basis of 1600 psi according to AWWA C906 Table 1.

D.3 Manufacturers to provide certification that stress regression testing has been performed on the pipe products. Materials shall also meet elevated temperature requirements as given in Table 2 AWWA C906.

D.4 Fittings shall be to AWWA C906, extruded or injection molded suitable for class of pipe required.

D.5 Joints for pipes and fittings shall be by heat fusion and in strict accordance with pipe manufactures recommendations. Joints shall have a tensile strength equal to that of the pipe. Fusion temperature, interface pressure, alignment and cooling time, shall be according to manufactures recommendations.

D.6 Tests on PE compounds: where PE is used for potable water, PE compounds in pipes and fittings are to contain no ingredients in an amount that has been demonstrated to migrate into water in quantities considered to be toxic. PE compounds are to be tested and certified suitable for potable water by the National Sanitation Foundation (NSF) Testing Laboratory - USA or the Canadian Standard Association (CSA) Testing Laboratory or other accredited testing agency. Tests are to be made in accordance with requirements no less restrictive than those in NSF Standard No. 14 (1976) Sections 3 and 4. The seal and mark of the testing laboratory are to be included on pipes and fittings.

E. Steel pipe

E.1 Steel pipe size 150 mm (6") and smaller shall be black steel, seamless or welded, and shall conform to BS 1387 medium class, ISO R65 or DIN 2440.

E.2 Steel pipe size 200mm (8") and larger shall be welded black steel, and shall conform to BS 3602, AWWA C200, grade A, or equivalent. Wall thickness to AWWA C200-91 Section 3-4. Minimum wall thickness to BS 3600 or as given in the Bill of Quantities.

E.3 Steel pipe shall be reasonably round and straight and shall be free from injurious defects. Defects shall be considered injurious when the depth of defect is greater than 12.5% of the tabulated wall thickness. Pipe shall be substantially free from rust.

E.4 Steel pipe shall be joined by double submerged arc welding. All welding shall be performed in conformance with the rules and regulations of the American Welding Society, including surface preparation methods, welding procedures and qualification of welders and welding operators.

E.5 Surface preparation: Prior to coating, surface is to be prepared by acid pickling until all scale has been removed.

E.6 Internal lining: all steel pipes and specials shall be lined internally to the thickness specified with concrete made from ordinary Portland cement to BS 12 and fine aggregate The materials used for lining, the method of lining and curing of the finished lining and the manufacture and testing of test cubes shall comply with BS 534 and shall be carried out to the approval of the Engineer.

E.7 External coating: steel pipes fittings and specials shall be protected externally with bituminous laminate tape 1.6mm thick and with 55% overlap or as recommended by manufacturer. Approved manufacturer's Denso, Serviurap… or equivalent.

F. Flanged Adaptors: Ferrous

F.1 Material: cast iron body to BS 1452 grade 14 or mild steel plate to BS 4360 - 4SA and malleable cast iron flange to BS 310 grade 20/10 or rolled steel to BS 970 - 060A12 with bolts to BS 970 - EN3A and rubber rings to BS 2494.

F.2 Length of adaptor is to be 200mm for diameters up to 150mm, 250mm for diameters between 200 and 300 mm and as approved for diameters larger than 300 mm.

F.3 Factory protection: coated with bitumen or coal tar to BS 3416 or 4164 respectively.

G. Tapping saddles: Cast iron

G.1 Type: suitable for tapping ductile iron pipe and for working pressure of 16kg/cm2.

G.2 Material: malleable cast iron, ductile cast iron or gunmetal to BS 310 - B310/10, BS 2789 - 420/2 or BS 1400 LG2- C respectively, with rubber '0' ring to BS 2494 suitable for water supplies and manganese bronze high tensile non-corrosive bolts, nuts and washers.

G.3 Dimensions: width not less than 38 mm and diameter of disc not less than 75 mm.

G.4 Threads for tapping to BS 21.

G.5 Factory protection: hot bitumen dipped to BS 4164 or cold bitumen coated to BS 3416.

10.01.03 WORKMANSHIP

Earthwork for pipelines to be according to Section 2.10 of Division 2.

A. Pipe laying and jointing - Generally

A.1 Lowering: do not lower pipe into trench until pipe bed is brought to grade and approved.

A.2 Lowering: use ropes, wire slings, band slings, spreader beams etc. as recommended by manufacturer for each type of pipe and as approved.

A.3 Examine Material carefully for damage: Tests in accordance with manufacturer's instructions before laying to the satisfaction of Engineer.

A.4 Examine material: ensure internal coating or lining and outer coating or sheathing are undamaged. If damaged, make good or dispose of as directed.

A.5 Pipe cleanliness: remove dirt and other materials before lowering.

A.6 Pipe cleanliness: clear construction debris from inside of before making joint.

A.7 Pipe placement: lay pipe-on an even formation true to grade and line, with sockets (if any) facing up the gradient.

A.8 Pipe on solid ground: cut holes in bottom of trench to allow proper jointing and for barrel of pipe to bear evenly on solid ground for its full length.

A.9 Pipe on granular bedding: scoop out locally at sockets/couplings to enable pipe to rest uniformly on barrel and adjust to exact line and level. After testing lay and compact further granular material in 150mm layers or as approved to levels shown on the Drawings.

A.10 Pipe on concrete bed or surround: provide rectangular blocks of concrete Class B, made in approved moulds at least 14 days before use, and approved hardwood folding wedges. Provide two concrete blocks for each pipe, set and bone into correct level on formation bottom and lay pipe properly centered and socketed. Insert two hardwood folding wedges, of width equal to width of concrete block, between body of pipe and block and drive together until pipe is brought to exact level required. Leave blocks and wedges undisturbed while pipes are being jointed and concrete bed and haunch or surround are being placed. Ensure blocks and wedges are of sufficient size and strength to prevent settlement of pipes. Leave sufficient space to enable joints to be made, tested and inspected.

A.11 Pipe plugs: when pipe laying is not in progress, close open ends of pipes with properly fitted temporary wooden plugs or standard caps as directed.

B. Jointing

B.1 Manufacturer's instructions are to be followed regarding placement of bedding and backfilling, cleanliness of joint surfaces, lubricant used, correct location of components,

provision of correct gaps between end of spigot and back of socket for flexible joints etc.

B.2 Deflection of joint: do not deflect flexible joints beyond maximum permissible angles given by manufacturer and/or relevant Standard.

B.3 Patent detachable and flexible joints: strictly comply with special instructions issued by manufacturer's of proprietary joints when laying and jointing.

B.4 Differing pipe and fitting material: joint with adaptors as recommended by pipe manufacturer.

C. Line and gradient

C.1 In open excavation: provide and maintain sight rails and boning rods properly painted to ensure correct alignment of pipe runs. Sight rails are to be positioned either vertically above the lines of pipes or immediately adjacent thereto. At no time are there to be less than three sight rails in position on each length of pipeline under construction to any one gradient.

C.2 In heading: provide and maintain marks to establish line and level of pipeline. Marks are to be fixed in each working shaft and two further marks established in each length of heading.

D. Tolerances

D.1 Gravity sewers: tolerances are to be 6 mm in level and 25 mm in line between manholes or access points unless otherwise specified. Where pipe is to be constructed in straight lines between manholes or lampholes the length will not be accepted if a light at each manhole or lamphole cannot be seen from adjacent manholes.

E. Floatation

E.1 Prevention: whenever-water is excluded from interior of pipe, place sufficient backfill above pipe to prevent floatation.

E.2 Removal of pipe: any pipe that has floated, correct bedding and relay.

F. Pipe built into structures

F.1 Treatment of external surface: thoroughly clean outside surface of pipes to be built-in immediately before installation. Remove protective coating to metal pipes, where ordered. Roughen clay and concrete pipes as directed. Paint plastic pipes with appropriate solvent cement and sprinkle with dry coarse sand whilst wet. Cut away sheathing from sections to be built-in and after installation restore protection up to external face of structure with approved bituminous material.

F.2 Flexible joints: provide two flexible joints or flexible patented joints adjacent to structures. Place first joint not more than one pipe diameter from face of structure and second not more than the following distances away from first:

- Pipelines not exceeding 450 mm: 2 pipe diameters
- Pipelines over 450 mm and not exceeding 1000 mm: 1.2 m
- Pipelines over 1000 mm: 1.8 m.

G. Field testing: Generally

G.1 Provision of test equipment: All items for test have to be provided on site before the test i.e. pressure gauges, instruments, water etc...

G.2 Carry out tests in the presence of the Engineer's Representative.

G.3 Fittings and joints: permanently anchor fittings before testing and leave all joints exposed for checking.

G.4 Test sections: limit test sections to not more than 500 m.

G.5 Test sections: test pressure lines between valve chambers whenever possible.

G.6 Test sections: test gravity sewers in sections between manholes.

G.7 Test sections: no testing shall be carried out against or through the pressure reducing valves. The setting of the pressure reducing valves shall not be changed for testing purposes.

G.8 Test plug: secure end of main and test plug by struts.

G.9 Closed valve: do not test against a closed valve unless there is no acceptable alternative.

G.10 Apply pressure by manually operated test pump or, in the case of large diameter mains, by power driven test pump, if approved.

G.11 Examine exposed joints and repair visible leaks.

G.12 Failure: should a test fail locate leak and replace or make good defective pipe or replace and make good faulty joint. Retest main.

G.13 Records: keep test records in an approved form. Hand original copy to the Engineer immediately after completion of test.

G.14 Pressure lines: carry out hydrostatic test while pipeline is partially backfilled.

G.15 Non-pressure lines not exceeding 1000mm diameter are to be air tested before backfilling and hydrostatic tested after backfilling.

G.16 Non-pressure lines over 1000 mm diameter are to be visually inspection tested from the inside as well as hydraulic individual joint tested.

G.17 Non-pressure lines: carry out infiltration tests where crown of pipe at high part of length under test is more than 1.2 m below water table.

H. Hydrostatic testing of pressure pipelines

Pressure test shall be made when pipeline section is partially backfilled, having all its joints exposed.

H.1 Fill pipe slowly with water from lowest point. Do not use power-driven pump unless approved.

H.2 Fill absorbent pipes with water and allow to stand for at least 24 hours to allow complete absorption.

H.3 Entrapped air is to be bled before pressurizing.

H.4 Pressurizing is to continue until specified test pressure is reached in lowest part of section under test. Bleed further quantities of entrapped air while raising pressure.

H.5 Maintain test pressure for specified test duration with pumping stopped.

H.6 Repressurize to original test pressure and record respective volumes of water pumped.

H.7 Failure: pipeline will be deemed to have failed test if:

- Visible leaks are detected, regardless of leakage being within specified limits.
- Volume of water lost during period when pumping was stopped, exceeds the allowable leakage volume.

H.8 Test pressure: Generally 1.5 times the maximum sustained pressure, minimum 13.5kg/cm^2.

H.9 Test period: 2 hours.

H.10 Allowable leakage 0.1 liter/mm diameter/km length/day/30 m of applied pressure.

I. Hydrostatic Testing of Non-pressure Pipelines

I.1 Procedure is to be as described for pressure pipelines.

I.2 Test pressure: 1.0 m head of water above pipe soffit at highest point and not greater than 6 m head of water at lowest point of section under test. If maximum head is exceeded, test section in stages.

I.3 Test period 30 minutes.

I.4 Allowable leakage: 0.02 liters/linear meter/meter diameter/30 minutes.

J. Air Testing of Pipelines

J.1 Carry out test to BS 8005. Plug effectively length under test.

J.2 Apply pressure by approved method (i.e. hand pump) until a pressure 3 psi head of water is indicated on a U-tube connected to the system.

J.3 Pressure drop: without further pumping, pressure is not to fall to less than 1 psi after period of 10 minutes.

J.4 Failure to pass the air test is not conclusive and if no leakage can be traced by external application of soapy water to all sealing areas then an hydrostatic test is to be carried out before final rejection.

K. Infiltration Test for Gravity Pipes

K.1 Timing: carry out test after total backfilling of length under test.

K.2 Plug effectively all inlets to system as directed.

K.3 Measure residual flow by approved method i.e. weir or other.

K.4 Infiltration limits: the following limits are not to be exceeded:

- Pipelines not exceeding 700 mm: 0.02 litres/hour/100 linear meters/mm diameter.
- Pipelines over 700 mm: 0.03 litres/hour/100 linear meters/mm diameter.

K.5 Failure: test will be deemed to have failed if allowable infiltration water is exceeded. Locate source of excessive infiltration by approved means i.e. traversing light and mirrors or inflated rubber plug etc. and make good. Repeat test until successful.

L. Visual Inspection Test

L.1 Timing: carry out test after total backfilling of length under test.

L.2 Limit of length to be tested at one time is three full- length pipes unless otherwise approved.

L.3 Apparatus: use rubber tyred bogies which do not damage lining of pipe and an adequate supply of electric lamps.

L.4 Check joints by means of feelers to ensure rubber rings are correctly located.

L.5 Check pipe barrel for visible cracks.

M. Hydraulic Individual Joint Test for Pipes Exceeding 1000 mm

M.1 Procedures: carry out to BS 5886, Type 2 testing after backfilling, or equivalent. Pressurize joint to 2 bars. Wait for 2 minutes at the end of which repressure to 2 bars. Wait for 5 minutes. No pressure drop shall be observed at the end of the latter period.

M.2 Test pressure: 2 bar.

M.3 Test period: 5 minutes.

M.4 Allowable leakage or pressure drop: None.

N. Flushing and Disinfection of Water Mains

N.1 Procedure: to AWWA C651.

N.2 Provide equipment, gauges, temporary connections, chlorine and water needed for flushing and disinfection

N.3 Arrange with the Employer to draw water from existing sources.

N.4 Sections: flush and disinfect mains in sections as directed by the Engineer.
N.5 Draining use washout valves and fire hydrants to drain flushing and disinfecting water.

N.6 First flushing: before commencing disinfection, flush main until effluent is clean and then clean as directed. 1 to 2 times volume of pipe is usually required for such flushing.

N.7 Type of chlorine: disinfect with chlorine gas or solutions of calcium hypochlorite or sodium hypochlorite and agree with the Engineer on method of application.

N.8 Initial dosing is to be 40-50 ppm.

N.9 Contact period is to be 24 hours.

N.10 Residual chlorine: after the contact period has been achieved, measure residual chlorine by orthotolidin test. Residual chlorine is not to be less than 5 ppm or test is to be repeated as directed.

N.11 Final flushing: after disinfection, reflush network until chlorine concentration in water leaving main is less than 1 ppm.

N.12 Tests: perform bacteriological tests to AWWA C651, Section 9. Number of samples is to be one per 1 km of main feeders and one per 0.25 km of distribution lines.

N.13 Procedure after cutting into existing main: generally to AWWA C651, Section 11.

O. Field Protection and Coating

O.1 Iron pipes: polyethylene encasement is to be to ANSI/AWWA C105, Section 4.1 minimum thickness 8 mils and or in accordance with the manufacturer's instructions.

O.2 Patented detachable and flexible joints and flanged connections: protect metal joints with mastic compound and protective tape in accordance with the manufacturer's instructions. Minimum overlap 55%. Press out firmly all folds and irregularities.

P. Water Supply House Connections

P.1 Location: agree location of tapping with the Engineer before starting construction.

P.2 Program connections to follow closely construction of main network.

P.3 Tapping: drill, thread and tap ferrule cocks to manufacturer's instructions.

P.4 Excavate, install, bed and backfill in same manner as main network.

P.5 Test with main network but excluding water meter.

P.6 Records: maintain accurate records of location of house connections to main network. Record details of the following:

- Diameter
- Length
- Location
- Stop valves.

P.7 Survey Logbook: keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. Transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

Q. Sewer house connections

Q.1 Location: agree location and invert level of connections with the Engineer before starting construction.

Q.2 Program connections to follow closely construction of sewer.

Q.3 Execution: connection to sewer is to be at manhole, where possible, or by T or Y junction.

Q.4 Minimum Grade: lay connections at minimum grade of 20 per 1000 unless otherwise approved.

Q.5 Install, Bed and Test connections in same manner as main sewers.

Q.6 Records: maintain accurate records of location of connection to main sewer. Record details of the following:

- Connection number
- Type of connection
- Diameter
- Downstream manhole number
- Distance from manhole
- Position (left or right) when facing upstream of street sewer
- Distance from center line of sewer to end lateral
- Invert of street sewer
- Lateral invert at end point
- Number of inspection chambers
- Cover type
- Location, description and elevation of obstructions and method of protection.

Q.7 Survey Logbook: keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. Transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

R. Cleaning and inspection of sewers

R.1 Cleaning: clean pipeline of silt and debris after backfilling pipe trenches and completing manholes, hatch boxes etc. but before surfaces are permanently reinstated and make ready for inspection by the Engineer.

R.2 Inspection: pipelines of 700 mm diameter and over are, where practicable, to be inspected from the inside and when necessary a suitable trolley is to be provided for this purpose.

R.3 Inspection: pipelines less than 700 mm diameter and larger pipelines which cannot be inspected from the inside, are to be inspected by passing a cylinder of diameter 25 mm less than the internal diameter of the pipe and length not less than the internal diameter of the pipe through each pipeline.

10.01.04 MEASUREMENT

A. Earthwork

Measurement and payment for trench excavation and backfilling shall be made in accordance with the provisions of Section 2.10.3 of Division 2.

B. Pipelines

B.1 Pressure pipes installation or relocation shall be paid for per linear meter measured as a straight line between the centers of consecutive coupling section. The distance between the two centers of the couplings on both sides of any fitting or valve shall be included as pipe length. No allowance will be made for cut ends and waste. No separate payment for any in-line fitting shall be made. The cost shall be included in the rate for pipelines.

For gravity networks, pipes installation or relocation shall be paid for per linear meter measured as straight line between inside edges of manholes plus 20 cm inside the manhole from each side. No allowance shall be made for cut ends and waste.

B.2 Rates for pipes installation shall include for the following:

1) Staking out, field surveying and preparation of shop Drawings.
2) Pipes, couplings and fittings.
3) Appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes.
4) Additional self-restrained coupling sections adjacent to bends.
5) Bolts, nuts, gaskets and others for flanged fittings.
6) Transportation and hauling about the Site, loading, unloading and lowering materials in the trench.
7) Lubricating agent used for assembling the pipe sections.
8) Cutting, machining, chamfering, etc. of standard length pipes.
9) Assembling the pipes and couplings and connecting to fittings and valves, or chambers, manholes and or structures as applicable.
10) Concrete thrust blocks including associated over excavation and anchors or additional self restrained coupling sections at bends. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
11) Testing as per specification.
12) Ancillary works and materials.
13) Flushing Cleaning painting, lining and coating.
14) Disinfections of water supply pipes.

B.3 Rates for pipes relocation shall include for the following:

1) Staking out, field surveying and preparation of shop Drawings.
2) Appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes.
3) Additional self-restrained coupling sections adjacent to bends.
4) Bolts, nuts, gaskets and others for flanged fittings.
5) Transportation and hauling about the Site, loading, unloading and lowering materials in the trench.
6) Lubricating agent used for assembling the pipe sections.
7) Cutting, machining, chamfering, etc. of standard length pipes.
8) Assembling the pipes and couplings and connecting to fittings and valves, or chambers, manholes and or structures as applicable.

9) Concrete thrust blocks including associated over excavation and anchors or additional self restrained coupling sections at bends. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
10) Testing as per specification.
11) Ancillary works and materials.
12) Flushing Cleaning painting, lining and coating.
13) Disinfections of water supply pipes.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Concrete Pipes (specify size)	Linear meter (m)
(2) Ductile Iron Pipes (specify size)	Linear meter (m)
(3) UPVC Pipes (specify size)	Linear meter (m)

SECTION 10.02 VALVES AND ACCESSORIES

10.02.01 SCOPE

A. These works shall consist of furnishing all materials, constructing, installing and completing all works described in this Section of the Specification and as shown on the Drawings.

10.02.02 MATERIALS

10.02.02.1 Valves

A. Gate Valves Cast Iron

A.1 Type: Size 50 mm and smaller to BS 5154 inside screw, solid wedge, rising stem and screwed bonnet.

A.2 Type: Size 65mm and larger to BS 5163, inside screw, solid wedge, resilient seated, for valves 350 mm and smaller and metal seated for valves 400 mm and larger, bolted bonnet, non-rising stem type, suitable for NP 16 for water supply networks.

A.3 Material of component parts from basic or alternative materials listed in BS 5163 and BS 5164.

A.4 End connections: Size 50 mm and smaller screwed end to BS 21.

A.5 End connections: Size 65 mm and larger flanged end connection to BS 4504.

A.6 End connections: These shall be as shown on the Drawings and/or as described in the Bill of Quantities. Plain end connections shall be machined to suit joints specified for adjoining pipes.

A.7 Operation: Valves larger than 400 mm diameter shall have spur gear drive operated by removable key. Valves smaller than 400 mm shall be operated by handwheel.

A.8 Factory protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat shall be 250 microns.

B. Butterfly Valves: Cast Iron

B.1 Type shall be to BS EN 593, double flange with resilient seating, for horizontal use and suitable for NP 16.

B.2 Size: Shall be used for 350 mm and larger.

B.3 Material of component parts: Shall be made from basic materials listed in BS EN 593 Table 3.

B.4 End connections: Flanged to BS 4505: PT3.

B.5 Operation: Shall be by hand wheel. Maximum shut off pressure against which valve is operated shall be 15 kg/cm2.

B.6 Factory protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat shall be 250 microns.

C. Ball Valves

C.1 Ball Valves 50 mm and under shall be full port of 2-piece construction, lever operated with bronze body and stem, chrome-plated brass ball, replaceable PTFE seats and packing, plastic coated steel handle, threaded end connection for steel piping, and copper compression or solder end connections for copper piping.

D. Globe Valves

D.1 Type: Shall be to ASTM A48 grade 30B with valve disc to ASTM A276 type 430, valve seat to ASTM A276 type 420 and stem to ASTM A276 type 403. Valve shall be suitable for a working pressure of 16 bars.

D.2 Construction: Non-rising stem, straight pattern with flanged connections.

D.3 Material of component parts: Valves Class PN 10 and 16 shall be cast iron with stainless steel trim.

D.4 Operation: Manual operated valves shall have hammer type handwheel and electric operated valves shall have motor actuator.

E. Check Valves

E.1 Type: Shall be to BS 5153, swing, straight, for horizontal use and suitable for working pressure of 16 bars.

E.2 Material of component parts: Ductile iron from basic materials listed in BS 5153 Table 5, under “copper alloy faced” column.

E.3 Special Requirements: Seating or facing rings shall be renewable. An arrow showing direction of flow shall be visible from outside and cast integral with the valve housing.

E.4 End Connections: Either flanged to BS 4504 or screw ended to BS 21 to suit joints specified for adjoining pipes.

E.5 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Minimum thickness of coating to be 250 microns.

F. Float Valves

F.1 Type: Globe pattern, with two operating chambers, sealed through piston disc.

F.2 Operation: To operate with a mechanical compensating float valve controlling flow to tank by modulating in direct ratio to minimum fall in water level. Control of valve shall be through mechanically operated, three-position, four- way valve. Moving four-way valve control in one direction shall open valve and moving lever in other direction shall

close-out valve. When lever is moved to center, valve will throttle in an intermediate position.

F.3 Valve positioning control consists of float operated linkage mechanism for remote mounting which feeds water level changes back to main valve through low friction, flexible push-pull cable supplied by same manufacturer.

F.4 Valve operating control consists of secondary linkage, mechanism functioning off common lever connected to both main valve position indicator rod and control valve position indicator rod and control valve operating lever. Minute changes in water level are transmitted through push-pull cable to three-position, four-way control valve.

F.5 Construction: Cast iron body to ASTM A 126, bronze valve trim and valve operating mechanism to ASTM B62 and all stainless steel valve float and pilots.

F.6 Factory Protection: Internal coating of epoxy to a thickness of 120 microns and external coating of epoxy and nickel plating to a thickness of 120 microns.

G. Air Valves for Water Mains

G.1 Generally: Valves shall have cast iron body and bolted cover to BS EN 1561 grade 14 minimum, rubber outlet seat, plastic or ebonite ball, forged bronze screws and guide for ball acting under pressure. Valves shall be dynamic type where there is no possibility of ball being drawn into orifice due to high air velocities. Valves shall be factory tested to 1.5 times working pressure and factory coated with coal tar or bituminous coating to BS 4164 or BS 3416 respectively. Thickness of coat to be 250 microns.

G.2 Double air valves (or combination air valves): These are required for relieving air under pressure and in bulk. Large orifice releases or admits air during charging or emptying of mains while small orifice releases air accumulated at summits of mains under pressure. Large orifice area shall be equal to or greater than inlet of valve. Valves shall be fitted with nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Valves shall be flanged to BS 4504 and suitable for working pressures up to NP16.

G.3 Single air valves: Type 1 (or air vacuum valve) for releasing or admitting air during filling or emptying of pipes. Type II (or air release valve) for automatically releasing, under pressure, accumulated air at summits of mains. Air valves larger than 50 mm shall be flanged to BS 4504 and shall have nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Air valves 50 mm and smaller shall have B.S.P. thread with brass or gun metal male screwed stop valves. Valves shall be suitable for working pressures up to NP16.

H. Air Valves for Pressurized Sewage Mains

H.1 Generally: Valves shall have cast iron body, cover and baffle to BS EN 1561, Grade 14, stainless steel float and float guide, Buna-N seat or needle and Dirlin internal linkages. Air valves shall have long float stem and body to keep valve operating mechanism free from contact with sewage by maintaining an air gap between mechanism and waste media. Float shall hang freely in center of valve body with 12 mm clearance all around to prevent large solids getting above the float. Valves shall be fitted with blow off valves, quick disconnect couplings and minimum 2.0 m of hose to permit backflushing without dismantling valve. Valves shall be factory tested to 1.5 times working pressure

and factory coated with bituminous coating to BS 4164 or BS 3416 respectively. Thickness of coat to be 250 microns.

H.2 Single air valves: Type I (or air vacuum valve) for releasing or admitting air during filling or emptying of pipes. Type II (or air release valve) for automatically releasing, under pressure, accumulated air at summits of mains. Air valves 50 mm and smaller shall have screwed inlet to B.S.P. thread with gunmetal male screwed stop valve. Air valves larger than 50 mm shall be flanged to BS 4504 and have nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Valves shall be suitable for working pressures up to NP10.

H.3 Double air valves (or combination air valves): These are required for relieving air under pressure and in bulk, shall be an assembly of an air vacuum and an air release valve. Valves shall be suitable for working pressures up to NP16.

I. Sluice Gates

I.1 Type: Shall be to AWWA C501, rising stem, having a flat back for bolting to wall, suitable for 6 meters seating pressure and 4 meters off-seating pressure, with standard conventional closure and rectangular or circular aperture.

I.2 Material of component parts: unless otherwise specified on the Drawings, any materials listed in Section 2 of the Standard may be used in manufacture except that materials identified as being subject to de-zincification or de-aluminumization shall not be used.

I.3 Operation shall be by floor pillar with gear box. The maximum operating head from surface of water to center line of gate shall be 6 meters.

I.4 Factory Testing: A leakage test to meet the requirements of Section 6.3 of the Standard shall be carried out on all sluice gates.

I.5 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat to be at least 250 microns.

J. Flap Valves

J.1 Type shall be flange mounted, designed for use on end closures to prevent entrance of backwater. Seating plane shall have 10 deg. inclination.

J.2 Materials: Cast iron body and cover, bronze seat faces, bronze hinge pins and spring pins, cast iron follow ring and plated steel ring draw bolts. Materials subject to de-zincification or de-aluminumization are not be used.

J.3 End Connections: If flange mounted, flanges shall be to BS 4504.

J.4 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat to be at least 250 microns.

10.02.02.2 Irrigation Specialties

A.1 Type: Normally closed 24 VAC 50/60 cycle solenoid actuated globe pattern with a balanced pressure diaphragm design. The valve operating pressure range shall be between 1.5 and 14 bars.

A.2 Material: The valve body and bonnet shall be constructed of heavy-duty glass-filled UV-resistant nylon and have stainless steel studs and flange nuts; diaphragm shall be of nylon reinforced rubber.

A.3 Operation: The valve shall have manual open/close control (internal bleed) for manual opening and closing of valve without electrically energizing the solenoid.

A.4 Operation: The valve shall have a brass flow control stem for accurate manual regulation and/or shut off of outlet flow.

A.5 Construction: The valve construction shall be such as to provide for all internal parts to be removable from the top of the valve without disturbing the valve installation.

B. Electric Remote Control Valves with Pressure Regulation

B.1 Type: Electric remote control valve as specified above shall have a pressure regulating module capable of regulating outlet pressure between 1 and 7 bars (15 and 100 psi).

B.2 Operation: module shall have an adjusting screw for setting pressure and Schrader valve connection for monitoring pressure. The pressure shall be adjustable from the pressure regulating module when the valve is manually bled.

C. Pop-Up Spray Sprinkler

C.1 Type: Fixed, non-rotating spray or stream spray adaptable for full circle, part circle, or strip wetting pattern, suitable for installation on a pop-up mechanism. Spray head to have built in check valve and pressure regulated stem.

C.2 Material: The sprinkler body, stem, nozzle, and screen shall be constructed of heavy duty, ultra-violet resistant plastic, with a heavy-duty stainless steel retract spring.

C.3 Construction: Spray head to retract flush with the finished ground level when not in operation. When spraying, net pop-up height to be 150 mm from finished ground level.

C.4 Performance shall meet requirements of discharge and spray radius as specified on the Drawings for the given nozzle pressure. The sprinkler shall have a matched precipitation rate nozzle with an adjusting screw capable of regulating the radius of flow.

C.5 Tests: The Contractor shall provide test results carried out at factory substantiating required performance (discharge and radius of throw at prescribed operating pressure and height above ground) and giving actual precipitation rate and its uniformity as obtained for uniformity test carried out using catch cans.

D. Pop-Up Rotor Sprinkler

D.1 Type: Full or part circle pop-up rotor sprinkler, single nozzle. The part circle sprinkler shall have adjustable arc coverage from 25° to 360°. The sprinkler shall have a built in check valve and pressure regulated stem.

D.2 Material: The sprinkler body, stem, nozzle, and screen shall be constructed of heavy duty, ultra-violet resistant plastic, with a heavy duty stainless steel retract spring.

D.3 Construction: Sprinkler head shall retract flush with the finished ground level when not in operation. When operating, net pop-up height to be 100 mm from finished ground level.

D.4 Performance shall meet requirements of discharge, radius and rotation angle as specified on the Drawings for the given nozzle pressure. The sprinkler shall have a matched precipitation rate nozzle, with an adjusting screw; capable of regulating the radius and the flow.

D.5 Tests: The Contractor shall provide test results carried out at factory substantiating required performance (discharge and radius of throw at prescribed operating pressure and height above ground) and giving actual precipitation rate and its uniformity as obtained for uniformity test carried out using catch cans.

E. Bubblers

E.1 Type shall be pressure compensating, of the full circle umbrella or trickily discharge, with inlet screen.

E.2 Construction: Bubbler shall be of a permanently assembled design constructed of durable ultra-violet resistant plastic.

E.3 Performance: Bubbler shall operate at constant flow discharge over a pressure range specified on the Drawings.

F. Emitters

F.1 Type shall be pressure compensating, single outlet.

F.2 Construction: Emitter shall have self piercing inlet barb constructed of durable ultra-violet resistant plastic.

F.3 Performance: The emitter shall have a self flushing action to minimize clogging, and shall operate at a constant flow discharge over a pressure range specified on the Drawings.

G. Quick Couplings Valve

G.1 Type: The quick coupling valve shall be a two piece type.

G.2 Construction: The valve body shall be constructed of heavy cast brass.

G.3 Cover: The cover shall be a durable, protective self-closing, locking rubber cover.

G.4 Valve operating key: The valve shall be opened and closed by a brass key supplied by valve manufacturer having a 25 mm male top pipe threads and 19 mm female top pipe threads outlet. The valve throat shall have a keyway with detent positions for regulating water flow. Operating keys shall be supplied at the rate of 1 per five valves installed or fraction thereof.

H. Backflow Preventers

H.1 Backflow preventers shall be installed in the locations shown on the Drawings. Normally for each control head in the system a backflow preventer shall be installed upstream of all other components in the control head. Backflow preventers shall only be installed in locations where they are readily accessible for maintenance and testing and shall not be located where any part of the device can become submerged at any time.

H.2 Backflow preventers shall be of the reduced pressure type.

H.3 Backflow preventers shall be evaluated and tested by an approved authority and certified by the American Society of Sanitary Engineering Standards 1013 (latest edition) for reduced pressure principle backflow preventers. Such valves shall also meet the performance requirements of AWWA C 511 and the performance requirements of the University of Southern California Foundation for Cross Connection Control Research or approved equivalents.

H.4 Backflow preventers up to 75 mm in size shall be of machined cast bronze body construction and up to 150 mm in size shall be of cast iron body construction and 11 with internal waterways epoxy coated, stainless steel and/or brass internal parts and stainless steel flange bolts, durable, tight-seating rubber check valve assemblies.

H.5 Backflow preventers shall be suitable for supply pressure up to 1.2 MN/sq.m (12 kg/sq.cm) and for water temperature up to 44 degrees C. The operating range for flow and pressure loss shall be as shown on the Drawings.

H.6 The backflow preventer assembly shall consist of a pressure differential relief valve located in a zone between two positive seating check valves. The relief valve shall contain a separate means whereby free air will enter the zone, and contained water will be discharged to the atmosphere, when the valve is fully open.

H.7 The backflow assembly shall include 2 gate valves for isolating unit, and 3 test cocks for testing the device to ensure proper operation.

H.8 Backflow preventers shall be designed for inline servicing.

10.02.02.3 Fire Hydrants

A. Post Type

A.1 Type: To AWWA C502, dry barrel, post type suitable for maximum working pressure of 16 bars. Hydrant size shall be 100 mm for 2 outlets and 150 mm for 3 outlets. Stand post shall be supplied with 2 nozzle hoses 65 mm for 100 mm hydrants; and 2 nozzle hoses 65 mm, and 100 mm pumpers for 150 mm hydrants. Hydrant shall be complete with duckfoot and isolating gate valve. Hydrants shall be of the tilt off version, and shall be provided with intermediate seal bush to guarantee leak tightness in case of breakage due to traffic accidents.

A.2 Material: Any materials stipulated in the Standard except that materials identified as being subject to de-zincification or de-aluminumization shall not be used.

A.3 End Connection: To be as shown on the Drawings. Flanged connections, if used, shall be to BS 4504.

A.4 Special Requirements: Finishing color of hydrant and threads of screwed outlet nozzles shall suit local fire Authority requirements.

A.5 Operation: Direction of rotation of operating nut to open hydrant shall be counter-clockwise. Operating keys shall be provided at the rate of 1 per 5 hydrants installed or fraction thereof.

B. Underground Type

B.1 Type: To BS 750 screw down type.

B.2 Flanges: To BS 4504.

B.3 Special Requirements: Threads of screwed outlet or mouth piece shall suit local fire Authority requirements.

B.4 Covers and Frames: Cast iron to BS EN 124, medium type.

B.5 Operation by Keys: Direction of opening shall be counter-clockwise. Operating keys shall be provided at the rate of 1 per 5 hydrants installed or fraction thereof.

10.02.02.4 Service Connections

A. Water Service Connection

A.1 Ferrule Cocks and Stop Valves:

A.1.1 Type: Plug, quarter-turn closing type.

A.1.2 Material: Cast gunmetal to BS 1400 - LG2-C or cast iron body to BS EN 1561 and copper alloy plug.

A.1.3 End Connection: One end screwed male fitted directly to pipe saddle and the other end to fit push fit joints to polyethylene pipe as shown on the Drawings.

A.1.4 Pressure Class: Suitable for main network pressure.

A.1.5 Accessories: Surface boxes, valve caps, extension spindles and protection tube and protective cover shall be same material as specified for gate valves with dimensions and constructional details as shown on the Drawings and/or to manufacturer's standards.

A.2 Underground Stop Valves:

A.2.1 Type: To BS 5433 with crutch or square head.

A.2.2 Materials: Unless otherwise specified, body, lead, gland, spindle and washer plate square head shall be gunmetal to BS 1400-LG2, seating-washer shall be vulcanized synthetic rubber to BS 3457 Clause 6 and head sealing '0' ring shall be to BS 2494 Class D or E.

A.2.3 End Connections: Inlets and outlets of valves shall be internally threaded to BS 2779, Class B, Table 4M to fit threaded specials to polyethylene pipe.

B. Taps for Hose Connection

B.1 Type: Globe valve to BS 5154 suitable for NP16, comprising ductile iron or brass hose outlet to match hose connection tip, enclosed in block work box, for buried installation, with ductile iron hinged lockable cover.

B.2 Factory protection of external surface of box shall be hot applied coal tar or bitumen to BS 4164 or 3164 respectively. Thickness of coat to be 250 microns.

B.3 Box locking key: Ductile iron, supplied at the rate of 1 in every 3 boxes.

C. Water Meters

C.1 Water flow meters shall be installed in the locations shown on the Drawings.

C.2 Unless stated otherwise on the Drawings, the meter shall be of the helical rotary type and suitable for a normal flow stated on the Drawings. It shall be accurate to within 5% over the specified how range.

C.3 The meters shall measure the instantaneous rate of flow as well as total flow.

C.4 No negative reading shall be imposed by air passage or suction due to the emptying of the pipe system upstream from the meter.

C.5 The meter shall be made of corrosion and wear resistant materials. It shall have dial glass wipers. The meter shall be scalable against unauthorized tampering

D. Tapping Saddles: Cast Iron

D.1 Type: Suitable for tapping ductile iron pipe and for working pressure of 16kg/cm^2.

D.2 Material: Malleable cast iron, ductile cast iron or gunmetal to BS EN 1561, BS EN 1563 and BS EN 1564 respectively, with rubber '0' ring to BS 2494 suitable for water supplies and manganese bronze high tensile non- corrosive bolts, nuts and washers.

D.3 Dimensions: Width not less than 38 mm and diameter of disc not less than 75 mm.

D.4 Threads for tapping to BS 21.

D.5 Factory protection; Hot bitumen dipped to BS 4164 or cold bitumen coated to BS 3416.

10.02.02.5 Jointing Materials and Adaptors

A. Generally

A.1 Gaskets: Elastomeric full face 3 mm thick joint rings to BS 2494 with dimensions to BS 3063.

A.2 Rings: Elastomeric to BS 2494 with dimensions to manufacturer's recommendations to suit type of joint required.

A.3 Bolts and Nuts: ISO metric black hexagon to BS 4190, minimum tensile strength 433MN/m^2, maximum elongation 17%. After fixing, bolt projection shall be maximum 6 mm, minimum 3 mm.

A.4 Washers: Black steel to BS 4320.

A.5 Dielectric Joints shall have insulating gasket between flanges and teflon sleeves and washers between bolts and nuts and flanges. Joints shall be suitable for operating pressure of system.

B. Flexible Couplings

B.1 Type shall be gasketed sleeve type, to allow angular deflection and axial movement of two joined pipe ends and to maintain permanent, leak-tight joint.

B.2 Components comprise one center sleeve, two end followers or flanges, two rubber-compounded wedge-section gaskets and sufficient draw bolts and nuts to properly compress gaskets. Tightening of bolts to draw end followers together shall compress gaskets in recess between center sleeve and followers onto pipe ends to effect positive seal.

B.3 Size: Couplings shall have diameter specifically supplied for and to properly fit type of joined pipe ends. Center sleeve shall be of adequate thickness and whole coupling suitable for minimum working pressures shown on the Drawings.

B.4 Center sleeve and followers shall be true circular sections, free from irregularities, flat spots or surface defects and formed from steel mill sections with space between sleeve and follower designed to provide confinement of gasket.

B.5 Bolts shall be special steel having minimum yield strength of 2800 kg/cm2 (40,000 psi) and ultimate strength of 4200 kg/cm2 (60,000 psi). Bolts shall be track-head design to prevent turning when nut is drawn up and threads shall be rolled with a nominal diameter larger than diameter of shank. Manufacturer shall supply information regarding recommended torque to which bolts shall be tightened.

B.6 Gaskets shall be synthetic rubber-base compound with other products to produce material which will not deteriorate from age, heat or exposure to air and which is resilient and able to resist cold flow of material so that joint will remain sealed and tight

indefinitely when subjected to shock, vibration, pulsation, temperature and adjustment of connected pipes.

B.7 Factory Protection: Coupling shall be factory painted internally with 250 microns coating of epoxy and externally with red primer to AWWA 203 Type B chlorinated rubber solution compatible with bitumen, coal tar and general paints.

B.8 Installation: Couplings shall be assembled on site in accordance with manufacturer's instructions to ensure permanently tight joints under all conditions of expansion, contraction, shifting and settlement.

C. Dismantling Couplings

C.1 Type shall ensure extensible connection between sections of pipework, to be mounted next to valves to enable easy dismantling from pipework or to permit joining pipework when butterfly valve is removed for maintenance.

C.2 Components: Dismantling piece shall be flanged type composed of two parts, one sliding into the other, and a free flange to compress a trapezoidal section seal to ensure water tightness. Coupling shall have locking devices to provide elements of complete rigidity.

C.3 Construction: All steel with flanges class PN 10, PN 16 or PN 25 depending upon coupling location on pipework.

C.4 Size: Couplings shall have diameter specifically supplied for and to properly fit type of joined ends of pipes and valves. Coupling shall permit tightening of end flanges without risk of misalignment. Seal shall be locked after end joints are tightened.

D. Flanged Adaptor: Ferrous

D.1 Material: Cast iron to BS EN 545.

D.2 Length of adaptor shall be 200mm for diameters up to 150mm, 250mm for diameters between 200 and 300 mm and as approved for diameters larger than 300 mm.

D.3 Factory protection: Coated with bitumen or coal tar to BS 3416 or 4164 respectively.

10.02.02.6 Valve Accessories

A. Accessories

A.1 Handwheels shall be BS 5163, of cast iron to BS EN 1561. Handwheels shall be marked “CLOSE” with an arrow to indicate clockwise direction of closure. Diameters and other constructional details shall be to manufacturer's standards. Handwheels shall be supplied at a rate of 1 in 5 valves.

A.2 Valve caps shall be to BS 5163, of cast iron or malleable iron to BS EN 1561 and BS EN 1562 respectively. Set screw of valve cap shall be mild steel Ml 2.

A.3 Operation Keys: Combination prizing bar and lifting key type, with 1.5 m vertical bar and 0.5 m horizontal bar. Keys shall be supplied at a rate of 1 in 5 valves.

A.4 Extension Spindles for Gate Valves: Steel to BS 2470 - Ml 2, hot dip galvanized to BS 1387, size 18x18 mm for valves up to 200 mm diameter and 24 x 24 mm for valves

250mm to 400 mm diameter. Length for each valve size shall suit excavation requirements. Spindles shall have cast iron or malleable iron cap and coupling, to BS EN 1561 and BS EN 1562 respectively, on both sides of extension spindle (cap for operating spindle and coupling for connecting to valve). Set screws of caps and couplings shall be mild steel Ml 2.

A.5 Protection Tubes: Either UPVC or cast iron. Shape, sizes and other constructional details shall be to manufacturer's standards and/or as shown on the Drawings. Tubes shall have caps circling extension spindles.

A.6 Surface boxes shall be to BS 5834: Part 2. Frames and lids shall be cast iron to BS EN 1561. Studs, bolts, nuts and hinge pins shall be mild steel Ml 2, chains shall be mild steel or wrought iron and lid shall have the letter 'W cast on. Boxes shall be of the following types:

- For carriageways (wheel loads up to 11.5 Tons) Heavy grade type A
- For use where heavy commercial vehicles are exceptional Medium grade type M
- For use in places inaccessible to wheeled vehicles Light grade type L

A.7 Lifting Key Sets: Malleable iron, supplied at the rate of 1 per 5 covers installed or fraction thereof.

A.8 Guards for Underground Stop Valves: PVC, shape and size and other constructional details to manufacturer's standards and/or as shown on the Drawings.

B. Valve Chambers and Markers

B.1 Unless shown otherwise on the Drawings all backflow preventers, gate valves, pressure regulators, electric solenoid valves, manual control valves, pressure gauges and water meters shall be installed in precast concrete access boxes of proper size for easy access. Access boxes shall be complete with precast concrete cover.

B.2 Unless shown otherwise on the Drawings all access boxes shall be installed on a suitable base of gravel for proper foundation of box and easy leveling of box to proper grade and also to provide drainage of the access box.

B.3 Valve markers showing the reference numbers of the valves shall be of materials and to the dimensions, shapes and details as shown on the Drawings.

10.02.02.7 Valve Operators

A. General

A.1 Gate, butterfly and ball valves shall be manually or electrically operated depending upon size, torque applied on valve stem or as shown on the Drawings.

A.2 Valves 350 mm and smaller shall be operated manually with a maximum applied torque on hand wheel of 100 Nm.

A.3 Valves 400 - 500 mm shall be operated manually with a maximum applied torque of l50Nm.

A.4 Valves of higher torque shall have appropriate thrust bearings, slides and gearboxes to fulfill these requirements.

A.5 Gate valves 600 mm and larger and ball valves, are always electrically operated using thrust bearings, gearboxes and motor actuators.

A.6 Butterfly valves 600 mm and larger shall be either manually or electrically operated as shown on the Drawings.

B. Manual Gearboxes

B.1 Type: Totally enclosed, sealed construction to protect moving parts from damage and corrosion. Gearbox shall be either spur or level type depending upon mounting position of valve.

B.2 Components shall include corrosion resistant bearings, gear of rugged cast iron construction, cast housing cover complete with seals and gaskets and handwheel actuator. Housing cover shall have indicator window to show position of valve. Gearbox shall also have stainless steel bolts.

C. Electric Valve Operators

C.1 Type shall consist of motorized unit including gear train mounted in cast iron housing, flange mounted electric motor, control cabinet and handwheel for manual operation.

C.2 Installation shall be suitable for flange mounting directly on valve body, for gate valves with non-rising stem and for manual operation locally.

C.3 Rating shall be of adequate horsepower and thrust ratings to open and close operated valve smoothly at all conditions of load and pressure.

C.4 Components shall include adjustable mechanical stop- limiting devices to prevent over-travel of valve in either direction. Operator housings, supports and connections to valve shall have a minimum safety factor of 5 based on ultimate strength of materials used.

C.5 Construction shall be weatherproof, with rugged cast iron housing and with handwheel having appropriate gearing for emergency manual operation such that maximum applied torque is 150 Nm. Declutch lever shall disengage drive motor during handwheel operation and prevent handwheel rotating during power operation for safety of personnel. Handwheels shall close valve in clockwise direction and shall have arrows and the word “CLOSE” cast on.

C.6 Controls shall comprise integral electric controls enclosed within weatherproof compartment and including magnetic starter and reversing controller for motor, open-stop-close push-button for local operation, limit switches to give remote indications when valve is fully opened or closed, torque switch to shut down drive on excessive thrust loads, indicating lights, control voltage transformer etc.

C.7 Electric motor shall be totally enclosed, squirrel cage, induction type conforming to NEMA Publication No. MGI including characteristics, tests and ratings. Motor shall carry maximum possible load encountered in valve operation under all normal and abnormal operating conditions without exceeding nameplate rating and without benefit of service factor.

10.02.02.8 Irrigation Valve Accessories and Operators

A. Plastic Valve Boxes

A.1 Generally: Valve boxes may be glass reinforced plastic (GRP) or plastic conforming to the following specifications.

A.2 GRP valve boxes shall be designed to suit site conditions and loadings. GRP shall be manufactured from E-glass type fibers and thermosetting resin and shall incorporate a corrosion resistant liner. Glass fibers shall be compatible with the resins used. Liner shall comprise an inner face being a smooth hard suitably reinforced resin rich layer. Exterior surface of valve box shall be resin rich.

A.2.1 Inside surface of valve box shall be hard, durable, free of tackiness and free of bulges, dents, ridges or other defects that result in a variation of inside dimensions of more than 3 mm from that obtained in adjacent unaffected portions of the surface.

A.2.2 No glass fiber reinforcement shall penetrate interior surface of valve box wall, and any glass fiber reinforcement on exterior surface must be thoroughly impregnated with resin.

A.2.3 Glass content will be determined by ignition loss analysis in accordance with ASTMD2584orIS01172.

A.3 Plastic valve boxes shall be manufactured from high impact, acid and heat resistant, self-extinguishing, hard, durable, low coefficient of expansion PVC compound.

B. Program Controllers

B.1 Type: Solid state or hybrid (combining electro-mechanical and micro-electronic circuiting), capable of fully automatic or manual operation of the remote solenoid valves, with dual program, independent station timing, 14-day calendar dial for every day or every other day or any sequence starts, time-setting control up to 60 minutes per station in 2 minutes increments 23 starts per day. Number of stations shall be as indicated on the Drawings or in the Bill of Quantities. Maximum number of 24 VAC solenoid valves that can be controlled by a station is 4. Controller shall allow for valve power output to be interrupted without affecting the controller timers.

B.2 Operation: The controller shall have a remote pump start circuit to activate a remote pump start relay to run the pump during the irrigation cycle.

B.3 Operation: The controller shall allow for opening the first remote control valve before operating the pump and also for closing the last remote control valve within 15 seconds after stopping the pump.

B.4 Installation: The controller shall be installed in pedestal weatherproof, heavy-duty, locking, steel cabinet adequately protected. Pedestal mount shall include terminal strips for the quick connection of cables.

B.5 Electrical Features: To accept 220 V 50/60 cycle current; to command 24 VAC solenoid valves; to include output surge protection to protect controller from power surges; to include one arrester for each valve wire and one for the common or ground wire; to include a master on-off switch.

B.6 The Controller without exception shall be of the same manufacturer as the remote control valve.

C. Cabling for Irrigation Control

C.1 Low Voltage Wiring: From automatic controllers to remote control valves shall be direct burial type, 600 volt solid copper single conductor wire with heat resistant insulation minimum of 0.4 mm thickness. The Contractor shall submit proposed low voltage wire routing shop drawing for the Engineer's approval prior to installation. The low voltage wire shall be encased in 5 mm diameter conduit.

C.2 Medium Voltage Cables: Shall conform to the requirements of BS 5467, IEC 502, or other approved comparable international standards as applicable. Cables shall be 600/1000 volt grade, multicore, stranded copper conductor, cross-linked polyethylene (XLPE) insulated, UPVC over heather type. The service cable for irrigation controllers shall be 3 core 10 mm2 minimum.

C.3 Conductors: Shall be annealed stranded copper in accordance with BS 6360. Conductor insulation shall be moisture and heat resistant, 90 degrees C, grade conforming to BS 6899. The cable cores unless otherwise approved shall be colored as follows:

- Single phase system: Red (phase), black (neutral), green or green/ yellow (ground).

10.02.03 CONSTRUCTION AND INSTALLATION

10.02.03.1 Generally

A. Prior to installation, the Contractor shall inspect for cleanliness of bores, seating surfaces etc. and for handling damage, cracks, missing parts and tightness of pressure-containing bolting.

B. The Contractor shall ensure gates and hydrants are in closed position before installation.

C. The Contractor shall operate hydrants through one complete opening and closing cycle in the position in which they shall be installed to ensure proper functioning.

10.02.03.2 Installation

A. Valves

A.1 The Contractor shall set and joint valves to pipe in manner specified for laying and jointing pipe and/or to manufacturer's instructions.

A.2 Concrete Pads: The Contractor shall provide valves with Class B concrete pads as shown on the Drawings so that pipe does not support weight of valve.

A.3 Valves Without Concrete Pads: The Contractor 'shall place on firm footing to prevent settling and excessive strain on connection to pipe.

A.4 The Contractor shall not use valve to bring misaligned pipe into alignment during installation.

A.5 The Contractor shall inspect all pressure-containing bolting (bonnet, seal plate and end connections) for adequate tightness after installation but prior to field testing.

B. Hydrants

B.1 The Contractor shall join hydrants to pipe in manner specified for laying and jointing pipe and/or to manufacturer's instructions.

B.2 The Contractor shall set hydrants to established grades as directed by the Engineer.

B.3 The Contractor shall set hydrants plumb with nozzles parallel with or at right angles to the curb. Where hydrants have a pumper nozzle, the Contractor shall set the latter facing the curb. Where hydrants have two hose nozzles 90 deg. apart, the Contractor shall set with each nozzle facing the curb at 45 deg. angle.

C. Sluice Gates

C.1 The Contractor shall install gate, wall thimble, operating mechanism, stem and stem guides in accordance with manufacturer's drawings and recommendations, avoid warping the frame and maintain tolerance between seating faces.

C.2 The Contractor shall protect tapped holes in thimbles during concrete paving and setting.

C.3 The Contractor shall protect surface of thimble and gate from concrete spillage, paint, oil and debris.

C.4 The Contractor shall support thimbles to prevent shifting during pouring and brace horizontally and vertically to prevent distortion.

C.5 The Contractor shall tighten nuts in sequence after setting.

C.6 The Contractor shall adjust and lubricate entire assembly after installation.

C.7 The Contractor shall operate through one complete cycle to ensure proper functioning.

D. Field Protection

D.1 Valves: The Contractor shall protect valves against action of external agents by a coat of approved bituminous compound applied cold by brush after pressure tests on pipelines have been completed.

D.2 Hydrants: The Contractor shall apply one coat of paint, of color specified by the Engineer, after backfilling and surface restoration is completed.

D.3 Gates: The Contractor shall protect against action of external agents with one coat of approved bituminous compound applied cold by brush after installation.

D.4 Bolts: The Contractor shall protect buried bolts against corrosion with approved paint or by polyethylene wrapping.

E. Water Supply House Connections

E.1 Location: The Contractor shall agree location of tapping with the Engineer before starting construction.

E.2 The Contractor shall program connections to follow closely construction of main network.

E.3 Tapping: The Contractor shall drill, thread and tap ferrule cocks to manufacturer's instructions.

E.4 The Contractor shall excavate, install, bed and backfill in same manner as main network.

E.5 The Contractor shall test with main network but excluding water meter.

E.6 Records: The Contractor shall maintain accurate records of location of house connections to main network. Record details of the following:

- Diameter.
- Length.
- Location.
- Stop valves.

E.7 Survey Logbook: The Contractor shall keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. The Contractor shall transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

F. Sewer House Connections

F.1 Location: The Contractor shall agree location and invert level of connections with the Engineer before starting construction.

F.2 The Contractor shall program connections to follow closely construction of sewer.

F.3 Execution: Connection to sewer shall be at manhole, where possible, or by T or Y junction.

F.4 Minimum Grade: The Contractor shall lay connections at minimum grade of 20 per 1000 unless otherwise approved.

F.5 The Contractor shall install bed and test connections in same manner as main sewers.

F.6 Records: The Contractor shall maintain accurate records of location of connection to main sewer. Record details of the following:

- Connection number.
- Type of connection.
- Diameter.
- Downstream manhole number.
- Distance from manhole.
- Position (left or right) when facing upstream of street sewer.
- Distance from centerline of sewer to end lateral.
- Invert of street sewer.
- Lateral invert at end point.
- Number of inspection chambers.
- Cover type.
- Location, description and elevation of obstructions and method of protection.

F.7 Survey Logbook: The Contractor shall keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. The

Contractor shall transfer information to sketches and tables as agreed with the Engineer provide three bound copies and hand to the Employer.

10.02.03.3 Installation of Irrigation System Components

A. Installation of Valves

A.1 Prior to installation, valves shall be inspected for cleanliness of bore, seating surfaces etc. and for handling damage, cracks, missing parts and tightness of bolting. Valves shall be in close position before installation.

A.2 Valves shall be operated through one complete opening and closing cycle in the position in which they shall be installed to ensure proper functioning.

A.3 Valves shall be set and jointed to the pipe in the manner specified for laying and jointing pipe and in accordance with the manufacturer's recommendations. Each valve shall be provided with a concrete pad as shown on the Drawings so that the pipe does not support the weight of the valve. Valves shall not be used to spring misaligned pipe into alignment during installation.

A.4 All stressed bolts (bonnet, seal plate and end connections) shall be inspected for adequate tightness after installation and prior to field-testing.

A.5 Valves shall be protected against action of external agents by a coat of approved bituminous compound, applied cold by hand brushing after pressure tests on pipelines have been completed. Buried bolts etc., shall be protected against corrosion, with approved paint or polyethylene wrapping.

B. Installation of Penstocks

General

All penstocks shall be designed and installed so that the maximum working pressure acts in a seating direction on the gate.

Both gate and frames shall be sufficiently rigid to withstand twice the maximum working pressure and any eccentric pressures created by the tightening of the anchor bolts during installation. All penstock frames shall have a spigot back.

The frame shall be designed to ensure that the gate is supported over not less than two thirds of its depth when the gate is fully raised.

Penstocks shall be of the rising spindle type unless otherwise specified, and the spindles shall be of adequate size to avoid buckling under load.

All spindle nuts shall be self aligning and their length shall be not less than twice the spindle diameter.

The top part of the penstock frames shall be sufficiently robust and substantial to prevent the frames bowing and if necessary, additional holding down bolts shall be fitted. The penstocks shall be fitted with matching wedges on doors and guides, the wedges shall be fitted with renewable seatings of zinc free bronze. Under no circumstances shall wedges be fitted to the bottom or lower sections of the penstock doors. The wedges shall be adjustable with stainless steel adjusting screws and shall be readily removable.

On rectangular penstocks the inverts shall be flush with renewable synthetic rubber seals on the bottom of the doors. The rubber shall be suitable for the application and of an approved type.

The doors shall have lifting eyes cast in, or eye bolts of sufficient size to permit the lifting of the door against seating pressure.

Where extended spindles installations require to be operated at elevated floor level, spindle guides or guide brackets shall be provided close to the floor level.

Where penstocks are required to be operated by the tee keys, spindles caps shall be fitted. The caps shall be drilled and each provided with nut and bolt for securing to the spindle which shall also be drilled. Where caps are fitted they shall each be supplied complete with operating tee key.

All penstock shall be provided with headstocks (except where the Handwheels can be mounted on the penstock frames). For penstocks of 300mm ND (square or circular) and above and for all motorized and actuator operated penstocks, unless otherwise stated, thrust tubes shall be provided between the penstocks frame and the headstock, in order to absorb the operating thrust in both directions. Thrust tubes shall incorporate all necessary fixing brackets and spindle quid plates.

Headstocks and foot brackets shall be provided for non-rising spindle penstocks where the latter are specifically called for. Guide brackets shall be provided where necessary. Non-rising spindles shall be fitted with thrust collars and arranged so as to transmit the thrust arising from operation of the penstock directly to the Penstocks frame. Where

headstocks are required on non-rings spindles installations they shall incorporate a penstock position indicator.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specifications and/or the contract drawings.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specification and/or the contract drawings.

All bolt holes shall be drilled and spot faced.

Simple templates shall be supplied as soon as possible after approval of drawings to enable the Civil contractor to position the holes for holding down bolts for all penstocks over 1.0 m square.

Penstock Materials

Penstock doors, wedge support beams, frames, guides, frame extensions, headstocks and bridge pieces shall be cast iron, of minimum grade 220 to BS 1452. Doors and frames shall be fitted with renewable seatings of zinc free bronze.
Spindles shall be manufactured from stainless steel 431S29 (EN 57) or similar approved material.

Extension Spindles

Extension spindles shall be adequately sized to prevent buckling and shall be attached to the valve/penstock stem by a suitable adaptor incorporating two muff couplings, scarf lap jointed and pinned with at least two coupling joints included. Universal joints and waterproof sleeves shall be provided where specified. Extension spindles shall be manufactured from 080M40 (EN 8) steel.

Intermediate bearing support or guide brackets of cast iron, with slotted holes for site adjustment, shall be fitted to long shafts where necessary. Bearings shall be of PTFE or similar approved type.

Pedestals and Spindle Covers

Penstock and valve pedestals shall be of cast iron or heavy duty, welded, mild steel construction with a substantial base and fixing provision. The base and top of the pedestals shall be machined normal to the axis of the drive shaft.

Where necessary, support guide bushes shall be fitted as the base of the pedestal.

The pedestal height shall be such that the handwheel is approximately 1 metre above the operator's floor level.

Clear polycarbonate covers of an approved type shall be provided for all rising spindles to totally enclose them when in the fully raised position.

Penstocks

Each tube shall be clearly and permanently engraved to indicate the position of the penstock.

B.1 For each penstock, the wall thimble, operating mechanism, stem and stem guides shall be installed in accordance with the manufacturer's recommendations. Tolerances between seating faces shall be maintained and any warping avoided.

B.2 Tapped holes in thimbles shall be protected during concreting and setting. Surfaces of thimbles and gates shall be protected from concrete spillage, paint, oil and debris. Thimbles shall be supported to prevent shifting during pouring and braced horizontally and vertically to prevent distortion.

B.3 Nuts shall be tightened in sequence after setting and the entire assembly shall be cleaned, adjusted and lubricated after installation.

B.4 Penstocks shall be operated through one complete cycle on installation to ensure proper functioning.

B.5 Penstocks shall be protected against action of external agents with one coat of approved bituminous compound applied cold by brush after installation. Buried bolts, etc. shall be protected against corrosion, with approved paint or polyethylene wrapping.

C. Installation of Other System Components

C.1 Irrigation components forming a control head shall be located in downstream order as follows: backflow preventer, control valve, fertilizer applicator and gate valve, pressure gauge, filter, pressure gauge, electric solenoid valve, water flow meter and pressure regulator.

C.2 Filter and fertilizer applicator equipment shall be mounted on a concrete pad forming an integral installation. The filter shall be located downstream of the fertilizer applicator to prevent contamination from the injection process. The concrete pad shall be Class 210/20 with dimensions as recommended by the equipment manufacturer.

C.3 Installation of miscellaneous components of the system shall be in accordance with the manufacturer's instructions.

10.02.04 MEASUREMENT

10.02.04.1 Valves and Accessories

A. Valves shall be paid for per unit installed according to size indicated in the Bill of Quantity.

B. Air valves shall be paid for per unit installed according to size indicated in the Bill of Quantity.

C. Drain or pipe flush valves shall be paid for per unit installed as per type and size indicated in the Bill of Quantity.

D. Rates for Gate valves shall include for:

- Supply of valves as specified.
- Lowering into the trench and installing.
- Over excavation for concrete supports and boxes.
- Concrete supports and thrust blocks. Concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
- Appropriate fittings and/or couplings and dismantling joint for connecting to adjacent pipe or fitting.
- Flanged and socket necessary adaptors for connecting to adjacent spigot ends.
- Valve chamber complete with cover lock, required couplings and rungs as shown on Drawings for valves placed in chambers.
- Valve surface box complete with cover, lock and key and concrete surround for directly buried valves.
- BOLTS, nuts, gaskets operating key, or hand wheel and others.
- Ancillary works and material required.
- Painting, lining and coating.
- Extension spindles plus square nuts to fit spindles.

E. Rates for air valves, shall include for:

- Supply of valve as specified.
- Items, tee and/or saddle for connecting to main line.
- Isolating gate valve.
- Drilling and fixing the flanged spool outlets for air valve connections. Ancillary works and material required.
- Installing, painting, coating and testing.
- Concrete valve chamber complete with cover and lock as shown on Drawings.

F. Rates for drain valves, end flush and low point flush shall include for:

- Supply of material, items forming the complete unit, as shown on the Drawings, pipes, flexible coupling, valve, flanged pipe, duckfoot elbow, housing, polyethylene pipe, etc...
- Bolts, nuts and gaskets.
- Thrust and support blocks.
- Valve chamber complete with cover, lock, surface box, rungs, etc..., all as shown on Drawings.
- Painting, lining and coating.
- Ancillary works and materials.
- Polyethylene pipe diameter 150 or 200 mm, 50 m long with protection and anchorage at outlet to allow free discharge into the wadi or drain.
- Ductile iron pipe and flexible couplings between invert level tee and valve chamber.
- Installing, painting, coating and testing.

10.02.04.2 Sluice Gates and Penstocks

A. Sluice gates and/or penstocks shall be measured and paid for per unit installed according to size and type indicated in the Bill of Quantity.

B. Rates for sluice gates and penstocks shall include for:

- Gate.
- Frame, rubber bottom seal, anchor bolts, stem and stem guide.

- Lift with wall brackets, anchor bolts and handwheel.
- Cleaning and painting.
- Assembly, installation, testing and adjustment.
- Stop planks.

10.02.04.3 Fire Hydrants

A. Rates for fire hydrants shall include for all the requirements in item (F) above (pipe drain or flush valves) with the exception of:

- Ductile iron pipe and flexible couplings between invert tee and valve chamber.

B. Fire hydrants are paid for per unit installed according to type indicated in the Bill of Quantity.

10.02.04.4 Service Connections

A. Potable water house connection shall be paid per connection installed.

B. Sewer connections are measured per connection installed.

C. Rates for taps for hose connections shall be paid per connection installed.

D. Rates for house connections for water supply shall include:

- Supply and installation of all materials including pipes, accessories and fitting specials,extension spindle, water service unit box and cover.
- Supply of stopcocks and saddles on mainline (tapping collar, elbows, tees, caps, valves).
- Excavation, bedding and backfilling, concrete works, thrust block, reistatement, and only if mentioned in the Bill of Quantities, “water meter installation and house chamber construction”.
- Installation and connection to new network and to the service box, or to the existing service connection, and testing.
- Coordination with the Enginner in collaboraion with water authority offices and bearing of all cost associated with their requirements and procedures for maintaining uninterrupted service.

E. Rates for sewer connections shall include:

- Supply and installation of all materials including pipes, fittings or specials.
- Excavation, bedding, backfilling concrete works and reinstatement, and only if mentioned in the Bill of Quantities, “new inspection chamber construction.”.
- Connection to adjacent inspection chamber or to existing building discharge line and to the collection network using all necessary fittings and machining required to facilitate connection.
- Installation, testing and commissioning.

F. Rates for taps for hose connections shall include:

- Supply of all materials including pipes, fitting specials, and service box and cover.
- Supply of stopcocks and saddles on mainline. Excavation bedding and backfilling, concrete works and reinstatement.

- Installation and connection to new network and to the service box, or to the existing service connection, and testing.

10.02.04.5 Irrigation Specials

A. Irrigators (excluding drip emitter distribution tubing) shall be measured by the number of each type and size installed, completed and accepted.

B. Drip emitter distribution tubing shall be measured by the lin.m of each size installed, completed and accepted.

C. Spares for the irrigation system shall be a Prime Cost Item and shall be measured by the numbers of each type and class of spare part authorized by the Engineer, purchased by the Contractor, handed over, and accepted.

PAY ITEMS		**UNIT OF MEASUREMENT**
(1)	Valves (Stating type and size)	Number (Nr)
(2)	Air valves (Stating type and size)	Number (Nr)
(3)	Drain valves or pipe flush valves (Stating type and size)	Number (Nr)
(4)	Sluice gates and/or Penstocks (Stating size and type)	Number (Nr)
(5)	Fire hydrants (Stating size and type)	Number (Nr)
(6)	Water service connection per connection installed	Number (Nr)
(7)	Sewer service connection per connection installed	Number (Nr)
(8)	Taps for Hose Connection (Stating type and size)	Number (Nr)
(9)	Irrigation Program Controller	Item
(10)	Irrigators (Each type and size)	Number (Nr)
(11)	Drip Emitter Distribution Tubing (each size)	Linear meter
(12)	Spares for Irrigation System	Prime Cost (P.C.)

SECTION 10.03 NOT APPLICABLE

SECTION 10.04 MANHOLES, CHAMBERS AND GULLIES

10.04.01 GENERALLY

A. Excavation and Backfilling generally are to comply with the appropriate requirements of Division 2 of the Specification.

B. Concrete Work generally is to comply with the appropriate requirements of Division 5 of the Specification.

10.04.02 PRODUCTS

A. Coatings

A.1 Coal tar epoxy coating for internal surfaces of precast concrete manholes and chambers.

A.2 Asphaltic Composition Coating for external surfaces of precast concrete manholes and chambers.

B. Components

B.1 Precast Units: to BS 5911, Section C & D, reinforced concrete Class 250/20 respectively. Cement is to be ordinary Portland cement.

B.2 Cast In Situ Units: plain and reinforced concrete 210/25 and 250/20 respectively. Cement is to be ordinary Portland cement to BS 12.

B.3 Bricks: to BS 3921.

B.4 Covers and Frames: Ductile iron to BS EN 124, or equivalent coated, non-rock, locking, solid top. Frame to be bolted to manhole / gully bricks to ensure proper fixity. Wording on cover to be related to service. Grades to be as follows:

- For roadways: Grade A.. Heavy duty test load 40 tons.
- For sidewalks, carriage drive and cycle tracks: Grade B medium duty test load 25 tons.
- For footpaths and fields: Grade C light duty, test load 7 tons.

B.5 Manhole covers are of circular pattern unless otherwise indicated on Drawings.

Covers and frames shall be coated to BS 3416. Minimum thickness 200 microns.

B.6 Road Gully Gratings: Ductile iron to BS EN 124, non-rock; coated to BS 3416. Minimum thickness 200 microns; Types to be as follows:

- For carriageways: Grade A, minimum test load 40 tons.
- For footpath cycle tracks and fields, tight duty, test load 7 tons.

B.7 Step Irons: to BS 1247.

B.8 Steel Ladders: to BS 4211, mild steel, galvanized to BS 729 with 240 grams of zinc per square meter.

B.9 Safety Chains: 12mm diameter wrought iron short link chain, galvanized to BS 729 with 200 grams of zinc per square meter.

B.10 Guardrailing: to be: one of the following as shown on the Drawings:

a) Tubular steel: mild steel, medium grade to BS 1387 with screwed joints, galvanized to BS 729.

b) Solid steel: round bars to BS 4229, Part 2 with welded joints, galvanized to BS 729.

c) Aluminum: tubular rails fixed to double ball pattern solid forged standards. Rails of alloy to BS 1471, type HT 30 WP or to BS 1474, type HV 30 WP. Standards of alloy to BS 1472, type HF 30 WP.

B.11 Fixing Bolts: to BS 1494, Part 2. When used to fix galvanized material, washers are to be galvanized and fixing bolts and nuts cut to pre-plating limits and electroplated with zinc to BS 1706.

10.04.03 WORKMANSHIP

A. Manholes and Inspection Chambers

A.1 Construction: In situ concrete or precast concrete as shown on Drawings or as proposed by Contractor. In-situ units shall be to Division 5 concrete works.

A.2 Precast Units: cast in steel watertight forms at least 3 weeks before sections are used. Bed lowest unit on in situ concrete base and bed and haunch in cement mortar. Liberally coat joints of units with approved bituminous material of trowelling grade prior to fixing. Ensure joints are filled solid and neatly strike off surplus compound. Do not disturb work for 7 days thereafter. Alternatively seal joints with approved preformed jointing strip in accordance with manufacturer's instructions. Bed precast concrete cover slab on top unit in cement mortar.

A.3 Manholes are to be precast or cast in situ as shown on the Drawings. Channels in bottom of manhole are to be smooth, semi-circular and size equal to diameter of adjacent sewers. For straight through manholes, construct channels of half pipe sections. Make changes in direction of flow with smooth curves as large as manholes permit. Changes in size and grade of channels are to be gradual and even.

A.4 Benching: form in sulphate resisting concrete Class 110/25 to rise vertically from top of channels to a height not less than soffit of outlet pipe, then slope upwards 1 in 10 to walls. Within 3 hours, float with coat of sulphate resisting cement-sand mortar 1:2 and finish smooth with steel trowel.

A.5 External Coating: cover faces of manholes and chambers with three coats asphaltic composition applied by brush in accordance with manufacturer's instructions. Minimum thickness 600 microns.

A.6 Internal Coating: cover faces of manholes and chambers with four coats of coal tar epoxy paint, 70% epoxy and 30% coal tar. Applied by brush in accordance with manufacturer's instructions. Minimum thickness 1000 microns.

A.7 Step Irons: cast into precast units or grout into preformed mortises. Do not use step irons as lifting eyes. Devices for lifting and handling are to be provided on exterior faces.

A.8 Adjustment for Level: build top courses of brickwork or concrete rings after completion of surrounding levels. Adjust as necessary to give accurate and even final levels.

A.9 Covers and Gratings: bed frame solidly in mortar and fix firmly using fixing bolts. Set cover in position to prevent twisting. Position centrally over opening and level and square with surrounding finishes.

A.10 Testing of Manholes: plug manhole inlets and outlets, fill manhole with water and allow to stand for at least 24 hours or such longer period to allow for complete absorption. Re-top with water. Allowable leakage over 24 hours is not to exceed 1 % of total volume of manhole, otherwise make good and retest.

B. Valve Chambers

B.1 Construction: to be in situ concrete, precast concrete or blockwork as shown on the Drawings.

B.2 External Coating: cover faces of chambers with two coats asphaltic composition applied by brush in accordance with manufacturer's instructions. Minimum thickness 400 microns.

B.3 Covers: bed frame solidly in mortar and fix firmly using fixing bolts. Set cover in position to prevent twisting. Position centrally over opening and level and square with surrounding finishes.

C. Road Gullies / Curb Inlets

C.1 Construction: to be in situ concrete or precast to size and shapes indicated on the drawings and conforming to the construction requirements of manholes.

10.04.04 MEASUREMENT

A. Manholes, Gullies, Inlets and Chambers

A.1 Manholes shall be paid for per unit and according to the depth categories shown in the Bill of Quantities.

A.2 Gullies and catch basins/curb inlets shall be paid for per unit including the outlet pipe and the connection to the main network. An average length of 10 meters shall be included with the rate for every gully. Additional length required will be paid for separately.

A.3 Interceptors shall be paid for per linear meter. Payment includes excavation, backfilling, concrete works, grates, frames, connection to the main network and all other ancillary works to make a complete unit.

A.4 Drop inlet shall be paid per unit complete, including all necessary material and ancillary works to make a complete unit.

A.5 Valve chambers, if priced separately, should be paid per unit complete including all necessary connections to the adjacent pipes.

A.6 Access shafts shall be paid per unit complete including all materials and necessary connections to existing culverts.

A.7 Inspection chambers shall be paid per unit complete, including all necessary connections to adjacent networks or houses. An average length of 10 meters shall be included with the rate for every chamber. Additional length required will be paid for separately.

A.8 Rates for manholes, drop inlet, gullies, curb inlets, inspection chambers, interceptors, access shafts and valve chambers shall include for as applicable:

1) Excavating in any natural material including rock in accordance with the preambles for "Excavation and Earthwork", including soil support, as required dewatering, if any, backfilling and carting away.

2) Concrete, reinforcing steel, blinding, beds, surrounds, benching and suspended slab in accordance with the preambles for "Concrete Work".

3) Supplying and application of protective and epoxy coatings to internal surface of concrete.

4) Two flexible couplings from each side as given in the specification.

5) Granolithic rendering to benching.

6) Protective coating to exposed faces of concrete.

7) Concrete rings or brick "blockwork" corbelling as required to make up levels.

8) Supply and fixing of labeled covers as specified, grates and frames with all ancillary works and protective coating.

9) Testing structures for water tightness and any subsequent re-testing.

10) Ladders, rungs and puddle flanges built properly into walls.

11) All other ancillary items necessary for the proper completion of works.

B. Protective Coatings

B.1 No separate payment will be made for protective coating. The cost shall be included with the rate of the respective item requiring such work.

B.2 The item for protective coatings shall include for applying the necessary coatings to surfaces of metalwork as detailed in the Specification and shall include for:

1) Preparation of surface.

2) Supplying all necessary tools and equipment, adhesives, bonding agents, etc.

3) Work in any location.

4) Any area or width.

5) Rubbing down between coats.

6) Cutting in edges.

7) Making good to damaged areas.

8) Protection.

9) Testing when required by the engineer.

PAY ITEMS	**UNIT OF MEASUREMENT**
(1) Storm water or Sewer Manholes (Specify size and depth)	Number (Nr)
(2) Road Gully (Specify size and depth)	Number (Nr)
(3) Interceptors (Specify size and depth)	Linear meter (m)
(4) Access Shaft (Specify size and depth)	Number (Nr)

SECTION 10.05 MEASUREMENT

10.05.01 EARTHWORK

A. Rates for excavation for pipe trenches manholes, chambers and inlets shall include for:

i Eexcavating in any material encountered,

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

iii Excavation at any level and to any depth,

iv Excavating curved on plan,

v Allowance for working space,

vi Increase in bulk for excavating,

vii Excavating below water table and dewatering as necessary,

viii Keeping excavations free from water,

ix Levelling, ramming, trimming and grading bottoms and trimming sides and bottoms of excavation,

x Planking and strutting,

xi returning, filling and ramming selected excavated material around foundations, multiple handling of excavated material and excavation from borrows and transporting about the Site,

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

xiii Disposal of 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.

B. Rates for trench excavation for pipelines and associated structure shall include for:

i requirements (i) to (xiii) of item A, hereof, where applicable,

ii pipe bedding and initial backfilling,

iii Filling over-excavation,

iv consolidation of primary backfill (initial backfill) material using water or hand tamping,

v compaction of secondary backfill (main backfill) material,

vi Reinstatement of surfaces at wherever applicable.

C. Trench excavation for pressure pipes shall be paid for per meter cube. Trench width and depth as shown on Drawings.

D. Trench excavation for gravity networks shall be paid for per meter cube. Trench length shall be measured between outer surfaces of manholes. Trench width and depth shall be as shown on Drawings.

10.05.02 PIPELINES

A. Rates for pipes shall include for the following as applicable for pressure and/or gravity pipes.

i supply of pipes and couplings,

ii transportation and hauling about the Site, loading, unloading and lowering materials in the trench,

iii lubricating agent used for assembling the pipe sections,

iv cutting, machining, chamfering, etc. of standard depth pipes,

v assembling the pipes and couplings and connecting to fittings and valves, or manholes and culverts,

vi supply of fittings as specified,

vii appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes,

viii bolts, nuts, gaskets and others for flanged fittings,

ix concrete thrust blocks,concrete supports, including associated over excavation and anchors. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES,

x testing as per specification,

xi ancillary works and materials,

xii Flushing, cleaning, painting, lining and coating for gravity pipes,

xiii Flushing and disinfection as specified of water supply pipes.

B. Pipes shall be paid for per linear meter measured as a straight line between the centers of consecutive coupling section. The distance between the two centers of the couplings on both sides of any fitting or valve shall be included as pipe length. Pipes within manholes shall be included as pipe length. No allowances will be made for cut ends and waste.

10.05.03 VALVES AND ACCESSORIES

A. Rates for valves shall include for:

i supply of valves as specified,

ii lowering into the trench and installing,

iii over excavation for concrete supports and boxes,

iv concrete supports and thrust blocks. Concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES,

v appropriate fittings and/or couplings dismantling joint for connecting to adjacent pipe or fitting,

vi flanged and socket adaptors (2 Nr) for connecting to adjacent spigot ends,

vii valve box complete with cover, lock and key, and concrete surround, for directly burried valve.

viii valve chamber complete with cover lock and rungs as showm on Drawings for valves placed in chambers.

ix Bolts, nuts, gaskets operating key, or hand wheel and others.

x ancillary works and material required,

xi painting, lining and coating,

xii extension spindles plus square nuts to fit spindles.

B. Valves shall be paid for per unit installed.

10.05.04 CONNECTION OF PRESSURE PIPES TO EXISTING PIPELINE

A. Rates for connecting to the existing pipelines shall include but not limited to:

i Hand excavation to expose and locate existing pipe and diposal of unsuitable backfill material.

ii Shutdown and drainage of the existing pipeline.

iii All cutting, machining, equipement and tools, required to facilitate connection,

iv Pumping out the water from the excavation.

v All co-ordination required with utility owners and all cost associated with their requirements and procedures for maintaining uninterrupted service,

vi Supply and installation of tee sections, valves, bends, all adaptors, accessories fittings, and connecting pieces on the main line,

vii Field testing,

viii Pipe protection and supports, including concrete thrust block if required,

ix Construction of reinforced concrete service chamber including frame, cover, steps, bituminous coating.

x Backfilling and reinstatement of surface wherever required.

xi Any other required necessary items for the proper completion of works.

B. The rate shall be a lump sum value based on the number of all required connections, completed and accepted.

10.05.05 CONNECTION OF GRAVITY PIPE OR CULVERT TO EXISTING CONCRETE WALL OF MANHOLE OR CULVERT

This item shall consist of supplying, transporting, storing & installing all materials and equipment necessary for a waterproof connection between a pipe or culvert (whatever its diameter is) and an existing or proposed reinforced manhole or culvert (or other structures) concrete walls.

A. Rate for such connection shall include for :

a- Submission of materials & acessories original thecnical data sheets.
b- Compliance with tender drawings.
c- Application of relevant specification division & standards.
d- Compliance with the method of measurement indicated here below.
e- Submission of application details & revision thereto if any subject to Engineer's consent.
f- Preparation of all submittals, design details, execution drawings subject to Engineer's consent.
g- Resources (Equipement, Materials, tools, Manpower,etc…)
h- Reinforced concrete demolition.
i- Supply, transportation, storing, pouring of a non shrink expanding mortar with all necessary admixtures and its application around the pipe.
j- Supply, transportation storing and installing of sealing ring around the pipe.
k- Supply, transportation, storing and installing of a sealing mastic around the pipe.
l- Supply, transportation storing and installing a short piece of pipe or a coupling inside the concrete wall.
m- Supply, transportation storing and installing of a waterproof membrane when requested by the Engineer around the external side of the short piece of the pipe.
n- Sampling & testing of materials as required in specification or requested by Engineer.

B. The rate shall be a lump sum value based on the number of all required connections, completed and accepted.