



REPUBLIC OF LEBANON
COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

Roads Routine Maintenance
For Lot 18 - Zahle Caza

Tender Documents

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Technical Specifications

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TABLE OF CONTENTS

DIVISION 01:	GENERAL REQUIREMENTS
SECTION 1.01	DESCRIPTION OF WORKS AND SITE
SECTION 1.02	QUALITY STANDARDS AND CONTROL
SECTION 1.03	TEMPORARY WORKS AND SERVICES
DIVISION 02:	EARTHWORKS
SECTION 2.01	CLEARING
SECTION 2.02	CLEANING OF DRAINAGE PIPES USING JETTING
SECTION 2.03	REPAIR OF CONCRETE MANHOLES COVERS
SECTION 2.04	STRUCTURAL EXCAVATION AND BACKFILL
SECTION 2.05	EXCAVATION AND FILLING FOR PIPE TRENCHES
DIVISION 03:	SUB-BASE AND BASE COURSES
SECTION 3.01	GENERAL
SECTION 3.02	CONTROL OF MATERIALS FOR SUB-BASE AND BASE COURSES
SECTION 3.03	MAJOR EQUIPMENT USED FOR SUB-BASE AND BASE COURSES
SECTION 3.04	AGGREGATE SUB-BASE AND BASE COURSES
DIVISION 04:	BITUMINOUS CONSTRUCTION
SECTION 4.01	MATERIALS FOR BITUMINOUS CONSTRUCTION
SECTION 4.02	BITUMINOUS PRIME AND TACK COATS
SECTION 4.03	BITUMINOUS COURSES
SECTION 4.04	BITUMINOUS BASE COURSE
SECTION 4.05	BITUMINOUS WEARING COURSES
SECTION 4.06	BITUMINOUS SEAL COATS AND SURFACE DRESSINGS
SECTION 4.07	BITUMINOUS LEVELING COURSE
SECTION 4.08	PAVEMENT REPAIR WORKS, PATCHING, CRACK SEALING, TRENCH EXCAVATION AND REINSTATEMENT WORKS

DIVISION 05:	CONCRETE AND STRUCTURES
SECTION 5.01	CONCRETE MIXES AND TESTING
SECTION 5.02	CONCRETE HANDLING, PLACING AND CURING
SECTION 5.03	STEEL REINFORCEMENT
SECTION 5.04	FORMWORK AND FALSEWORK
SECTION 5.05	PLAIN AND REINFORCED CONCRETE STRUCTURES
SECTION 5.06	REINFORCED CONCRETE FOR THE REPAIR OF CULVERS AND DRAINAGE STRUCTURES
SECTION 5.07	PATCHING USING STRUCTURAL MORTAR FOR REPAIR
SECTION 5.08	REINFORCED CONCRETE FOR CHANNELS COVERS

DIVISION 06:	INCIDENTAL CONSTRUCTION
SECTION 6.01	CURBS, GUTTERS, SIDEWALKS AND PAVED MEDIANS
SECTION 6.02	ROAD SIGNING
SECTION 6.03	ROADWAY MARKING
SECTION 6.04	SPEED HUMPS AND RUMBLE STRIPS
SECTION 6.05	DELINEATORS, MARKER POSTS AND MONUMENTS
SECTION 6.06	STEEL GUARDRAIL AND CONCRETE SAFETY BARRIER
SECTION 6.07	GABION AND MORTARED MASONRY WALLS
SECTION 6.08	REPAIRING STONE MASONRY WALLS
SECTION 6.09	TEMPORARY SAFETY MEASURES

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DIVISION 1

GENERAL REQUIREMENTS

TABLE OF CONTENTS

SECTION 1.01	DESCRIPTION OF WORK AND SITE	1
1.01.01	THE WORKS	1
1.01.01.01	<i>Background</i>	1
1.01.01.02	<i>Scope of Works</i>	1
SECTION 1.02	QUALITY STANDARDS AND CONTROL.....	3
1.02.01	GENERALLY	3
1.02.01.01	<i>Good Practice</i>	3
1.02.01.02	<i>Setting Out And Record Drawings</i>	3
1.02.02	MATERIALS	3
1.02.02.01	<i>Product List Schedule</i>	3
1.02.02.02	<i>Standards</i>	3
1.02.02.03	<i>Single Sources</i>	3
1.02.02.04	<i>Checking Compliance of Products And Materials</i>	3
1.02.02.05	<i>Protection of Products And Materials</i>	4
1.02.02.06	<i>Materials Supplied By Employer</i>	4
1.02.02.07	<i>Local Material Sources</i>	4
1.02.02.08	<i>Removal From Site</i>	4
1.02.03	WORKMANSHIP	5
1.02.03.01	<i>Work</i>	5
1.02.03.02	<i>Manufacturer's Recommendations</i>	5
1.02.03.03	<i>Suitability Of Previous Work And Conditions</i>	5
1.02.03.04	<i>Defects In Existing Work</i>	5
1.02.03.05	<i>Rectification Of Defective Work</i>	5
1.02.03.06	<i>Warranties</i>	5
1.02.03.07	<i>Warranties Employer Recourse</i>	6
1.02.04	SAMPLES AND APPROVALS	6
1.02.05.01	<i>Samples</i>	6
1.02.05.02	<i>Source Tests</i>	6
1.02.05.03	<i>Approvals</i>	7
SECTION 1.03	TEMPORARY WORKS AND SERVICES	8
1.03.01	GENERALLY	8
1.03.01.01	<i>Locations</i>	8
1.03.01.02	<i>Standards And Details</i>	8
1.03.01.03	<i>Temporary Works</i>	8
1.03.01.04	<i>Traffic Control Plans (TCPs)</i>	8
1.03.02	TEMPORARY SITE FACILITIES	9
1.03.02.01	<i>Roads</i>	9
1.03.02.02	<i>Temporary Nameboard</i>	9
1.03.03	CONTRACTOR'S TEMPORARY OFFICES.....	9
1.03.03.01	<i>Contractor's Temporary Offices</i>	9
1.03.03.02	<i>Temporary Laboratory</i>	9
1.03.04	TEMPORARY SERVICES.....	9
1.03.04.01	<i>Water</i>	9
1.03.04.02	<i>Electricity</i>	9
1.03.04.03	<i>Power</i>	9
1.03.04.04	<i>Lighting</i>	9
1.03.04.05	<i>Permanent Electric Supply And Lighting Installation</i>	10
1.03.05	TEMPORARY FACILITIES FOR THE ENGINEER AND/OR EMPLOYER	10
1.03.05.01	<i>General</i>	10
1.03.05.02	<i>Representative's Site Offices</i>	10
1.03.05.03	<i>Telephones</i>	10
1.03.05.04	<i>Car Ports</i>	10
1.03.05.05	<i>Representative's Vehicles</i>	10
1.03.05.06	<i>Test Equipment</i>	11
1.03.05.07	<i>Inspection Facilities</i>	11

1.03.05.08	Digital Camera	11
1.03.05.09	Computer	11

SECTION 1.01 DESCRIPTION OF WORK AND SITE

1.01.01 The Works

1.01.01.01 Background

The Project aims to upgrade the transport connectivity in Lebanon by providing roads routine maintenance activities for a period of one year for the highway and primary roads located within Lot 18 (ZAHLE Caza).

1.01.01.02 Scope of Works

The purpose of the project consists of maintaining the existing level of service for the highway and primary roads and any reconstruction works are excluded from the scope of work.

The proposed maintenance works includes mainly the following:

1) Incidental repair works that includes mainly:

- 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 box culverts,
- Remove of damaged Galvanized Steel Guardrail and replace by new one.
- Concrete Repair Works: including repair of existing concrete channels, box culverts, safety barriers and retaining walls

2) Pavement Repair Works:

Periodic Pavement repairs should be performed as needed to preserve the structural integrity of the road. Roadway repair works can be grouped into the following categories.

Preventative measures are minor repairs which include joint and crack sealing, temporary and permanent patching, other miscellaneous paving, drainage improvements.

- Shallow patching works for limited area, includes removing the existing pavement (milling), generally between 4 to 5 cm, paving the area that was milled. Ideally no additional work is required (such as adjusting of manholes), since the existing grade is usually the same.
- Pavement overlay for limited area, consists of paving over the existing roadway to cover cracks, fill potholes and increase the strength of the

roadway. Various items should be reviewed prior to placing an overlay on a road.

- Milling & overlay for trench utilities where pavement settlement occurred and the structural integrity of the pavement is still in good condition.
- Deep patching works, for limited section, may be needed when the structural integrity of the road is compromised. Prior to reconstructing the roadway, an engineer should determine the extent of work required and the type of repairs needed.
- Removal and reinstatement of damaged trench

3) Maintenance and Upgrade of Traffic Safety & Control Devices

- The proposed works related to traffic safety includes mainly the construction of new concrete safety barrier along the critical locations.
- Roads Marking applications including road cat-eyes,
- Roads delineator installations
- Installation of Warning signs and speed calming measures

SECTION 1.02 **QUALITY STANDARDS AND CONTROL**

1.02.01 **Generally**

1.02.01.01 Good Practice

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

1.02.01.02 Setting Out And Record Drawings

A. Setting Out

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

1.02.02 **Materials**

1.02.02.01 Product List Schedule

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

1.02.02.02 Standards

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

1.02.02.03 Single Sources

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

1.02.02.04 Checking Compliance of Products And Materials

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

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

1.02.02.05 Protection of Products And Materials

The Contractor shall:

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

1.02.02.06 Materials Supplied By Employer

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

1.02.02.07 Local Material Sources

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

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

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

1.02.02.08 Removal From Site

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

1.02.03 Workmanship

1.02.03.01 Work

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

1.02.03.02 Manufacturer's Recommendations

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

1.02.03.03 Suitability Of Previous Work And Conditions

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

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

1.02.03.04 Defects In Existing Work

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

1.02.03.05 Rectification Of Defective Work

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

1.02.03.06 Warranties

The Contractor shall:

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

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

- c) Replacement cost : upon determination that the work covered by a warranty has failed, replace or rebuild the work to an acceptable condition complying with the requirements of the Contract Documents. The Contractor shall be responsible for the cost of replacing a rebuilding defective work regardless of whether the Employer has benefited from use of the Work through a portion of its anticipated useful service life.
- Submit written warranties for approval to the Engineer prior to date certified for completion or completion of parts as may be designated.
- At final completion, compile four copies of each required warranty and bind in loose leaf binders in a clear and logical manner.

1.02.03.07 Warranties Employer Recourse

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

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

1.02.04 Samples And Approvals

1.02.05.01 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.

1.02.05.02 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.

1.02.05.03 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 Traffic Control Plans (TCPs)

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

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

The temporary safety devices shall include but not limited to:

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

1.03.02 Temporary Site Facilities

1.03.02.01 Roads

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

1.03.02.02 Temporary Nameboard

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

1.03.03 Contractor's Temporary Offices

1.03.03.01 Contractor's Temporary Offices

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

1.03.03.02 Temporary Laboratory

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

1.03.04 Temporary Services

1.03.04.01 Water

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

1.03.04.02 Electricity

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

1.03.04.03 Power

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

1.03.04.04 Lighting

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

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

1.03.04.05 Permanent Electric Supply And Lighting Installation

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

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

1.03.05 Temporary Facilities For The Engineer And/Or Employer

1.03.05.01 General

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

1.03.05.02 Representative's Site Offices

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

1.03.05.03 Telephones

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

1.03.05.04 Car Ports

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

1.03.05.05 Representative's Vehicles

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

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

1.03.05.06 Test Equipment

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

1.03.05.07 Inspection Facilities

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

1.03.05.08 Digital Camera

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

1.03.05.09 Computer

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

DIVISION 2

EARTHWORKS

TABLE OF CONTENTS

SECTION 2.01	CLEARING.....	1
2.01.01	SCOPE.....	1
2.01.02	CONSTRUCTION	1
2.01.03	MEASUREMENT	2
SECTION 2.02	CLEANING OF DRAINAGE PIPES USING JETTING.	3
2.02.01	SCOPE.....	3
2.02.02	EQUIPMENT	3
2.02.03	WORKMANSHIP	3
2.02.04	MEASUREMENT	3
SECTION 2.03	REPAIR OF CONCRETE MANHOLES COVERS,	4
2.03.01	SCOPE.....	4
2.03.02	CONSTRCUTION	4
2.03.03	MEASUREMENT	4
SECTION 2.04	STRUCTURAL EXCAVATION AND BACKFILL	5
2.04.01	SCOPE.....	5
2.04.02	EXCAVATION	5
2.04.03	BACKFILLING	6
2.04.04	MEASUREMENT	8
SECTION 2.05	EXCAVATION AND FILLING FOR PIPE TRENCHES	9
2.05.01	EXCAVATION FOR PIPE TRENCHES	9
2.05.02	BACKFILLING FOR PIPE TRENCHES	10
2.05.03	MEASUREMENT	11

SECTION 2.01 CLEARING

2.01.01SCOPE

These Works shall consist of the removal and satisfactory disposal of all vegetation, surface debris and scattered stones and rocks within the limits of the right-of-way, easement areas and borrow pits.

2.01.02CONSTRUCTION

A.1 All surface objects, trees, stumps, roots, stones and rocks (up to 0.2m³ or 500 kg individual size or weight), and other protruding obstructions, not designated to be retained, shall be cleared from site. In case of trees of one meter or less girth should be removed entirely or as instructed by the Engineer.

A.2 Stump holes and other holes from which obstructions are removed within the right-of-way of construction, shall be backfilled with suitable material and compacted, and those holes which are outside the right-of-way shall be filled to the adjacent level.

A.3 Perishable material shall be burned under the constant care of competent watchmen at such times and in such a manner that any vegetation or other items designated to remain in the right-of-way, or other adjacent property, will not be jeopardized. Burning shall be carried out in accordance with applicable laws and ordinances.

A.4 Materials, stones, rocks, and debris, shall be removed from the right-of-way and disposed of at approved dumping areas off the Site, provided permission of the respective property owners has been obtained in writing to dump such materials on their land. Where designated on the drawings, the Contractor shall make all necessary arrangements with property owners for obtaining written permission to dispose of materials, at his own expense.

A.5 Temporarily divert as necessary ditches, field drains and other waterways encountered during excavations and reinstate on completion. If reinstatement is not possible obtain instructions.

A.6 Existing watercourses, must be cleared of all vegetable growth and soft deposits.

A.7 Existing hydraulic structures, pipes culverts, box culverts & manholes, must be cleared of all deposits.

2.01.03 MEASUREMENT

- Clearing of roadway shall be measured by Meter Square within the limits of works cleared and grubbed, completed and accepted. Measurements shall be of the horizontal projection of the cleared areas.
- Cleaning waterways, hydraulic structures, pipes culverts, box culverts & manhole shall be measured by Meter Cube of removed desposit soil.
- Cleaning of concrete channel shall be measured by Meter Cube of removed desposit soil.

PAY ITEMS

UNIT OF MEASUREMENT

(1) Clearing of roadway	(m ²)
(2) Cleaning waterways, hydraulic structures, pipes culverts, box culverts & manhole	(m ³)
(3) Cleaning of concrete channel	(m ³)

SECTION 2.02 CLEANING OF DRAINAGE PIPES USING JETTING.

2.02.01 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.

2.02.02 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

Hoses 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.

2.02.03 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.

2.02.04 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

(1) Cleaning pipes by water jetting

UNIT OF MEASUREMENT

Linear meter (lm)

SECTION 2.03 REPAIR OF CONCRETE MANHOLES COVERS,

2.03.01SCOPE

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.

2.03.02CONSTRCUTION

- 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.

2.03.03MEASUREMENT

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) Repairing of concrete manhole covers by reuse the existing cover with all necessary installation works. | (Nr). |
| (2) Replacing of damaged manhole concrete frame and cover Type A with new manhole cover (heavy duty) and manhole concrete frame Class 450/20 with SBR additive. | (Nr). |
| (3) Replacing of damaged manhole concrete frame and cover Type B located within Highway area with new manhole cover (heavy duty) and manhole concrete frame having cement based high strength fast hardening micro-concrete (max. aggregate size 10mm). | (Nr). |

SECTION 2.04 STRUCTURAL EXCAVATION AND BACKFILL

2.04.01SCOPE

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

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

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

2.04.02EXCAVATION

A. General

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

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

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

In areas where the excavation is adjacent to public roads and walkways, the Contractor shall erect all necessary barricades, barriers, enclosed walkways, and warning signs necessary to restrict the exposure of the public to the excavation.

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

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

In areas where the excavation is adjacent to public highways and walkways, no excavation shall be scheduled to be left in an exposed condition for more than 3 days unless otherwise approved.

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

B. Temporary Support System

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

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

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

C. Excavation for box culverts, ducts and miscellaneous structures

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

C.2 Foundation material supporting the bedding or structure shall be AASHTO M 145 Class A-1-a, A-1-b or A-2-4 compacted to 95% AASHTO T 180 maximum density. If the natural material does not meet the classification requirements, it shall be subexcavated to a depth of at least 200 mm and replaced with material meeting the specified requirements. Any rock or hard material within 200 mm of the bottom of the pipes shall be similarly subexcavated and replaced with material meeting the specified requirements.

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

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

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

2.04.03 BACKFILLING

A. General

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Backfilling for Box Culverts, and Miscellaneous Structures

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

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

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

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

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

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

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

B.8 Any existing highway pavement cut through, damaged or removed during excavation for pipe culvert installation shall be reinstated, after pipe installation and trench backfilling, using approved base and surfacing course materials at least equivalent to those in the original pavement. Materials and construction shall conform with the relevant requirements of Section 4.08 - "Pavement repair works, patching, crack sealing, trench excavation and reinstatement works".

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

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

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

2.04.04 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.

SECTION 2.05 EXCAVATION AND FILLING FOR PIPE TRENCHES

2.05.01 EXCAVATION FOR PIPE TRENCHES

A. Excavating

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

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

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

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

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

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

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

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

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

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

Formation for beds generally:

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

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

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

2.05.02 BACKFILLING FOR PIPE TRENCHES

A. Filling materials

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

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

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

B. Workmanship: Backfilling

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

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

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

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

C. Restoration of surfaces

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

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

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

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

C.5 Proceed with restoration of surfaces as soon after completion of other work as is practicable, but in no case more than 10 days after backfilling of trenches and other excavated areas and complete within a further 20 days.

2.05.03 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 3

SUB-BASE AND BASE COURSES

TABLE OF CONTENTS

SECTION 3.01	GENERAL	1
3.01.01	SCOPE	1
3.01.02	STANDARDS AND CODES	1
SECTION 3.02	CONTROL OF MATERIALS FOR SUB-BASE AND BASE COURSES	2
3.02.01	SOURCES OF MATERIALS	2
3.02.02	STORAGE AND HANDLING OF MATERIALS	2
3.02.03	INSPECTION, TESTING AND CONTROL OF MATERIALS	2
3.02.04	UNACCEPTABLE MATERIALS.....	3
3.02.05	TEST METHODS	3
3.02.06	WATER.....	3
SECTION 3.03	MAJOR EQUIPMENT USED FOR SUB-BASE AND BASE COURSES	4
3.03.01	GENERAL REQUIREMENTS	4
3.03.02	SPREADERS	4
3.03.03	TRAVEL MIXERS	4
3.03.04	CENTRAL MIXERS	4
3.03.05	ROLLERS.....	4
3.03.06	UNACCEPTABLE EQUIPMENT	5
SECTION 3.04	AGGREGATE SUB-BASE AND BASE COURSES	6
3.04.01	GENERAL REQUIREMENTS	6
3.04.02	MATERIALS REQUIREMENTS FOR AGGREGATE SUB-BASE AND BASE COURSES	6
3.04.03	CONSTRUCTION REQUIREMENTS FOR AGGREGATE SUB-BASE AND BASE COURSES	7
3.04.01	MEASUREMENT	10

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 equipped with an accurate depth control device to avoid the disturbance of previously accepted layers. After mixing, the material shall be deposited by the mixer in its final position so that prior to compaction no spotting, picking-up or otherwise shifting the material will be required. Mixers may be equipped with pressure spray bars which can supply a uniform distribution of metered water during the mixing process.

3.03.04 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 pneumatic-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.

Sieve Size: (square openings)	Design Range (weight percentages passing)		Job Mix Tolerances (weight percentages passing)	
	<u>Bases</u>	<u>Sub-bases</u>	<u>Bases</u>	<u>Sub-bases</u>
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 $\pm 2\%$ 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.

3.04.01 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

SECTION 4.01 MATERIALS FOR BITUMINOUS CONSTRUCTION.....	4
4.01.01 SCOPE	4
4.01.02 AGGREGATE MATERIALS GENERAL.....	4
4.01.03 AGGREGATES FOR BITUMINOUS PAVING MIXES	5
4.01.04 AGGREGATES FOR SEAL COATS	8
4.01.05 BITUMEN	10
4.01.06 BITUMEN PRODUCTS	12
SECTION 4.02 BITUMINOUS PRIME AND TACK COATS.....	24
4.02.01 SCOPE	24
4.02.02 MATERIALS	24
4.02.03 EQUIPMENT	24
4.02.04 CONSTRUCTION OF TRIAL SECTIONS	24
4.02.05 APPLICATION PROCEDURES	25
4.02.06 MEASUREMENT	27
SECTION 4.03 BITUMINOUS COURSES.....	28
4.03.01 SCOPE	28
4.03.02 MATERIALS	28
4.03.03 MIX DESIGN.....	28
4.03.04 JOB MIXES AND PROJECT MIXES.....	32
4.03.05 EQUIPMENT	34
4.03.06 CONSTRUCTION OF TRIAL SECTIONS	36
4.03.07 MIXING PROCEDURES	36
4.03.08 SURFACE PREPARATION.....	37
4.03.09 DELIVERY, SPREADING AND FINISHING	38
4.03.10 SAMPLING AND TESTING.....	43
4.03.11 SURFACE TOLERANCES	45
4.03.12 DETERMINATION OF LAYER COURSE THICKNESSES	46
4.03.13 MEASUREMENT	46
SECTION 4.04 BITUMINOUS BASE COURSE.....	47
4.04.01 SCOPE	47
4.04.02 MATERIALS	47
4.04.03 JOB MIX AND PROJECT MIX.....	47
4.04.04 EQUIPMENT.....	47
4.04.05 CONSTRUCTION OF TRIAL SECTIONS	47
4.04.06 MIXING PROCEDURES	47
4.04.07 SURFACE PREPARATION.....	48
4.04.08 DELIVERY, SPREADING AND FINISHING.....	48
4.04.09 SAMPLING AND TESTING.....	49
4.04.10 SURFACE TOLERANCES	49
4.04.11 DETERMINATION OF THICKNESS	49
4.04.12 MEASUREMENT	49
SECTION 4.05 BITUMINOUS WEARING COURSE	50
4.05.01 SCOPE.....	50
4.05.02 MATERIALS.....	50
4.05.03 Job Mix AND PROJECT MIX	50
4.05.04 EQUIPMENT.....	51
4.05.05 CONSTRUCTION OF TRIAL SECTIONS.....	52
4.05.06 MIXING PROCEDURES	52
4.05.07 SURFACE PREPARATION.....	52
4.05.08 DELIVERY, SPREADING AND FINISHING.....	52
4.05.09 SAMPLING AND TESTING.....	53

4.05.10	SURFACE TOLERANCES	53
4.05.11	DETERMINATION OF THICKNESS	53
4.05.12	MEASUREMENT	53
SECTION 4.06 BITUMINOUS SEAL COATS AND SURFACE DRESSINGS.....		54
4.06.01	SCOPE	54
4.06.02	MATERIALS	54
4.06.03	EQUIPMENT.....	55
4.06.04	CONSTRUCTION OF TRIAL SECTIONS	55
4.06.05	RATES OF APPLICATION	55
4.06.06	CONSTRUCTION	56
4.06.07	TOLERANCES AND RECORDS	59
SECTION 4.07 BITUMINOUS LEVELING COURSE		61
4.07.01	SCOPE	61
4.07.02	MATERIALS	61
4.07.03	JOB MIX AND PROJECT MIX.....	61
4.07.04	EQUIPMENT.....	61
4.07.05	CONSTRUCTION OF TRIAL SECTIONS.....	61
4.07.06	SURFACE PREPARATION.....	61
4.07.07	DELIVERY, SPREADING AND FINISHING.....	62
4.07.08	SAMPLING AND TESTING.....	62
4.07.09	SURFACE TOLERANCES	62
4.07.10	DETERMINATION OF THICKNESS	62
SECTION 4.08 PAVEMENT REPAIR WORKS, PATCHING, CRACK SEALING, TRENCH EXCAVATION AND REINSTATEMENT WORKS.....		63
4.08.01	SCOPE	63
4.08.02	MATERIALS	63
4.08.03	EQUIPMENT.....	64
4.08.04	GENERAL REQUIREMENTS.....	64
4.08.05	PREPARATION OF PAVEMENT	65
4.08.06	PLACING AND FINISHING REPAIR MATERIALS	65
4.08.07	MILLING PROCEDURES FOR ASPHALT OVERLAYS AND CONSTRUCTION OF PAVEMENT.....	67
4.08.08	PROCEDURES FOR ASPHALT OVERLAY OR RESURFACING.....	69
4.08.09	MAINTENANCE OF SURFACE RESTORATION.....	70
4.08.10	ADDITIONAL REQUIREMENTS FOR REPAIRS TO EXISTING PAVEMENT	70
4.08.11	ADDITIONAL REQUIREMENTS FOR ROAD OPENINGS	70
4.08.12	SAMPLING AND TESTING.....	71
4.08.13	SURFACE TOLERANCES	72
4.08.14	MEASUREMENT AND PAYMENT	72

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 Density (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 2489	Standard Practice for Estimating Degree of Particle Coating of Bituminous Aggregate Mixtures
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 4215	Standard Specifications for Cold-Mixed, Cold-Laid Bituminous Paving Mixtures
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

AASHTO

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- μ m (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.

4.01.03 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
Resistance to Stipping	ASTM D3625/3625M	95% minimum
Flakiness and Elongation (5:1 aspect ratio) OR Flakiness Index	ASTM D4791 BS EN933-3	10% maximum 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 SO₃) 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°C to +60°C.

D. Heating of Bitumen

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

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

D.3 Thermometers of approved types and adequate range (calibrated in 1°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:



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 ($G^*/\sin\phi$) 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 ($G^*/\sin\phi$) at 10 rad/s	AASHTO T315	Min 2.2 Pa.s
Pressurized Aging Vessel Residue (AASHTO R28)		
Dynamic Shear ($G^*\sin\phi$) at 10 rad/s	AASHTO 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 Butadiene 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 °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 °C
MC - 30	21 - 63
MC - 70	45 - 80
MC - 250	70 - 110
MC - 800	95 - 125
MC - 3000	110 – 145

F. Slow-Curing (SC) Cutback Bitumen

F.1 SC cutback bitumen shall conform to the requirements of ASTM D 2026 grades SC-70, SC-250, SC-800, and SC-3000 with properties as listed in Table 4.1.6.

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 °C
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

	<u>SC - 70</u>		<u>SC - 250</u>		<u>SC - 800</u>		<u>SC - 3000</u>	
	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°C, except for Grade RS-2 where the range shall be 50-75°C. The temperature range for pugmill mixing for medium and slow setting types shall be 15-65°C.

I. Cationic Emulsified Bitumen

I.1 Cationic emulsified bitumens shall, prior to dilution, conform to the requirements of AASHTO M 208 or M 316, for Types CSS-1 and as listed in Table 4.1.8.

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

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°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

<u>Type of Surface</u>	<u>Litres/ m²</u>
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°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 (MM)	SIZE	% PASSING		
		12.5mm NMAS	19.0mm NMAS	25.0mm NMAS
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	Gyratory compaction level and % theoretical maximum specific gravity, Gmm			Minimum voids in the mineral aggregate (VMA %)			Voids	Dust to Binder Ratio
ESALs				Nominal Maximum Aggregate Size				
Million	N _{initial}	N _{design}	N _{max}	25.0	19.0	12.5		
<0.3	6 ≤ 91.5%	50 ≤ 96.0%	75 ≤	12.0	13.0	14.0	70-80	0.8 – 1.6
0.3 to <3	7 ≤ 90.5%	75 ≤ 96.0%	115 ≤				65-78	
3 to <10	8 ≤ 89.0%	100 ≤ 96.0%	160 ≤				65-75	
10 to <30	8 ≤ 89.0%	100 ≤ 96.0%	160 ≤				65-75	
>30	9 ≤ 89.0%	125 ≤ 96.0%	205 ≤				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)		Uncompacted Void Content of Fine Aggregate (% min)		Sand Equivalent (% min)	Flat & Elongated (% max)
	Depth from Surface (mm)		Depth from Surface (mm)			
	≤ 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°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.

4.03.07 MIXING PROCEDURES

A. Each aggregate ingredient shall be heated and dried such that the temperature recorded in the hot fines bin after screening shall not exceed 170 °C. If any aggregates contain excess moisture that may cause foaming in the mixture or their temperature is in excess of 170 °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°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

<u>Penetration Grade of Bitumen</u>	<u>PG Grade of Bitumen</u>	<u>Viscosity (Centistokes)</u>	<u>Max. Temperature °C Immediately after discharge from Pugmill</u>
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:

$$\text{Mixing time (sec)} = \text{Pugmill dead capacity (kg)} \text{ divided by } \text{pugmill output (kg/sec)}$$

4.03.08 SURFACE PREPARATION

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

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

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

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

4.03.09 DELIVERY, SPREADING AND FINISHING

A. Delivery of Mix to Site

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

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

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

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

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

consistent failure to meet the temperature requirement the Engineer shall order paving operations to stop until suitable measures are taken by the Contractor to ensure that temperature requirements are met.

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

B. Setting Out and Reference Lines

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

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

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

C. Spreading and Finishing

C.1 Bituminous mixes shall only be laid when the air temperature is at least 5°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

<u>Asphalt Course Thickness</u>	<u>Minimum Surface Temperature °C</u>
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 be 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/m².

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

TABLE 4.3.4 RECOMMENDED SPEEDS OF ROLLERS (Km/Hr)

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

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

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

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

the width of the rear wheels. Alternate passes of the rollers shall be of slightly differing lengths.

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

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

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

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

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

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

4.03.10 SAMPLING AND TESTING

A. Sampling and testing shall conform to the relevant requirements of 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.

4.03.11 SURFACE TOLERANCES

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

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

C. When the finished surface is tested with a 3 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.

4.03.12 DETERMINATION OF LAYER COURSE THICKNESSES

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

4.03.13 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/mm² 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/m² 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/m².

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 $\pm 6\text{mm}$.

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 SBSB 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 °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/ m²

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 LEVELING 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 leveling 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 or 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.
- C.** Cold-mix bituminous pavements are composed of asphalt cement and liquefier (kerosene), liquid asphalt, emulsified asphalt or tar, and a well-graded mineral aggregate having a gradation conforming to the requirements of Section 4.03 - Bituminous Courses.
- C1.** The Bitumen shall be maintained at a proper temperature to allow for pumping and uniformly distribution throughout the mixture. The temperature of the bitumen should not exceed the values in the following table:

Bitumen	Temperature	
	°F	°C
Cutback asphalt	250	121
Emulsified asphalt	180	82
Road tar	225	107

Care should be taken for flashpoints of respective type of bitumen.

C2. The Job Mix Formula shall conform to the relevant procedure and requirements of Section 4.03 - Bituminous Courses. The proportions of the components shall be established by the Contractor so as to produce a satisfactory mixture recognized by achieving the best coating or percentage of coated particles as determined by Test Method D 2489.

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 values 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 outside 150 mm strips adjacent to the traffic edges and then rolling towards the center in the direction of traffic overlapping on successive trips at least one-half the width of the roller. Operate the roller at a speed that displacement of the material does not occur. Roll bituminous mixtures until roller marks are eliminated. 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. If cold-laid asphalt is used, allow the mixture an adequate amount of time for aeration and curing. Shape the mixture approximately to the specified lines and grades and loosen to its full depth and width. Begin compaction as soon after placing as the mixture bears the load without undue displacement.

H. 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.

I. No excavated areas shall remain open overnight.

J. Provide a finished surface with a uniform texture. If the surface becomes rough, corrugated, uneven in texture, or traffic-marked prior to completion, scarify, rework or replace such unsatisfactory portion as directed. If the course, when laid, becomes water-soaked, remove that portion immediately, and place the mix in a windrow, aerated, and then spread, shaped, and rolled as specified. If required, this will be at no additional expense.

K. Do not allow traffic on newly repaired sections prior to completion of compaction and curing period of at least 12 hours.

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 planing, 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 cracks 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 centerline 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 (<i>state depth</i>) 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)
(4.08.14.4) Cold ready mixed asphalt for permanent repair of potholes (5cm)	Square metre (m ²)

**** END OF SECTION ****

DIVISION 5

CONCRETE AND STRUCTURES

TABLE OF Content:

SECTION 5.01. CONCRETE MIXES AND TESTING	1
5.01.01 SCOPE.....	1
5.01.02 MATERIALS	1
5.01.03 DEFINITIONS	4
5.01.04 CONCRETE STRENGTH REQUIREMENTS	5
5.01.05 COMPOSITION OF CONCRETE.....	6
5.01.06 REQUIREMENTS FOR COMBINING MATERIALS	6
5.01.07 READY-MIXED AND CENTRALLY- MIXED CONCRETE.....	9
5.01.8 MEASUREMENT	11
SECTION 5.02: CONCRETE HANDLING, PLACING AND CURING.....	11
5.02.01 SCOPE.....	11
5.02.02 MATERIALS	11
5.02.03 PLACING.....	12
5.02.04 COMPACTION.....	12
5.02.05 CURING	13
5.02.06 HOT WEATHER CONCRETING	13
5.02.07 COLD WEATHER CONCRETING	14
5.02.08 NIGHT CONCRETING	14
5.02.09 MEASUREMENT	14
SECTION 5.03: STEEL REINFORCEMENT	15
5.03.01 SCOPE.....	15
5.03.02 MATERIALS	15
5.03.03 CONSTRUCTION	15
5.03.04 MEASUREMENT	17
SECTION 5.04: FORMWORK AND FALSEWORK	18
5.04.01 SCOPE.....	18
5.04.02 DEFINITIONS	18
5.04.03 MATERIALS	18
5.04.04 DESIGN	18
5.04.05 FINISHES.....	19
5.04.06 TOLERANCES	20
5.04.07 CONSTRUCTION REQUIREMENTS.....	20
5.04.08 REMOVAL OF FORMWORK AND FALSEWORK	20
5.04.09 MEASUREMENT	20
SECTION 5.05: PLAIN AND REINFORCED CONCRETE STRUCTURES	21
5.05.01 SCOPE.....	21
5.05.02 MATERIALS	21
5.05.03 CONSTRUCTION	21

5.05.04	MEASUREMENT	23
SECTION 5.06: REINFORCED CONCRETE FOR THE REPAIR OF WALLS, DRAINAGE STRUCTURES AND CONCRETE BARRIERS		24
5.06.01	SCOPE.....	24
5.06.02	MATERIALS	24
5.06.03	PLACING.....	24
5.06.04	MEASUREMENT	24
SECTION 5.07: PATCHING USING STRUCTURAL MORTAR FOR REPAIR.		25
5.07.01	SCOPE.....	25
5.07.02	MATERIALS	25
5.07.03	CONSTRUCTION	25
5.07.04	MEASUREMENT	25
SECTION 5.08: REINFORCED CONCRETE FOR CHANNELS COVERS.....		26
5.08.01	SCOPE.....	26
5.08.02	MATERIALS	26
5.08.03	PLACING.....	26
5.08.04	MEASUREMENT	26

SECTION 5.01. CONCRETE MIXES AND TESTING

5.01.01 SCOPE

The works covered in this Section consists 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

Cement shall be Portland cement, originating from manufacturers approved by the Engineer and shall comply with BS EN 197-1:2000 for Ordinary Portland Cement and with BS 4027:1996 for Sulphate Resisting Portland Cement. Only one type of cement shall be used in one member.

Certificates of compliance from an approved manufacturer shall be submitted prior of approval. Tests in accordance with ASTM standards shall be performed upon request from the Engineer. Storage shall not be permitted for more than six months.

B. Aggregates

Proposed aggregate sources shall be examined by the Engineer who shall check the name, location, grid reference, type of deposit, potential variability, methods of extraction, proper control during extraction, process, laboratory facilities, stock piling, potential variations in end-products, etc..

The Contractor shall provide proof of applicability including samples, tests, photographs of each of the proposed new sources upon the request of the Engineer. Each size of aggregate shall be stored separate from other sizes. Only one source of aggregates shall be used for one structure.

C. Testing Aggregates

Each production sample shall be tested for the proportion of natural (uncrushed) material (% by weight) passing a 75mm sieve, total acid soluble chloride content and total acid soluble sulphate content (% by weight), flakiness and elongation indices.

The following tests shall be performed upon the request of the Engineer:

- ASTM Soundness Test C88, using a sodium sulphate solution.
- Aggregate Impact Value by the Los Angeles test in accordance with ASTM C131-81 and ASTM C535-81.
- Specific Gravities and Water Absorption to BS EN 1097-3:1998 or BS 812-2:1995.
- Aggregate Abrasion Value to BS EN 1097-8:2000.
- 10% Fines Value to BS EN 1097-2:1998 or BS 812-111:1990.

The Initial Drying Shrinkage of all the proposed concrete mixes prepared and tested in an approved laboratory in accordance with BS EN 1367-4: 1988 shall not exceed 0.06 percent.

D. Fine Aggregates

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% of the fine aggregate shall pass the 9.5 mm sieve and 2% to 10% shall pass the 0.15 mm sieve. The fine aggregate shall not contain organic impurities and/or harmful materials including iron pyrites, coal, mica, shale or similar laminated materials, flat or elongated particles or any materials which may adversely affect the reinforcement or the strength, durability and texture of the concrete.

The Contractor shall wash the fine aggregates with fresh water to remove deleterious substances. Total sulphate content (as SO_3) 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. Sand equivalent shall not be less than 75% according to AASHTO T176.

E. Coarse Aggregates

Coarse concrete aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel or crushed stone free from coatings of clay or other deleterious substances. It shall not contain harmful materials which can attack the reinforcement or adversely affect the strength and durability of the concrete. Coarse aggregate shall be washed to remove acids, sulphates, chlorides, and other deleterious substances. Abrasion, in accordance with AASHTO T96 shall not be more than Max 40% loss. The grading of coarse aggregate shall comply with AASHTO M43.

F. Combined Aggregates

Combined aggregate comprises of a mixture of coarse and fine aggregates. They shall be used only in proportions agreed with the Engineer.

Materials passing the No. 200 (0.075 mm) sieve shall not exceed 3% by weight of the combined aggregate.

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 1/2"	63	88-95	100	-	-	-	-	-
2"	50	78-90	88-95	100	100	-	-	-
1 1/2"	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. Site Storage of Aggregates

Adequate stocks of tested and approved aggregates shall be maintained on site and stored in a manner acceptable by the Engineer using wind breakers and protected from moisture and weather.

H. Rejection of Aggregates

The Engineer shall reject any stockpiled material that has an excess build- up of fines or suffering from segregation and/or contamination regardless of the prior approval.

I. Washing and Processing Aggregate

The Contractor shall carry out on site supplementary processing or effective washing of coarse and fine aggregates as necessary to comply with all requirements of the Specification.

J. Water

In general, only potable water shall be used. Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt. 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 BS EN1008:2002. All sources of water, whether for mixing or curing of concrete or compaction of backfill around the concrete structures shall be approved by the Engineer. Water used concrete shall not contain chloride ions.

K. Admixtures

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.

The Contractor shall submit full manufacturer documentation to the Engineer for approval prior to any usage. This information shall include recommended quantities to be used, effects of adding this material and the detrimental effects in case of greater or less quantities being used, chemical ingredients and other information needed or required by the Engineer for approval. Trial mixes may be required.

L. High Workability Admixtures

L.1 Superplasticising agents shall be used when detailed on the Drawings or directed by the Engineer. The superplasticiser shall be stored and used strictly in accordance with the manufacturer's instructions and shall 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 shall 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 shall such a mix be used in the Works.

L.2 The Contractor's mixing and transporting plant shall include accurate metering equipment for the measurement of superplasticising agents so that additives 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 be inclusive for compliance with the Specification 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 prepared in accordance with AASHTO T23 and AASHTO T126 or standard cubes prepared with 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 first two hours after the addition of water to the mix.

E. Batch

The quantity of concrete mixed in one cycle of operations of a batch mixer, 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

Mixes for the classes of concrete (shown in Table 5.1.4) shall be designed by the Contractor. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted in the particular location required. Unless otherwise approved by the Engineer, the mix designs shall use continuously graded aggregates. All mix designs shall be submitted to the Engineer for approval.

The ultimate compressive strength of concrete shall be determined on test specimens obtained from test cylinders prepared and tested in accordance with AASHTO T23 and AASHTO T126. Six inch by twelve inch cylinders shall be used for all compression tests or cubes prepared and tested in accordance with BS 1881.

TABLE 5.1.4: CONCRETE CLASS AND DESIGN MIXES

Class of Concrete	Cylinder Works Strength at 28 days: Kg/cm ²	Equivalent Works Cube Strength @ 28 days: Kg/cm ²	Maximum Size of Aggregate: mm	Minimum Cement Content Kg/m ³
110/25 (Blinding)	110	140	25	220
170/60	170	210	60	275
200/20 (B20)	200	250	20	300
250/20 (B25)	250	310	20	350
310/20	310	385	20	375
360/20	360	450	20	400
450/20*	450	565	20	450

* Concrete Type 450/20 shall not have a Water/Cement ratio of more than 0.4

B. Cyclopean Concrete

Plums used in cyclopean concrete shall consist of non-reactive broken stone spalls or boulders ranging in size from 200mm to 300mm. 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 be evenly distributed in the concrete mix with a minimum cover of 100mm. The compressive strength the rock plums shall be at least 100 Kg/cm² to ASTM D2938. The concrete used in cyclopean concrete shall be Class B20

C. Compliance with Strength Requirements

Cylinders or cubes from concrete as mixed for the Work will be tested in accordance with AASHTO T22 or BS 1881, as appropriate, after both seven and twenty eight days. Test specimens shall be made and cured in accordance with AASHTO T23 or BS 1881. These specimens will be the basis for acceptance of the concrete in the structure.

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.

5.01.05 COMPOSITION OF CONCRETE

A. Mix Proportions

The Contractor shall consult with the Engineer on mix proportions at least two weeks (14) days prior to the commencement of concrete work. The actual mix proportions of cement, aggregates, and water shall be determined by the Contractor.

No class of concrete shall be placed until its job-mix proportions have been approved by the Engineer. The approval of the job-mix proportions by the Engineer or his assistance to the Contractor in establishing those proportions, does not relieve the Contractor of the responsibility of producing concrete which meets the specified requirements.

B. Design Limits

The following limits of the concrete mix shall be respected. The minimum cement content shall not be less than 325 kg/m³ of concrete. The maximum allowable water/cement ratio in grade 250/20 shall not exceed 0.46. Slump shall not be less than 150mm.

5.01.06 REQUIREMENTS FOR COMBINING MATERIALS

A. Measurement of Materials in Mix

A.1 Cement shall be measured in bulk or as packed by the manufacturer (in 50 kilogram sacks). Measurement shall be accurate to within (+/-) 3.0 %.

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 %.

A.3 Aggregates: The aggregates shall be measured by weight. The measurement shall be accurate to within (+/-) 2.0% for fine and coarse aggregates.

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 %.

B. Assembly and Handling of Materials

B.1 Assembly: Aggregates shall be delivered and stored 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 material of uniform moisture content to ensure continuous operation. The Contractor shall take measures to ensure that no foreign matter or materials capable of changing the desired proportions are included in the mix. If two or more sizes or types of coarse or fine aggregates are used on the same Project, only one size or type of each aggregate may be used on a 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 and to provide uniform conditions for proportioning plant control. The use of equipment or methods of handling aggregates which results in the degradation or segregation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles and all equipment used for handling aggregates shall be approved by the Engineer. Methods of stockpiling aggregates shall be approved by the Engineer. Segregation shall be prevented by making no layer higher than 1.5 metres and, if two 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 or weighing devices.

B.3 Segregation: Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when so 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 deposited.

B.5 Storage of Cement: Cement may be stored in securely locked dry places either in bulk (unpacked) or in bags.

- a) All cement bags shall be marked with the date of manufacture and 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 unless it has been retested in accordance with 5.01.02 A13.
- 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

Concrete shall be mixed in the quantities required for immediate use. Concrete shall not be used which has developed initial set. Re tempering concrete by adding water or by other means shall 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 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 shall be mixed at the site of the Works, in a central-mix plant, or in truck mixers. The mixer shall be of a type and capacity approved by the Engineer. 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 continuously added throughout mixing. Additives, if required and approved by the Engineer, shall be added according to the manufacturer's instructions. Retarders shall be added within one minute or 25% of the total mixing time whichever is the smaller.

C.4 The manufacturer's instructions shall be followed in respect of overloading the mixer and the selection of the rate of revolution of the mixers.

C.5 To avoid segregation in the fresh concrete, the free drop height on emptying the mixer shall be not greater than 1.5 metres.

C.6 After mixing, the concrete shall be homogeneous and comply with the provisions of these specifications. The Engineer shall, 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: The provisions for storing cement shall be approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous cement batches 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 be provided from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous aggregate batches 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 or 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 the following:

For concrete produced on site and transported by means other than transit mixers or agitated trucks.

- Thirty minutes when the air temperature is 25°C or higher.
- Forty minutes when the air temperature is 18°C or below.
- Interpolated time when the air temperature is 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: When supplying concrete from a central plant, the Contractor 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 regulated to provide for proper handling, placing and finishing of the concrete and the method of delivery and handling the concrete shall be organised to facilitate placing with a minimum of rehandling and avoidance of damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved by the Engineer. The Engineer shall 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 AND CENTRALLY- MIXED CONCRETE

A. General

A.1 Ready-Mixed Concrete and Centrally-Mixed Concrete shall consist of a mixture of cement, water and aggregate, without air entrainment or water-reducing admixture. Air-entrainment, water-reduction or other type of admixture shall only be used 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 shall only be used in construction of the Works with the Engineer's approval.

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:

- a) 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 (centrally-mixed concrete).
- b) Mixed completely in a truck mixer at the batching plant or while in transit (transit-mixed concrete).
- c) Mixed completely in a truck mixer at the point of use following the addition of mixing water (truck-mixed concrete).

A.5 Permission to use ready-mixed concrete from any previously approved plant shall be rescinded 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 of the type and number as outlined in the Contractor's Programme 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 watertight and equipped with gates permitting controlled discharge of concrete and 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 the pour and mixed at the speed and number of turns in accordance with the manufacturer's recommendations.

D.2 Where concrete is mixed at a central plant, on or off site, the concrete shall be supplied to the pouring area by agitator trucks or transit mixers which rotate at the speed specified by the manufacturers. Non-agitating trucks shall only be permitted if the central plant is on site.

D.3 The time of haul shall not exceed the maximum stated in sub-item D.5 of subsection 5.01.6 of the Specification.

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 the Specification.

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 Drivers 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 relevant information.

G.2 The Engineer shall send representatives to the central plant at any time to:

- 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 the Specification.

G.4 Concrete delivered in outdoor temperatures lower than 5 °C, or if the temperature is expected to drop below 5 °C during the curing period, shall arrive at the Works having a temperature of not less than 10 °C nor greater than 32 °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 be sufficient for the proper handling, placing and finishing of concrete. If the rate of delivery is not sufficient for a continuous concrete operation, the Engineer shall suspend all or parts of further concrete work until such time as the Contractor provides adequate additional delivery equipment which, in the opinion of the Engineer, provides a continuous concrete operation.

5.01.8 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 5.02: CONCRETE HANDLING, PLACING AND CURING

5.02.01 SCOPE

The work covered in this Section consists of the placing, compacting and curing of concrete for mass concrete, reinforced concrete and prestressed concrete structures.

5.02.02 MATERIALS

All concrete materials shall comply with Specification section 5.01: Concrete Mixes and Testing.

5.02.03 PLACING

A. General

Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval, specifying the characteristics of the concrete to be employed, the time at which placing is to start the methodology and the duration. The Engineer's approval at least 24 hours in advance of each placing is required.

- In order to allow satisfactory vibration, the concrete shall be placed in horizontal layers, no thicker than fifty centimetres.
- Before each successive placing, the surface of the in-place concrete shall be carefully roughened, cleaned, washed free of loose particles and dampened.
- Concrete shall be placed so that it shall be undisturbed once trowelled.
- Placing of the concrete or the pouring shall start during the cooler hours of the day and be suspended when the temperature rises above 33 OC, unless otherwise agreed with the Engineer.
- The free-drop height of concrete shall be not greater than 1.5m and the method of placing shall suit the conditions and prevent segregation.
- 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 external surface of all concrete shall be thoroughly worked during the placing using appropriate tools. The method of working shall force all coarse aggregate from the surface and bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets and honeycombing.

B. Pumping

The use of pumps shall be permitted only after they have been checked and approved by the Engineer. Only low pressure piston type pumps, working with a water/cement ratio of not more than sixty five hundredths (0.65), shall be permitted. The use of superplastizisers to facilitate pumping for low water/cement ratios shall be permitted, subject to Engineer's review and approval. Before approving the use of a pump, the Engineer shall verify that the Contractor has sufficiently resources in the concrete placing team and the necessary equipment for placing and vibrating the concrete.

5.02.04 COMPACTION

Compaction shall be done by vibration of the concrete which shall 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. Vibration shall be limited to prevent segregation.

Vibration shall be carried out by the internal method using a poker. The diameter of this poker shall not be less than 20mm nor more than 40mm.

Other types of vibration may be used only if approved by the Engineer.

5.02.05 CURING

A. Materials

Curing shall be done by using hessian or burlap, impermeable membrane or curing compound which shall conform to AASHTO M148 (ASTM-C309). Water shall satisfy the requirements of Section 5.01 of the Specification.

B. Method of Curing

The method of curing 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.

The method of curing can be ponding, sprinkling, wet hessian/burlap, waterproofing membrane or curing compound which shall be applied in two applications at a rate of not less than 1 litre/ 7.5 m² per application or as recommended by the manufacturer using a hand operated spray equipment which shall be capable of supplying a constant and uniform pressure to provide a uniform and adequate distribution of the curing membrane at the rates required.

C. Curing Time

The minimum curing time shall be 4 days for ordinary Portland cement or as directed by the Engineer for other types.

5.02.06 HOT WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Hot Weather is as defined in ACI 305R-77 (Revised 1982) Chapter 1.

B. General

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.

C. Control of Temperature

Aggregate stockpile shall be protected from direct sunlight by suitable covering. Water shall be stored in tanks away from sunlight. Water tanks liable to be exposed to sunlight shall be covered with suitable reflective paint such as white gloss. The temperature of the concrete at the time of placing shall not be permitted to exceed 33 °C.

D. Mixing and Placing

The Contractor shall take appropriate precautionary measures when handling and placing of concrete during periods of high temperatures. Concrete shall be covered with damp hessian during transportation. No additional water shall be added at the time of mixing without the approval of the

Engineer, to minimise the risk of additional shrinkage of the concrete. Water shall not be added during transportation or placing of the concrete.

Aggregates and cement shall be thoroughly pre-mixed before adding water.

Transit mixers, if used, shall be coated with a reflective paint and shall be kept out of direct sunlight while waiting to be discharged.

E. Concrete Protection

Before the concrete shutters are struck, the formwork and shuttering shall be cooled with a water spray.

The concrete and the falsework shall be protected against sunlight.

Concrete exposed to strong winds shall be protected with windbreaks.

5.02.07 COLD WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Cold Weather is as defined in ACI 306.1-87, Section 1, Part 1.2.

B. General

No concreting shall commence when the air temperature is 6°C and falling, unless authorised by the Engineer.

C. Mixing and Placing

Aggregates, water, forms, reinforcement etc. shall be free of snow, frost or ice. Pre-heating is allowed but the water and aggregate mix, before the introduction of cement, shall not exceed 38°C. The temperature of concrete at the time of discharge shall be between 10°C and 27°C and for three days after the pour not less than 5°C.

D. Protection

Concrete shall be protected against cold winds by suitable windbreaks until the concrete attains a strength of at least 65% of the characteristic strength.

5.02.08 NIGHT CONCRETING

Night concreting shall not be carried without prior approval from the Engineer. Lighting system shall be submitted in advance of the proposed concreting for the Engineer's approval utilising a stand-by generator at all times during concreting operation.

5.02.09 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 5.03: STEEL REINFORCEMENT

5.03.01 SCOPE

The work covered in this Section consists 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 Specification.

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 4449:2005.

A.2 Mild steel reinforcing bars shall conform to AASHTO M31 (ASTM A615) Grade 40 or BS 4449:2005.

A.3 High tensile, low-alloy steel deformed bar shall conform to ASTM A706.

B. Welded Fabric Reinforcement

Welded steel wire fabric shall conform to AASHTO M55 (ASTM A185) or BS 4482:2005.

C. Fabricated Mat Reinforcement

Fabricated mat reinforcement shall conform to AASHTO M54 (ASTM A184).

D. Certification and Identification

Mill Test Report shall be submitted to the Engineer for each lot of billet steel reinforcement supplied for use on the Contract. The Mill Test Report shall give the processes used in the manufacture of the steel from which the bars were rolled and the identification of the furnaces and/or each lot of steel from which the bars were rolled.

The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator. The tag shall show the manufacturer's test and lot number or other designation that will identify the material with the certificate issued for the lot of steel. Sampling and testing of reinforcement bars shall be inspected and sampled after arrival at the site.

5.03.03 CONSTRUCTION

A. General

Reinforcing steel shall be protected at all times from damage. All reinforcement shall be free from dirt, mill scale, scaly rust, paint, grease, oil or other foreign substances. There shall be no evidence of pitting or visual flaws in the test specimens or on the sheared ends of the bars. Rust shall be removed by wire brushing or by sand blasting.

B. Storage

Reinforcement shall be stored clear of the ground on platforms, skids or other supports and be protected against contamination by dirt, grease, oil etc. Reinforcement of different grades shall be stored separately. If directed by the Engineer, the Contractor shall provide cover to the reinforcement.

C. Cutting and Bending

Cutting and bending of reinforcement shall be based on bar bending schedules detailed on the Drawings and/or approved by the Engineer. Reinforcement shall be cut using specialist cutting machines or cold cut by hand only. Bars shall be bent to the diameters 4 times the diameter of bar as a minimum and hooked as detailed on the drawings. If bending of a bar causes the bar to crack, the bar shall be rejected.

D. Fixing

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.

5.03.04 MEASUREMENT

Measurement - Reinforcing steel bars incorporated in the concrete shall unless otherwise indicated, be measured in metric tonnes based on the total computed weight for the sizes and lengths of bars, as shown on the Drawings or authorized by the Engineer.

For computing the weight of reinforcing steel bars for payment, the theoretical weights shall be used.

No allowance will be made for clips, wire, separators, wire-chairs and other material used in fastening the reinforcing steel in place. If bars are substituted upon the Contractor's request and as a result more steel is used than specified, only the amount specified shall be included.

For long bars the measurement will allow one lap at 10 metre centres unless the position of the lap is shown differently on the Drawings. When laps are made for splices, other than those shown on the Drawings the extra steel shall not be included.

The accepted quantities of reinforcing steel bars, determined as provided above, shall be paid for at the rates included in the Bill of quantities, which rates shall be full compensation for all labour, materials, equipment and incidentals required for proper installation and completion of the work.

Where reinforcing steel bars to be incorporated in concrete work involving reinforced concrete for which all inclusive items are prescribed in the Bill of Quantities for such work, the reinforcing steel bars shall not be measured nor paid for separately.

PAY ITEM

UNIT OF MEASUREMENT

(1) High Tensile Steel Reinforcement

Ton.

SECTION 5.04: FORMWORK AND FALSEWORK

5.04.01 SCOPE

The work covered in this section consists of the design, supply and use of formwork and falsework for the construction of concrete structures.

5.04.02 DEFINITIONS

A. 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 or plastic sheet in direct contact with the concrete; and joists or stringers directly supporting the sheeting.

B. Falsework

Any temporary structure used to support a permanent structure while it is not self-supporting.

C. Scaffold

A temporary structure that provides access to and/or a working platform for labour, materials, plant and/or equipment.

D. Tower

A composite structure, usually tall, used principally to carry vertical loading.

5.04.03 MATERIALS

Formwork may be constructed of soft wood, hardwood, plywood, steel, plastics, aluminium and/or other material as approved by the Engineer.

5.04.04 DESIGN

Formwork and falsework shall be designed by the Contractor in accordance with B.S 5972 "Code of Practice for Falsework" and submitted to the Engineer with full design calculations, detailed drawings, material specifications and test certificates for approval. Falsework shall be capable of temperature changes without causing damage to the concrete.

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 is acceptable.

Notwithstanding any approval of falsework design by the Engineer, the Contractor shall not be relieved of his responsibility for the adequacy and correctness of the design, manufacture and assembly of the falsework.

A. Forms and Formwork

Formwork shall be sufficiently rigid so as to prevent any grout loss during concreting and shall not distort due to environmental effects and concreting operations in order that member dimensions, shape, required finish and texture are within the tolerances specified.

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. All exposed edges shall be bevelled by using dressed, mill cut, triangular moulding, having 20mm sides. Forms shall be maintained after erection to eliminate warping and shrinkage.

B. Falsework

Falsework and centring 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. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to the approval of the Engineer.

All timber shall be of sound wood, in good condition and free from defects that might impair its strength. 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 using a method approved by the Engineer.

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

Finishes of concrete works shall be done as shown on the drawings and as directed by the Engineer for each type and/or item of construction. Samples shall be furnished to the Engineer upon request. The finish is intended to be left as struck. Imperfections such as fins and surface discoloration shall be made good as and when required by the Engineer.

B. Unformed Finishes

The concrete shall be uniformly levelled and screeded to produce a plain or ridged surface as described in the Contract. After the concrete has hardened sufficiently, the concrete shall be floated by hand or machine sufficiently to produce a uniform surface free from screed marks.

5.04.06 TOLERANCES

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 the Specification.

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

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. The inside surfaces of all forms shall be cleaned and coated with a release agent approved by the Engineer. Forms that are to be re-used shall be thoroughly cleaned and re-oiled.

5.04.08 REMOVAL OF FORMWORK AND FALSEWORK

Formwork shall be removed without causing damage to the concrete and after sufficient time to allow for adequate curing.

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. The period before striking shall be a minimum of 4 days for soffits and 18hours for vertical members.

5.04.09 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 5.05: PLAIN AND REINFORCED CONCRETE STRUCTURES

5.05.01 SCOPE

This Section of the Specification describes the construction of plain and reinforced concrete structures.

5.05.02 MATERIALS

A. Concrete

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

B. Reinforcement

Reinforcement shall conform to Section 5.03: Steel Reinforcement.

5.05.03 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 formwork meets the Specification requirements
- The falsework and support props are in accordance with the approved Drawings.
- The reinforcement conforms to the Drawings and that the correct cover has 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 Handling, Placing and Curing.

C. Slump

Slump shall be within the limits given in Section 5.02 of the Specification unless otherwise agreed by the Engineer.

D. Construction and Expansion Joints

Whenever placing of concrete is delayed until after the previously placed concrete has undergone initial set, the point of the break in pouring shall be deemed a construction joint. The location of construction joints shall be either as shown on the Drawings or planned in advance and the placing of concrete shall be carried out continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and at points of minimum shear unless otherwise agreed with the Engineer. Dowels, reinforcing bars or other ties shall be done as directed by the Engineer.

E. Cold Joints

When the continuous placement of concrete in any structural member is interrupted or delayed 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 shall be made for the initial placement or the removal of concrete that is wasted because of a cold joint. The Engineer shall suspend all or any part of the subsequent concrete work until he deems the Contractor has corrected the cause for the cold joint occurrence.

F. Finishing

Unless otherwise indicated in the Drawings or agreed by the Engineer, the following classes of finishes, as defined in Paragraph 5.01.04, shall be used for formed surfaces:

G. Concrete Cover to Reinforcement

The concrete cover to reinforcement shall be as shown on the Drawings. If no cover is detailed the cover shall be either the size of the bar or the maximum aggregate size, plus 5 mm, whichever is the greater. The minimum cover to reinforcement under special 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, except cross-sections, shall be within the following tolerances:

<u>Length (mm)</u>	<u>Tolerance (mm)</u>
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 and piers shall be within the following tolerances:

<u>Member Dimensions (mm)</u>	<u>Tolerance (mm)</u>
Up to 500	6
501 -750	10
Additional for every subsequent 100 mm	±1 mm up to ±20 mm

H.2 Precast Construction

H.2.1 Length: The horizontal and vertical dimensions of precast members, except for cross-sections, shall be within the following tolerances:

<u>Length (mm)</u>	<u>Tolerance (mm)</u>
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 and piers, shall be within a tolerance of ± 3 mm.

H.3 Squareness

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

<u>Member Size (mm)</u>	<u>Tolerance (mm)</u>
Up to 3000	± 3
3000 and over	± 6

H.4 Straightness

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

<u>Member Length (mm)</u>	<u>Tolerances (mm)</u>
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 1.5 metre straight edge shall be not greater than 6 mm at any point.

H.7 Twist

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

<u>Member Length (mm)</u>	<u>Tolerance (mm)</u>
Up to 6000	6
Above 6000	12

5.05.04 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.

SECTION 5.06: REINFORCED CONCRETE FOR THE REPAIR OF WALLS, DRAINAGE STRUCTURES AND CONCRETE BARRIERS

5.06.01 SCOPE

This Section of the Specification describes the construction of reinforced concrete parts of a structure to be repaired such as walls, drainage structures and concrete barriers.

5.06.02 MATERIALS

A. Concrete

Concrete shall be type 250/20 concrete produced and supplied in accordance with Section 5.01: Concrete Mixes and Testing.

B. Steel Reinforcement

Steel reinforcement 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.

5.06.03 PLACING

A. General

Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval, specifying the characteristics of the concrete to be employed, the time at which placing is to start, the methodology and the duration for the Engineer's approval at least 24 hours in advance of each placing is required according to the general requirements of these specifications.

5.06.04 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 for reinforced concrete of both in-situ and precast construction of a general nature.

B. Measurement

Concrete for repair of box culverts, headwalls and wingwalls, concrete channels and retaining walls (all types and shapes) and concrete barriers shall be measured by the cubic metre in place and accepted by the Engineer, as otherwise directed by the Engineer. Unless otherwise stated, steel reinforcement is considered excluded in the price of concrete.

PAY ITEM

UNIT OF MEASUREMENT

(1) Concrete (250/20, *ordinary finish*) for Repair Works

Cubic Metre (m³)

SECTION 5.07: PATCHING USING STRUCTURAL MORTAR FOR REPAIR.

5.07.01 SCOPE

This Section of the Specification describes the construction of Dry pack Repair Mortar used for repairing existing reinforced concrete members in case of damages to be used in structures such as retaining walls, culverts, concrete barriers, manholes, drainage ditches, and any other concrete structure suitable for such repairs.

5.07.02 MATERIALS

A. Mortar

Mortar to be used shall be Dry pack Proprietary make according to ACI 546R-04 Concrete Repair Guide. 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.

5.07.03 CONSTRUCTION

Construction of the concrete repair with dry pack structural mortar shall be as shown on the drawings. The contractor shall submit a method statement for construction and submit it to the Engineer for approval at least 24 hours in advance of each placing according to the general requirements of these specifications.

5.07.04 MEASUREMENT

A. Scope

Structural Mortar for Patching shall be measured by the square metre in place and accepted by the Engineer, as otherwise directed by the Engineer. Steel reinforcement where needed is considered included in the price of patching.

PAY ITEM

UNIT OF MEASUREMENT

(1) Structural Mortar for Patching

(thickness not more than 10cm and concrete
compressive strength 40Mpa)
Square Metre (m²)

SECTION 5.08: REINFORCED CONCRETE FOR CHANNELS COVERS.

5.08.01 SCOPE

This Section of the Specification describes the construction of reinforced concrete covers of drainage channels weather cast in situ or precast.

5.08.02 MATERIALS

A. Concrete

Concrete shall be type 250/20 concrete produced and supplied in accordance with Section 5.01: Concrete Mixes and Testing.

B. Steel Reinforcement

Steel reinforcement 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.

5.08.03 PLACING

A. General

Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval, specifying the characteristics of the concrete to be employed, the time at which placing is to start, the methodology and the duration for the Engineer's approval at least 24 hours in advance of each placing is required according to the general requirements of these specifications.

5.08.04 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 for reinforced concrete of both in-situ and precast construction of a general nature.

B. Measurement

Concrete shall be measured by the linear metre in place and accepted by the Engineer, based on the dimensions shown on the Drawings or as otherwise directed by the Engineer. Unless otherwise stated, steel reinforcement is considered included in the price of concrete. No difference in price shall be made for different sizes of the channels except if the clear width of the channel is more than 0.8m. in that case the price of ordinary concrete will be applied.

PAY ITEM

UNIT OF MEASUREMENT

(1) Concrete cover of channels (250/20, *ordinary finish*)

Linear Meter (1m)

**** END OF SECTION ****

DIVISION 6

INCIDENTAL CONSTRUCTION

TABLE OF CONTENTS

SECTION 6.01	CURBS, GUTTERS, SIDEWALKS AND PAVED MEDIANS.....	1
6.01.01	SCOPE	1
6.01.02	MATERIALS AND PRECAST MANUFACTURE	1
6.01.03	CONSTRUCTION AND INSTALLATION	3
6.01.04	MEASUREMENT	9
SECTION 6.02	ROAD SIGNING	11
6.02.01	SCOPE	11
6.02.02	MATERIALS	11
6.02.03	CONSTRUCTION AND INSTALLATION	21
6.02.04	MEASUREMENT	28
SECTION 6.03	ROADWAY MARKING.....	29
6.03.01	SCOPE	29
6.03.02	MARKING COLORS	29
6.03.03	MATERIALS	30
6.03.04	APPLICATION AND INSTALLATION	39
6.03.05	SAMPLING AND TESTING	45
6.03.06	GUARANTEE BY CONTRACTOR	46
6.03.07	TYPES OF PAVEMENT MARKINGS	46
6.03.08	MEASUREMENT	48
SECTION 6.04	SPEED HUMPS AND RUMBLE STRIPS	50
6.04.01	SCOPE	50
6.04.02	MATERIALS	50
6.04.03	CONSTRUCTION AND INSTALLATION	51
6.04.04	MEASUREMENT	52
SECTION 6.05	DELINEATORS, MARKER POSTS AND MONUMENTS	54
6.05.01	SCOPE	54
6.05.02	MATERIALS	54
6.05.03	INSTALLATION.....	55
6.05.04	MEASUREMENT	56
SECTION 6.06	STEEL GUARDRAIL AND CONCRETE SAFETY BARRIER.....	57
6.06.01	SCOPE	57
6.06.02	MATERIALS	57
6.06.03	CONSTRUCTION AND INSTALLATION.....	60
6.06.04	TESTING	62
6.06.05	MEASUREMENT	63
SECTION 6.07	GABION AND MORTARED MASONRY WALLS	64
6.07.01	SCOPE	64
6.07.02	MATERIALS	64
6.07.03	MEASUREMENT	66
SECTION 6.08	REPAIRING STONE MASONRY WALLS.	67
6.08.01	SCOPE	67
6.08.02	MATERIALS	67
6.08.03	EQUIPMENT.....	67
6.08.04	WORKMANSHIP	67
6.08.05	MEASUREMENT	67
SECTION 6.09	TEMPORARY SAFETY MEASURES.	68
6.09.01	SCOPE	68
6.09.02	REFERENCES.....	68
6.09.03	EQUIPMENT.....	68

6.09.03.1 WARNING SIGNS.....	68
6.09.03.1.1 MEASUREMENT	68
6.09.03.2 PLASTIC BARRIER.....	69
6.09.03.2.1 MEASUREMENT	69
6.09.03.3 SOLAR FLASHING BEACON	70
6.09.03.3.1 SCOPE	70
6.09.03.3.2 MATERIALS	70
6.09.03.3.3 MEASUREMENT	70
6.09.03.4 FLASHING ARROW OR CHEVRON BOARDS.....	71
6.09.03.4.1 SCOPE	71
6.09.03.4.2 DESCRIPTION	71
6.09.03.4.3 OPERATION.....	71
6.09.03.4.4 MEASUREMENT	72

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 for 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 is 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 $15Ph/b^2$ 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 be 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 be 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 m² 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)

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/ cm² and a minimum yield strength of 2,000 kg/ cm².

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/cm².

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. Specification L-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	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20
151 to 280	32
281 to 500	50
501 to 1,200	80
1,201 to 3,200	125
3,201 to 10,000	
10,001 to 35,000	

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 $\alpha = 0.2^\circ$), otherwise Entrance - Angle β_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 D₆₅
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 $71^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

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 $-35^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

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 $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 50 RH \pm 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 of Retro-reflection:

The values of the minimum coefficient of retro-reflection, given in G.7a Table A, are described as the average of representative readings covering the entire surface of a retro-reflective traffic sign measured on cut-out test specimens. The coefficient of retro-reflection shall be measured in accordance with CIE Publication No. 54, retro-reflection, 1982, using CIE Standard Illuminant A.

d) Color:

The color of retro-reflective traffic signs shall conform to G.7b Table B, when measured as specified in CIE Publication No. 15.2, material is illuminated by CIE Standard Illuminant D65 at an angle of 45° with the normal to the surface, and the observation is made in the direction of the normal (CIE 45 / 0 geometry)

e) Adhesion to Substrate:

The traffic signs of cut-out specimens from the signs to be tested, shall be conditioned for at least 24 hrs at conditions described in Section a. With a tool (razor blade or 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 $35^{\circ}\text{C} \pm 2^{\circ}\text{C}$, 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 $71^{\circ}\text{C} \pm 3^{\circ}\text{C}$ 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 $-35^{\circ}\text{C} \pm 3^{\circ}\text{C}$ 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 tampers. 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

Stockpiled 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 m² 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 1m² 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 m².
- C. Rectangular signs intended for mounting on overhead support structures shall be measured by m² 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 m².
- 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 m ² 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 gradation.

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°C of 60, a Brookfield thermoseal viscosity of between 45 and 100 and a minimum flash point of 230 °C. The drying time at an ambient temperature of 32 °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 $102.5 \pm 9.5^{\circ}\text{C}$ after heating for 240 ± 5 min at $218 \pm 2^{\circ}\text{C}$ 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 °C 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/m ² /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/m²/lux
 - Yellow: 125 mcd/m²/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 °C Max. 82 °C	205 – 245 °C
Paint	Min. 10 °C Max. 82 °C	38 °C (heated to reduce drying time)
Preformed Thermoplastic	Min. 10 °C Max. 82 °C	Manufacturer Specific
Preformed Plastic Tapes	Varies with manufacturer and adhesive 15 °C	65 °C (Inlay method) 21 °C (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	Long Lines	1.5 mm
Extended Service Life	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 as per 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	<ul style="list-style-type: none"> - Lines are crisp and well defined on smooth surfaces - Easy to control line thickness and width. - Ensures maximum burn in bonding to 	<ul style="list-style-type: none"> - Slow application rate - Hard to maintain good line definition on rough surface

Application Method	Description	Advantages	Disadvantages
	Shall be applied using truck-mounted units.	<ul style="list-style-type: none"> - asphalt surfaces - Shielded from air and wind, thus preventing loss in temperature at the point of application 	
Ribbon Application	<p>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.</p> <p>Shall be applied using truck-mounted units or motorized ride-on equipment.</p>	<ul style="list-style-type: none"> - Lines are well defined on irregular surfaces - Moderate application rate - Better control of line thickness and width compared to spray application 	<ul style="list-style-type: none"> - 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	<p>Consists of the thermoplastic material passing through a spray gun under pressure.</p> <p>Shall be applied using truck-mounted units or motorized ride-on equipment.</p>	<ul style="list-style-type: none"> - Maximum adhesion to pavement surface - Fastest application rate - Provides good thermal and mechanical bond 	<ul style="list-style-type: none"> - 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°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

G.4 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 SPEED HUMPS AND RUMBLE STRIPS

6.04.01 SCOPE

These Works shall consist of furnishing materials and constructing speed humps, concrete rumble strips, ceramic marker rumble strips, TPR rumble strips and scored shoulder rumble strips, at the locations and as shown on the Drawings.

6.04.02 MATERIALS

A. Tack Coat

Liquid asphalt for tack coat shall be rapid curing type cutback grades RC-250 or RC-3000 as directed, and shall conform with the relevant requirements of Section 4.02 - "Bituminous Prime and Tack Coats".

B. Bituminous Mix

Bituminous mix for speed bumps shall conform with the relevant requirements of Section 4.05 - "Bituminous Binder and Wearing Courses", or an equivalent mix if approved.

C. Concrete

Unless otherwise shown on the drawings, portland cement concrete, for concrete rumble strips shall be Class 210/20 and shall conform with the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

D. Reinforcement

Steel mesh for concrete rumble strips shall be of the sizes shown on the Drawings and shall conform with the relevant requirements of Section 5.03 - "Steel Reinforcement and Fixing".

E. Ceramic Raised Pavement Markers

Ceramic raised pavement markers for rumble strips shall be of the size shown on the Drawings. Ceramic markers and the epoxy adhesives shall conform with the relevant requirements of Section 6.03 - "Roadway Markings".

F. Reflective Paint

White reflectorized paint (RP) used to distinguish the speed humps shall conform with the relevant requirements of Section 6.03 - "Roadway Markings".

6.04.03 CONSTRUCTION AND INSTALLATION

A. Speed humps

A.1 Prior to application of the tack coat, the bituminous surface shall be cleaned free of all dirt, dust, and other foreign substances which, in the opinion of the Engineer, would prevent proper bonding of the tack coat.

A.2 Immediately after the surface has been cleaned and approved by the Engineer, the tack coat shall be applied by pressure distributor, or by hand-spraying equipment which shall achieve a uniform mist type coverage without blotches or streaks. The rate of application shall be approximately 0.2 to 0.3 ltr/sq.m unless otherwise required by the Engineer.

A.3 When the tack coat has set and has been approved, the Contractor shall place the speed hump form in position. The hot bituminous mix shall be placed in the forms by approved hand methods and consolidated by approved hand methods and struck flush with the top of the form.

A.4 After the bituminous mix has been placed in the form and consolidated, the form shall be carefully lifted and removed and rolling operations shall be started. Rolling shall be performed with an approved type pneumatic roller traveling parallel to the roadway centerline initially and finally at right angles to the centerline until the speed hump is compacted to uniform cross section. The height of the speed humps above the pavement surface shall not exceed 100mm.

A.5 The finished surface of the speed hump shall be painted with white reflectorized paint in accordance with the relevant requirements of Section 6.03 - " Roadway Markings ."

B. Concrete Rumble Strips

B.1 Concrete rumble strips shall be installed after completion of the bituminous wearing course. Locations shall be staked as shown on the Drawings or as ordered by the Engineer. Saw cutting shall be performed to a minimum depth of 200 mm for a distance along the centerline of 1.8m. Underlying subgrade or base material shall be compacted to 100% AASHTO TI80 maximum density and moistened immediately prior to placing of concrete.

B.2 Concrete pavement shall be placed, vibrated and screeded in accordance with the relevant requirements of Section 5.05 - "Portland Cement Concrete Pavement". Machine placing and finishing will not be required. Portable screeds shall, however, extend the full 1.8 m width (parallel to the roadway centerline). The installation shall be checked with a full width straightedge before texturing.

B.3 Immediately after initial texturing, the rumble texture shall be achieved using a template which shall produce the size, shape and pattern of scalloped depressions shown on the Drawings. Depression molds may be vibrated or forced into the surface of the fresh concrete. The template shall form uniform depressions 20 mm to 30 mm deep, and 75 mm between peaks.

B.4 Molds shall be withdrawn on completion, without damaging the edges of the depression. The Contractor shall periodically check the top surface of the concrete with a straightedge and ensure the template is not displacing the concrete.

B.5 Concrete edges shall be properly finished and the concrete shall be cured in accordance with the relevant requirements of Section 5.02 - "Concrete Handling, Placing and Curing". If

curing compound is approved for use, additional care shall be taken that all vertical surfaces of depressions are adequately coated.

C. Ceramic Marker Rumble Strips

Raised ceramic pavement markers for rumble strips shall be installed in the appropriate geometric patterns as shown on the Drawings and in accordance with the relevant requirements of Section 6.03 - " Roadway Markings ."

D. Scored Shoulder Rumble Strips

D.1 Scored shoulder rumble strips shall consist of a series of depressions as shown on the Drawings, extending transversely across the paved shoulder, except for a 300 mm strip adjacent to the traveled way and a 300 mm strip at the outside edge. Each depression shall be the shape of a semi-circular cylinder of 25 mm diameter. Depressions shall be 10 mm to 15 mm deep and spaced 0.2 m or 0.25 m apart longitudinally.

D.2 Scored shoulder rumble strips shall be installed to the required dimensions using a specially constructed steel wheel roller, with ridges added to the roller drive drum of the length, spacing, and cross section appropriate to the required scoring.

D.3 Rolling of the depressions shall be performed in lieu of, or immediately following, breakdown rolling of the bituminous shoulder material. The Contractor shall select the weight and sequence of rollers to achieve the required depressions and the required density of finished pavement.

D.4 The Engineer may adjust the required minimum density of the bituminous course used for the shoulders so as to be compatible with construction of the scored shoulder rumble strips.

E. Thermoplastic Reflectorized Paint (TRP) For Rumble Strips

Construction of TPR rumble strips and shall be installed in the appropriate linear geometric patterns as shown on the drawing and in accordance with the requirements of Section 6.03 - " Roadway Markings ."

F. Raised Crosswalk

Crosswalks should be constructed interlocking paving (thick 10cm) at a height of 100 mm in order to maintain the same level of crossing from the footpath.

6.04.04 MEASUREMENT

- A.** Bituminous Speed humps, Raised crosswalk, Concrete Rumble Strips, and Scored Shoulder Rumble Strips shall be measured by the sq.m of each type constructed, completed, and accepted.
- B.** TPR Rumble Strips shall be measured by linear meter installed, completed, and accepted.
- C.** Unless shown as Pay Items in the Bills of Quantities, all other Works prescribed in this Section 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 ITEM

UNIT OF MEASUREMENT

- (1) Bituminous Speed humps
- (2) Raised crosswalk
- (3) TPR Rumble Strips

Square Meter (m²)
Square Meter (m²)
Linear meter

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 hardware

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, terminal unit, and all complementary works (i.e. stone clading, galvanized steel tubes, etc,) completed all as specified and as shown on drawings.
- C.** Impact Attenuators shall be measured by the unit of each type furnished, constructed or installed, completed, and accepted.
- D.** Excavation, backfilling, concrete footings, anchors, lifting device, dowel bars and other ancillary items, shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for Pay Items.

PAY ITEMS

UNIT OF MEASUREMENT

- | | | |
|-----|--|-------------------|
| (1) | Steel Guardrail (specify type) | Linear meter (lm) |
| (2) | Safety Concrete Barrier (specify type) | Linear meter (lm) |
| (3) | Impact Attenuators (specify type) | Nr |

SECTION 6.07 GABION AND MORTARED MASONRY WALLS

6.07.01 SCOPE

- A.** These Works shall consist of the furnishing of all materials and the construction of gabion, mortared masonry walls and mortared concrete block masonry, as and where shown on the Drawings.

6.07.02 MATERIALS

A. Stones

A.1 Stones for masonry walls shall consist of field stones furnished in broad flat shapes to the maximum extent practicable. All stone shall be hard, sound, durable, highly resistant to weathering and shall be suitable as protection material for the intended purpose.

A.2 Samples of the stone material proposed for use in the Works shall be submitted to the Engineer for approval prior to its use in the Work.

A.3 The minimum apparent specific gravity shall be 2.5 and the maximum absorption shall be 6% when tested in accordance with AASHTO T 85. The stone shall have an abrasion loss not greater than 45% when tested in accordance with AASHTO T 96.

A.4 Stones for gabion walls shall be angular, neither elongated nor flat. Dimensions shall range from 250 mm to approximately 125 mm diameters. Not more than 5% shall be smaller than 100 mm.

A.5 The weight of stones for Gabion walls shall be as follows:

% of Total Weight Smaller than Size Shown	WEIGHT OF STONE (KILOGRAMS)
95-100	50
50-100	20
0-50	5
0-10	1

B. Mortar

B.1 Mortar for mortared masonry walls shall consist of 1:3-4 cement: sand mortar by volume with a compressive strength at 28 days of 5 Mpa. Water added shall be the least amount which will yield a mix of suitable consistency to ensure proper mortaring of masonry. Sand and cement shall conform with the relevant requirements of Section 5.01 - "Concrete and Concrete Mixes and Testing".

B.2 Mortar for masonry walls shall be composed of 300 kg of cement to one cubic meter of sand and shall be thoroughly mixed prior to the addition of water.

C. Gabions

C.1 Gabions shall consist of approved type galvanized steel wire mesh baskets (or other approved types such as heavy duty plastic mesh) filled with selected riprap before installation.

C.2 Galvanized steel wire mesh shall conform to ASTM A 390 Class 3, or equivalent and with the requirements shown on the Drawings. The wire mesh shall be twisted to form hexagonal or rectangular openings of uniform size. The maximum nominal opening size shall be 100 mm. Mesh shall be constructed so as to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section is cut.

C.3 Baskets shall be furnished in one or more sizes which can be assembled to provide the minimum dimensions, stability, and structural integrity of the installation specified. Sizes of gabion baskets will normally be 2 m long by 1 m wide by 1 m high. Non-standard sizes shall be provided to suit the particular installation, as shown on the Drawings.

C.4 Baskets shall be fabricated in such a manner that the sides, ends, lid, and diaphragms can be assembled on Site into rectangular baskets of the specified sizes. Gabion baskets shall be of single unit construction. Long gabions assembled with diaphragms between adjacent baskets, for use as foundation mattresses, etc., may not require lids.

C.5 Base, lid, ends and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in such a manner that strength and flexibility at the point of connection is at least equal to that of the mesh.

C.6 All perimeter edges of the mesh forming the basket shall be securely clip bound or selvaged so that the joints formed by tying the selvages have at least the same strength as the body of the mesh.

C.7 Perimeter (edge), tie, and connection wires shall conform to ASTM A 641, Class 3, Medium Temper, and the minimum diameters shown on the Drawings.

D. Concrete Blocks

D.1 Concrete Blocks: unless otherwise specified, are to be to BS 6073 Part 1, ASTM C90 nominal size 400 x 200 mm and to the thicknesses shown on the Drawings. Minimum average net-area compressive strength shall be 10N/mm² (10 MPa).

D.2 Concrete masonry units shall be manufactured from ordinary Portland cement to BS 12 and natural aggregates to BS 882. Concrete facing blocks are to have true undamaged surfaces and clean and sharp arises.

D.3 Web thickness for units less than 100mm thick shall be not less than 20mm.

D.4 Web thickness for units 150mm thick shall be not less than 25mm.

D.5 Web thickness for units 200mm thick and over shall be not less than 35mm.

D.6 For units in walls supporting stone cladding, web thickness shall be less than 40mm.

6.07.03 MEASUREMENT

- A.** Gabion, walls and mortared masonry walls shall be measured by Cubic Meter including dismantling and dumping damaged material, surface levelling, furnishing, installing, all completed and accepted. Dimensions shall be as shown on the Drawings.
- B.** Concrete block walls shall be measured by sq.m., stating the thickness, furnished, completed and accepted.
- C.** Stone cladding shall be measured by sq.m. furnished, installed, completed and accepted.
- D.** Excavation, backfilling, furnishing, transporting, storing, surface preparation, cyclopean concrete, wire fabric weepholes, baskets, riprap, ties and other ancillary items shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for Pay Items.
- E.** Permeable Drainage Layer behind retaining walls (permeable backing shall 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) Gabion Walls	Cubic Meter (m ³)
(2) Mortared Masonry Walls	Square Meter (m ²)
(3) Stone Cladding	Square Meter (m ²)
(4) Concrete Block Walls (specify thickness)	Square Meter (m ²)

SECTION 6.08 **REPAIRING STONE MASONRY WALLS.**

6.08.01 SCOPE

These Works shall consist of the repairing of stone masonry walls, mortared, grouted and/or loose and return them to their original status in strength and shape.

6.08.02 MATERIALS

The materials used to repair stone masonry walls are stone masonry blocks, gabions and mortar as specified in section 6.07.

6.08.03 EQUIPMENT

The equipment used to repair stone masonry walls shall be simple hand tools consisting of hammers, chisels, trowels, wood wedges, wood hammers, timber for bracing if needed and any other tools necessary for the good workmanship.

Grouting using mortar and/or other grouts may be used in specific locations if approved by the Engineer and only if grouting will not alter the original face shape of the wall.

6.08.04 WORKMANSHIP

The procedure to be used for stone masonry walls repair is shown on the drawings which shall be followed by the mason who shall have enough experience in such works to follow the procedure and add his own experience for the good finishing of the final wall face. The wall face shall be as close as possible to the original wall face in size of stones, shape of the stones and pointing to the satisfaction of the Engineer.

6.08.05 MEASUREMENT

This item shall be measured per area in square meters. The area of each repair location shall be measured to the nearest one square meter and paid accordingly. Any point of area less than one square meter shall be paid as one square meter.

PAY ITEMS

UNIT OF MEASUREMENT

(1) Repair of Stone masonry walls.

Square meter (m²)

SECTION 6.09 **TEMPORARY SAFETY MEASURES.**

6.09.01 SCOPE

These Works shall consist of temporary measures taken during the construction works to protect public from any damages due to the construction works. These works include but limited to providing signs, barriers, warning lights, etc..

6.09.02 REFERENCES

All materials, color code, locations, etc.. shall be in accordance with the drawings and Lebanese standards (Libnor). In case of any contradiction, Libnor will be the final and only reference while the drawings are only for guidance.

6.09.03 EQUIPMENT

The equipment used in this section are as listed below but not necessary limited to the following:

6.09.03.1 Warning Signs

Warning signs and mandatory signs of any type shall be furnished with all relevant fixation. Ismanteled and relocated for each temporary job ans as directed.

6.09.03.1.1 Measurement

Warning signs and mandatory signs of any type shall be measured by the number of signs intalled and accepted by the Engineer.

PAY ITEMS

UNIT OF MEASUREMENT

(1) Warning sign type KD or KA Type B.	Number
(2) Warning sign Type KC of size more than 1 sq.m and less than 2 sq.m.	Number

6.09.03.2 Plastic Barrier

Plastic water-filled Barrier must be linked together in an approved manner in accordance with the manufacturer's guidance to form a continuous delineation boundary. The plastic barrier shall be used in accordance with the related Traffic Control Plan and subject to the Engineer's approval.

6.09.03.2.1 Measurement

PAY ITEMS	UNIT OF MEASUREMENT
(1) Plastic Barrier 145cm long and 40cm wide installed and accepted on site.	Number

6.09.03.3 Solar Flashing Beacon

6.09.03.3.1 Scope

The work covered in this section consists of purchasing and installing solar flashlight as shown on the Drawings or as directed by the Engineer.

6.09.03.3.2 Materials

- A. Shell material: Polycarbonate(PC) engineering plastic, metal covering
- B. Light-emitting area size: Ø300 mm
- C. LED No.: 95 pcs Yellow Led /pc
- D. LED wavelength: 590±5 nm for yellow
- E. Led luminance: >8000 mcd Power:>10w
- F. LED lifespan: ≥10,0000 hours
- G. Working mode: 24 hours continuous working or light-sensor control
- H. Flashing frequency:45 times/minute
- I. Visibility: ≥1000 m
- J. Battery type: 12V /7AH Lead-acid battery
- K. Solar panel type:18V/8W, mono-crystalline silicon solar cell, lifespan more than 25 years.
- L. Working temperature: -20~ 70°C
- M. Working hours: can working continuously more than 120 hours(exceed 5days) in cloudy and rainy days.
- N. Wind load resistance: ≥1.5KN/m2

6.09.03.3.3 Measurement

The Solar Flashlight shall be measured by the number of flash lights installed, functioning and accepted by the Engineer as per the details Drawings and the material specifications.

PAY ITEMS

UNIT OF MEASUREMENT

(1) Solar Flash Light Ø 300 mm installed and accepted on site.

Number

6.09.03.4 Flashing Arrow or Chevron Boards

6.09.03.4.1 Scope

The work covered in this section consists of purchasing and installing Flashing Arrow Boards (FAB) as shown on the Drawings or as directed by the Engineer.

6.09.03.4.2 Description

Flashing Arrow Boards (FAB) displaying arrow or chevron ‘Route Deviation’ symbols shall be located within the Transition Area to supplement ‘Keep Left’ or ‘Keep Right’ signs, or Route Deviation chevron boards, particularly on high-speed roads. FABs shall be mounted also on trucks or trailers for both stationary and moving operations shadow vehicles. Arrow boards should have a solid rectangular appearance.

FABs shall meet minimum requirements for size, legibility distance, number of elements, and other factors as per the following:

Minimum Size (arrow length x arrow-head width)	Minimum Visibility Distance	Minimum Number of Elements	Application (regular posted speed limit)
244 cm x 120 cm	1,000 m	15	Short or Long duration work ≥ 70 km/h

Vehicle-mounted arrow boards should have remote controls and elements capable of at least 50% dimming from full brilliance. Full brilliance should be used for day-time operations, and a dimmed mode should be used for night-time operations.

A FAB is mounted on a vehicle, trailer, or other suitable support.

The minimum mounting height measured vertically from the bottom of the board to the roadway should be 2.0 m. Vehicle-mounted arrow boards are mounted at a height of at least 1.0 m.

A FAB should always be used in combination with appropriate signs, channelizing devices, and/or other temporary traffic control devices.

6.09.03.4.3 Operation

For flashing and sequencing arrow boards, the minimum element “on time” shall be 50% for the flashing mode, with equal intervals of 25% for each sequential phase. The flash rate should be between 25 and 40 flashes per minute.

Sequencing arrow panels have several arrowheads that flash in a series, directing traffic to the right or left.

An arrow board in arrow or chevron mode can be used only for stationary or moving lane closures on multilane roadways.

6.09.03.4.4 Measurement

The Flashing Arrow Boards shall be measured by the number of boards installed, functioning and accepted by the Engineer as per the details Drawings and specifications.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Flashing Arrow or Chevron Boards installed and accepted on site.	Number

**** END OF SECTION ****