Republic of Lebanon

JBEIL Union of Municipalities

PROJECT

QARTABA CONCRETE WATER CHANNELS

إنشاء اقنية لتصريف مياه الامطار في بلدة قرطبا – قضاء جبيل

Volume 3
Technical Specifications

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EARTHWORKS

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SECTION 2.01 CLEARING AND GRUBBING

2.01.01 SCOPE

A. 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 (except items designated to remain or which are to be removed at a later stage of the Works).

B. Removal of structures and similar obstructions and removal of utilities shall be as specified in Section 2.02 -"Removal of Obstructions and Utilities".

2.01.02 CONSTRUCTION

The Contractor shall set out the approved construction limits and the Engineer will designate all trees, shrubs, plants, vegetation, etc. and other items to remain within the Right-of-way. The Contractor shall carefully preserve all such items from damage or defacement.

All surface objects, trees, stumps, roots, stones and rocks (up to $0.2m^3$ or 500 kg individual size or weight), and other protruding obstructions, not designated to be retained, shall be cleared or grubbed to ground level. In case of trees of one meter or less girth should be removed entirely or at least one meter below ground level or as instructed by the Engineer.

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 in accordance with Section 2.06 "Embankment Construction", and those holes which are outside the right-of-way shall be filled to the adjacent level.

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.

Materials, stones, rocks, and debris which cannot be burned and perishable materials, 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.

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

Existing watercourses, which have been diverted and are to be filled must be cleared of all vegetable growth and soft deposits before filling.

Protection of Existing Trees and Vegetation: Protect existing trees and other vegetation indicated to remain in place by Engineer against unnecessary cutting, breaking or skinning of roots, skinning or bruising of bark, smothering of trees by stockpiling construction materials or excavated materials within drip line, excess foot or vehicular traffic, or parking of vehicles within drip line. Provide temporary guards to protect trees and vegetation to be left standing.

Water trees and other vegetation to remain within limits of contract work as required to maintain their health during course of construction operations.

Provide protection for roots over 4 cm in diameter that are cut during construction operations. Coat cut faces with an emulsified asphalt or other acceptable coating formulated to use on damaged plant tissues. Temporarily cover exposed roots with wet burlap to prevent roots from drying out, cover with earth as soon as possible.

2.01.03 MEASUREMENT

Unless shown as Pay Item in the Bill of Quantities, the 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.

If shown as Pay Item in Bill of Quantities, Clearing and Grubbing of areas within the limits of work shall includes but not limited to removal of all vegetation, large rocks and boulders, surface debris and scattered stones and any abandoned material etc., and disposal of the resulting materials to approved dumping areas, as directed by the Engineer.

Clearing and Grubbing shall be measured by Meter Square of areas within the limits of works cleared and grubbed, completed and accepted. Measurements shall be of the horizontal projection of the cleared areas.

SECTION 2.02 REMOVAL OF OBSTRUCTIONS AND UTILITIES

2.02.01 SCOPE

The Works shall consist of the removal, wholly or in part, and satisfactory disposal of all buildings, fences, structures, abandoned pipelines, and any other obstructions, as shown on the Drawings, which are not designated or permitted to remain, except for any obstructions as shown on the Drawings which are to be removed and disposed of at a later stage of the Works. It shall also include the salvaging of designated materials and backfilling the resulting trenches, holes and pits.

The Works shall also consist of the realignment of existing functional utilities, fences, etc.

The Contractor shall examine the Site and record all obstructions and utilities at the commencement of the Works, as specified in part I section 1-2-3 “Existing Utilities and Obstacles”.

Any information or data, whether expressed or implied obtained by the contractor with respect to the existence or locations of above or belowground obstructions or utilities, shall not be construed nor deemed to construe any passing of responsibility to the Employer or the Engineer for the correctness, accuracy, validity or use of any such information and data. The contractor shall be solely responsible for his own assessment, interpretation and evaluation thereof and have made due allowance in his Tender as to risks, contingencies and all other circumstances which my influence or affect the undertaking of the works. This information shall be obtained without prejudice to the contractor’s obligation to inspect the site and have satisfied himself prior to submitting his Tender.

2.02.02 CONSTRUCTION

General

The Contractor shall raze, remove and dispose of all buildings, foundations, structures, fences and other obstructions, any portions of which are on the right-of-way, except utilities and items for which other arrangements for removal have been made. All designated salvageable material shall be removed, without causing unnecessary damage, and in sections or pieces which may be readily transported, and shall be suitably stored by the Contractor at approved locations, for later reuse or possession of others.

Unusable perishable material shall be destroyed. Non-perishable material may be disposed of off the Site, provided permission of the respective property owners has been obtained in writing to dump such materials on their land.

Basements or cavities left by structure removed within the Row of construction shall be backfilled with suitable material to the level of the surrounding ground and, shall be compacted to the type of compaction within the range for the adjacent roadway embankment as specified in Section 2.06 - "Embankment Construction".

Salvaged pipe culverts and other re-usable structures shall be stored at accessible approved locations on Site and shall become the property of the Employer.

Location of existing utilities shall be investigated and established by the Contractor in consultation with the relevant Authorities.

Any utility which is damaged in the course of the work shall be replaced with equivalent materials by the Contractor without additional payment.

Any action by the Contractor, with respect to power cables, telephone cables and water mains encountered during the course of the work, shall comply with the requirements of the responsible Authority, without additional payment

Removal of Bridges, Culverts and Ditches

Bridges, culverts and other drainage structures in locations traversed by traffic shall not be removed until approved arrangements have been made by the Contractor to maintain the flow of traffic.

Substructures shall be removed down to the elevations of the natural stream bed. Those parts outside the stream shall be removed 300 mm below natural ground surface. Where such portions of existing structures lie wholly or in part within the limits for a new structure, they shall be removed to the extent necessary to accommodate construction of the proposed structure.

Steel bridges and timber bridges, designated to be salvaged, shall be dismantled without causing unnecessary damage. Steel members shall be match marked, unless this requirement is waived by the Engineer. All salvaged material shall be stored as previously specified for reuse or possession of others.

Blasting or other operations necessary for removal of existing structures or other obstructions, and which may damage new construction in the vicinity, shall be completed prior to commencing the new construction. Necessary safety measures shall be taken by the Contractor during all blasting operations to ensure that no injury to be done to persons or properties or to the finished work. Blasting or other operations shall be performed at the entire risk and responsibility of the Contractor.

Where necessary or directed, the Contractor shall provide heavy mesh blasting mats for protection of persons, properties and the Works. If, in the opinion of the authorities and the Engineer, blasting would be dangerous to persons or adjacent structures, or is being carried out in an unsafe or unacceptable manner, the Engineer may prohibit blasting and order to carry out the demolishing works by other methods.

Removal of Pipes

All pipes unless otherwise directed shall be removed and precautions taken to avoid breaking or damaging the pipes. The Contractor shall exercise utmost care during the removal of pipes so as to avoid unnecessary damage.

Removal of Rocks and Boulders

Large rocks and boulders of individual size greater than 0.2 m^3 or greater than 500 kg in individual size or weight which lie within the limits of the Works shall be removed and disposed of as directed.

Removal of Fences and Gates

When fences and gates enclosing pasture land or farm land are to be removed, the Contractor shall notify the Engineer sufficiently in advance to permit the property owner reasonable time to construct alternative fencing or make other suitable arrangements.

Removal of Wells

Existing wells, abandoned or active, which lie within the limits of the Works, as shown on the Drawings, shall be dismantled, backfilled, and compacted. All salvageable materials shall be removed and stored at approved locations on Site. All salvageable material shall become the property of the Employer. Wells shall be filled to the level of the surrounding ground and if within the prism of construction, shall be compacted after obtaining the Engineer's permission to the type of compaction within the range designated.

Removal of Utilities

The Contractor through the Engineer shall notify all Utility Owners and co-operate with them in respect of removing, rerouting, relocating, or diverting utilities.

The Contractor shall carry out the removal of all disconnected or abandoned Utilities within the right-of-way, unless the Utility Owner indicates his intention to carry out such removal and the salvaging of materials, fittings, parts, etc.

The Contractor shall coordinate with the Engineer and shall advise each affected Utility Owner in writing of his proposed construction schedule and liaise with the Employer who will arrange for inspection by the Utility Owners and interruption or disconnection of the Utilities as appropriate.

The Contractor shall be responsible for supporting and protecting realigned Utilities, and existing Utilities that are to remain in place/ for the duration of the Contract and shall provide all necessary Temporary Works in this respect. Any damage caused to Utilities and attributable to the Contractor shall be repaired at his expense, including any fees to be paid to Authorities relating to service interruptions.

The relocation of water pipes shall not be carried out until the Contractor gets written approval from the Water Authority. The Contractor shall provide on his own expense all bonds and guarantees required by the Water Authority before relocation.

The Works related to the relocation of electric cables, posts, electric pylons, telephone cables and posts, etc. shall be carried out as specified and to the Engineer’s satisfaction and according to the Utility Owners' requirements. The Contractor shall contact the Utility Owners and prepare the necessary plans for the relocation of these utilities. Relocation works shall be carried under the supervision of the Utility Owners and completed works shall be subject to their acceptance.

The contractor shall carry out the removal of all advertising signs and billboards located in the ROW, unless the Utility Owners indicate their intention to carry out such removal. The removed signs and billboards shall be transported and stored at the Owner's premises as directed by the Engineer.

Where necessary for the construction of the Permanent Works, or when instructed by the Engineer, the Contractor shall remove all roadside furniture including traffic signs, vehicular

safety barriers, posts and foundations etc.

All excavation and backfill shall conform with the requirements of Section 2.06 - "Embankment Construction" and Section 2.09 - "Structural Excavation and Backfill " as appropriate.

Removal of Existing Bituminous and Cement Concrete Pavement

Unless otherwise specified in the Specifications, the Contractor, at his option, may remove, pulverize, crush, blend and process existing bituminous and cement concrete pavement (including sidewalks, curbs, gutters and stairs) which are specified to be removed, and use such materials in the new construction, or dispose of the materials as specified in Contract Documents. All such salvaged pavement, proposed for use in new construction, shall be processed to conform to all specified gradation and quality requirements for the material to be placed in the new construction.

Unless bituminous surface courses are specifically designated for milling or recycling, full-depth removal and disposal of all bituminous surface courses irrespective of thickness, including treated base courses and bituminous plant mix materials, shall be as specified herein.

Removal of Existing Railway Tracks

The Contractor shall liaise with the Railway Authority in connection with removal of railway lines within the ROW. Dismantling of railway tracks and railway structures should be carried out with precaution in a manner approved by the Railway Authority. The Contractor shall comply with all regulations and requirements of the Railway Authorities in executing work over or adjacent to their property.

The railway tracks are designated to be salvaged. All salvaged materials shall be inventoried, transported and delivered to the Railway Authorities stores.

Demolition of Existing Structures

These works shall consist of the demolition or partial demolition of existing structures adjacent to or within the works as indicated on the drawings or as directed by the Engineer, including building foundations and supporting works to a uniform depth of 300 mm below the lowest foundation level.

Submittals

Submit proposed schedule of coordination for shut-off capping and continuation of utility services as required.

Schedule: Submit proposed schedule of coordination for shutoff, capping, and continuation of utility services as required.

Provide a detailed sequence of demolition and removal work to ensure uninterrupted progress of Employer's on-site operations.

Job Conditions

Occupancy: Structures to be demolished will be vacated and discontinued in use prior to start of work.

Condition of Structures: Employer assumes no responsibility for actual condition of structures to be demolished. Conditions existing at time of inspection for bidding purpose will be maintained by Employer insofar as practicable. However, variations within structure may occur by Employer's removal and salvage operations prior to start of demolition work.

Salvaged Materials: items of salvable value to Contractor may be removed from structure as work Progresses. Salvaged items must be transported from site, as they are removed, to an approved storage yard as directed by the Engineer. Storage or sale of removed items on site will not be permitted.

Explosives: Use of explosives will not be permitted.

Traffic: Conduct demolition operations and removal of debris to ensure minimum interference with roads, streets, walks, and other adjacent occupied or used facilities

Do not close or obstruct streets, walks or other occupied or used facilities without permission from authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by governing regulations.

Protections: Ensure safe passage of persons around area of demolition. Conduct operations 10 prevent injury to adjacent buildings, structures, other failures, and persons.

Erect temporary covered passageways as required by authorities having jurisdiction.
Provide interior and exterior shoring, bracing, or support to prevent movement, settlement or collapse of structures to be demolished and adjacent facilities to remain.

Damages: Promptly repair damages caused to adjacent facilities by demolition operation at no cost to Employer.

Utility Services: Maintain existing utilities indicated to remain, keep in service, and protect against damage during demolition operations.

Do not interrupt existing utilities serving occupied or used facilities, except when authorized in writing by authorities having Jurisdiction. Provide temporary services during interruptions to existing utilities, as acceptable to governing authorities.

Employer will shut-off utilities serving structures. Disconnecting and scaling indicated utilities before starting demolition operations is part of this work.

Utility Services: Refer to related sections for disconnecting, removal, and capping of utility services. Do not start demolition work until utility disconnection have been completed and verified in writing.

Execution

Demolition

Pollution Controls: Use water sprinkling, temporary enclosures, and other suitable methods to limit dust and dirt rising and scattering in air to lowest practical level. Comply with governing regulations pertaining to environmental protection.

Do not use water when it may create hazardous or objectionable conditions such as ice, flooding, and pollution.
Clean adjacent structures and improvements of dust, dirt, and debris caused by demolition operations, as directed by Engineer and governing authorities. Return adjacent areas to condition existing prior to start of work.

Building Demolition: Demolish buildings completely and remove from site. Use such methods as required to complete work within limitations of governing regulations.

- Small structures may be removed intact when acceptable to Engineer and approved by authorities having jurisdiction.
- Proceed with demolition in systematic manner, from top of structure to ground. Complete demolition work above each floor or tier before disturbing supporting members on lower levels.
- Demolish concrete and masonry in small sections.
- Remove structural training members and lower 10 ground by hoists, derricks, or other suitable methods
- Break up and remove concrete slabs-on-grade, unless otherwise shown to remain.
- Locate demolition equipment throughout structure and remove materials so as to not impose excessive loads to supporting walls, floors or framing.

Below-Grade Construction:

Demolish foundation walls to a depth of not less than 300 mm below existing ground surface or as shown in drawings. Demolish and remove below-grade wood, metal construction, and floor construction except concrete slabs on grade.

Demolish and remove below-grade construction and concrete slabs on grade.

Filling Basements and Voids: Completely fill below-grade areas and voids resulting from demolition of structures by an approved material.

Use plain concrete or approved soil materials consisting of stone, gravel, and sand, free from debris, trash, frozen materials, roots and other organic matter.

Prior to placement of fill materials, ensure that areas to be filled are free of standing water, frost, frozen material, trash and debris.

Place fill materials, if not concrete, in horizontal layers not exceeding 15 mm, in loose depth. Compact each layer at optimum moisture content of fill material to a density equal to original

adjacent ground, unless subsequent excavation for new work is required.

After fill placement and compaction, grade surface to meet adjacent contours and to provide flow to surface drainage structures.

Salvaged Materials

Remove carefully to avoid damages. Materials for reuse on this project (if any) may be incorporated into new work as directed by the Engineer.

All salvaged materials shall remain the property of the Owner (usually the local municipality) and shall be stockpiled, as specified by the Engineer, at the location designated by the Owner. Therefore, before removal of any salvaged over ground material, or abandoned underground utility which are considered as Owner's properties, the Contractor has to inform the Engineer on site and shall further, at his own expenses, remove, protect from any damage, and transport these materials to an approved storage yard as directed by the Engineer. Storage or Sale of removed items from site will not be permitted.

During excavation, if any archeological material has been encountered, the contractor has immediately to inform the Engineer and stop excavating. The Engineer shall directly inform the related concerned authority and the excavation work will not be continued until the Contractor obtain a written permission from the Engineer on site.

Disposal of Demolished Materials

General: Remove from site debris, rubbish, and other materials resulting from demolition operations.

Burning of removed materials from demolished structures will not be permitted on site.

Removal: Transport materials removed from demolished structure shall be disposed of off site and as directed.

2.02.03 MEASUREMENT

Removal and disposal of large rocks and boulders which exceed 0.2 m^3 or 500 kg individual size or weight shall be measured by cubic meter of "Unclassified Road Excavation" as prescribed in Section 2.03 - "Road Excavation".

Demolition of existing structure/s shall be deemed to include:

Disposal of materials other than those remaining the property of the Employer or those for reuse.
Setting outside, clearing storing and protecting materials remaining the property of the Employer or those for reuse.
Temporary support incidental to the demolition winch is at the discretion of the Contractor.
Leaving parts of existing walls temporarily in position to act as buttresses.
Temporarily directing, maintaining or scaling of existing services.
Making good structures not demolished.

All excavation and backfill shall conform with the requirements of Section 2.06 "Embankment Construction" and Section 2.09 - "Structural Excavation and Backfill", as appropriate.

Temporary realignment or support of existing utilities shall not be measured for direct payment but shall be considered as subsidiary work the cost of which is deemed to be included in the contract prices for Pay Items.

Demolition and removal of existing buildings shall be measured by square meter of build-up surface area irrespective of the floor heights, floor numbers and including ground floor slab. The prices inserted in the BOQ shall include the demolition and disposal of all kinds of materials in the existing building including any foundations, walls, or retaining structures, disconnecting and sealing of sewer outlets and all services to the Buildings, temporary protection, shoring and all other safety measures, excavation works, compaction and backfilling with suitable approved materials to the previous or required natural ground level.

Removal of roadways and existing bituminous and cement concrete with pavement with all related coarse layers, shall be measured by cu.m of “Unclassified Excavation” as prescribed in Section 2.03 “ Road Excavation”.

Replacement of existing fences shall be measured in linear meter of property fences affected by construction activities. The new fences shall be located outside the limit of the right-of-way and shall be of the same type and height as those existing.

Careful removal of existing manhole covers and frames, storage of existing covers and frames for reuse, adjusting the level of the existing manhole neck, and reinstallation of the manhole covers and frames shall be enumerated in the Bill Of Quantities. The rate shall include saw cutting of the existing asphalt layer, where applicable, excavating around the manhole (or the like) to the ceiling level, demolishing of the access shaft, removing, cleaning, painting and reinstalling the existing manhole cover and frame (or the like) 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. It shall also include the additional concrete ring 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 elsewhere. The rate shall also include all manpower, equipment materials and accessories necessary to complete the work including the placement and compaction of the base course as specified in the drawings, in accordance with the specifications and as directed by the Engineer. Adjustment of manholes covers levels item shall be measured by the number of manholes lowered or raised to the required levels, as specified and accepted.

Cleaning of existing box culverts, waterways within the limits of ROW, open concrete side drains and covered concrete side drains shall be measured in cubic meters of deposited material, cleaned, loaded and carry away from site as directed by the Engineer.

The dismantling and removal of existing bridges shall be measured by number for each type separately including all construction elements.

Payment shall be at the rate inserted in the Bill of Quantities, which rates shall be deemed to include the survey of all existing bridge structures along the proposed route of the roads; the preparation and submission of the detailed method statement for the demolition or partial demolition of bridges, all as detailed in this section of specification; all materials, labour, equipment necessary to execute such works; the removal of all surplus demolished materials to an approved dumping site to any hauling distance; temporary protection, shoring and all other safety measures and necessary works for the proper completion of demolition.

Removal of railway tracks shall be paid by linear meter of tracks (twin), measured along the centerline of the tracks, for the works specified.

Removal of fences, any kind of walls, reinforced concrete structures other than buildings and bridges, relocation or removal of trees, removal of abandoned pipes and culverts, ducts, wells, ditches, sidewalks, curbs, light poles, abandoned telephone and electrical poles, traffic and advertising signs, poles and signs foundation, road furniture, and any other obstructions and disposal of resulting materials to an approved dumpsite, 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.

Demolition of existing concrete barriers shall be paid by meter cube of concrete to be demolished. The rates shall include demolition, removal and disposal of the resulted materials to an approved dumpsite as directed by the Engineer.

Permanent Realignment, (Relocation) or Replacement of Utilities shall be measured and paid in accordance with the rates set in the Bill of Quantities of respective works. Where the Bills of Quantities contain a PROVISIONAL SUM for "Realignment or Replacement of Utilities", this SUM will be used by the Employer for approved realignment, replacement or permanent diversion works carried out by the Contractor as directed by the Engineer and agreed with the Employer. This SUM shall only be expended against works, which are not accounted for as Pay Items elsewhere in the Specification or the Bill of Quantities.

The relocation of electric overhead cables, underground cables, posts, electric pylons, telephone overhead cables, underground cables and posts, lighting poles, etc shall be carried out as specified and to the Engineer's satisfaction and according to the Utility Owner's requirements. Relocation works shall be carried under the supervision of the Utility Owner's and completed works shall be subject to their acceptance. Rate for electrical or telephone relocation works shall include preparation and submittal for the necessary plans for the relocation of these utilities, relocation of utilities, all related incurred costs, including cost of coordination with EDL and Telephone authorities and all fees required by these authorities for the supervision of the relocation works.

Rate for relocation of potable water pipe lines shall be carried out as specified and to the Engineer's satisfaction. Rate for potable water relocation works shall also include preparation and submittal for the necessary plans for the relocation of these utilities, relocation of utilities including excavation and backfilling if necessary, all related incurred costs, including cost of coordination with water authority during the relocation to supervise any works including any fees related thereto.

The relocation of storm water and sewer pipes shall be carried out as specified and to the Engineer's satisfaction. Rate for sewer or stormwater relocation works shall include preparation and submittal for the necessary plans for the relocation of these utilities, relocation of utilities including excavation and backfilling if necessary, all incurred costs related to the proper completion of the work and coordination with the related responsible authorities.

Temporary Relocation and Diversion of Utilities required during construction, supporting and protecting realigned Utilities, and existing Utilities that are to remain in place, including all necessary Temporary Works in this respect, shall not be measured for direct payment, but shall be considered as subsidiary Works the costs or which will be deemed to be included in the Contract prices for Pay Items.
Survey works, trial pits investigation and mapping of existing utilities and obstructions,

coordination costs, and fees requested by Utility Owners 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)	Realignment of existing overhead power distribution lines	Linear Meter (m)
(2)	Relocation of existing power distribution poles	Number (Nr)
(3)	Relocation of pole-mounted transformers	Number (Nr)
(4)	Realignment of existing underground power cables	Linear Meter (m)
(5)	Realignment of existing overhead telephone cables	Linear Meter (m)
(6)	Relocation of existing telephone poles	Number (Nr)
(7)	Realignment of existing underground telephone cables	Linear Meter (m)
(8)	Realignment of existing water pipes of different sizes	Linear Meter (m)
(9)	Realignment of existing sewer pipes of different sizes	Linear Meter (m)
(10)	Realignment of existing stormwater pipes of different sizes	Linear Meter (m)
(11)	Relocation or Replacement of existing fences	Linear Meter (m)
(12)	Relocation of existing wells	Linear Meter (m)
(13)	Relocation of existing lighting columns	Number (Nr)
(14)	Demolition of Concrete barriers	Cubic meter (m^3)
(15)	Demolition and Removal of Building	Square Meter (m^2)
(16)	Demolition and Removal of existing Bridge	Number (Nr)
(17)	Removal of Railway Track (Twin)	Linear Meter (m)
(18)	Adjustment of manholes covers levels	Number (Nr)
(19)	Cleaning of box culverts	Cubic meter (m^3)
(20)	Cleaning of open concrete side drain	Cubic meter (m^3)
(21)	Cleaning of covered concrete side drain	Cubic meter (m^3)

SECTION 2.03 ROAD EXCAVATION

2.03.01 SCOPE

A. General

A.1 These Works shall consist of excavating material in the cut sections of the Road, including watercourses, ditches and wadi relocations (but excluding borrow pits and structural excavation) all as and where shown on the Drawings, and hauling the excavated material either to locations for Road embankments or to stockpiles or to waste.

A.2 These Works shall also include any necessary excavations outside the right-of-way ordered by the Engineer to safeguard and protect the Works. These may include diversion of existing wadi channels, excavation of materials obstructing or impairing the flow along stream channels; and excavation of unstable materials which may slide or encroach into ditches or onto the right-of-way. Disposal of all such excavated materials shall be as instructed by the Engineer.

A.3 The work shall also include all excavation work within the site limits to attain the final grading levels indicated on drawings.

B. Classification of Road Excavation

Road Excavation shall be considered as "Unclassified Excavation" which includes all materials encountered of any nature including silts, clays, sand gravel and granular materials and fractured, jointed and solid rock, and unsuitable material.

Any information concerning properties of the soil which may be shown on the plans, in the Bill of Quantities, in supplementary reports, or as a result of discussion with the Engineer or others shall be considered as gratis and shall not be a basis for the Contractor's determination of his bid prices.

2.03.02 CONSTRUCTION

Utilization of Excavated Materials

All materials removed from the excavation shall be used in the formation of the embankment, subgrade, shoulder, and at such other places as directed, unless it is declared unsuitable and ordered to be wasted by the Engineer.

Unsuitable material shall include:

Unstable materials incapable of being compacted to the specified density using ordinary compaction methods at optimum moisture content for the equipment being used for compaction.
Material too wet to be compacted and circumstance prevent suitable in-place drying prior to incorporation into the work.
Materials that are otherwise unsuitable for use in or under the embankment.

No excavation material shall be wasted without written permission from the Engineer.

If the Contractor chooses to excavate suitable material to waste or put it to other uses, and replace it by borrow excavation for embankment areas, this shall be undertaken at no extra cost to the Employer.

Excavated rock which is not immediately suitable for incorporation in the works can either be broken down to acceptable sizes or wasted at contractor's own expense. If such material is wasted or used in concrete or any other works, the Contractor will replace it by borrow excavation for embankment at no extra cost to the Employer.

Materials such as existing concrete, bituminous or other surfaces or other materials shall, if shown on the Drawings, be stockpiled for a specific purpose or for future use. Such materials shall be excavated and handled in a manner that will exclude foreign or undesirable material. Stockpiles shall be neatly formed and maintained in an approved manner.

Suitable topsoil material if specified shall be stockpiled during excavation operations and shall subsequently be spread and compacted on embankment slopes and elsewhere as directed, to facilitate regrowth of vegetation.

Drainage of Excavation Areas

During construction, surfaces in excavation areas shall be adequately drained at all times. Side ditches or gutters emptying from cut to embankment shall be so constructed as to avoid damage to embankments by erosion.

The Contractor shall at an early stage of the Works provide adequate drainage by scheduling ditch and other construction so as to prevent saturation or erosion of embankments and cut slopes. All such drainage ditches and construction grades shall be cleaned and trimmed at regular intervals and when directed so that there will be an unobstructed runoff of stormwater during construction.

Damage to the Works attributable to saturation or erosion through failure to provide adequate drainage shall be repaired by the Contractor at his own expense.

Whenever groundwater is encountered which may adversely affect construction the Contractor shall advise the Engineer who will evaluate the situation and order necessary remedial measures.

Obliteration of Disused Roadways

Obliteration of roadways which are no longer in use shall include filling of all ditches and rough grading of the old roadway to produce within the right-of-way a neat and well drained ground surface.

Rock Blasting

When blasting of rock slopes is carried out a reasonably uniform face shall be left regardless of whether or not the excavation is carried beyond the specified side slopes as shown on the drawings. All breakage and slides shall be removed by the Contractor and disposed of as directed.

Unless otherwise approved all excavation of rock cuts higher than 4.5 m and requiring blasting for their excavation shall be carried out in accordance with the requirements of Section 2.05 "Presplitting Rock Cuts".

All drilling and blasting shall be done in such a manner as will most nearly complete the excavation to the required grade lines and produce the least practicable disturbance of the material to be left in place. Blasting by means of drill holes tunnels or any other methods shall be entirely at the Contractor's risk.

Where necessary or directed, the Contractor shall provide heavy mesh blasting mats for protection of persons properties and the Works. If in the opinion of the Authorities and the Engineer, blasting would be dangerous to persons or adjacent structures, or is being carried out in an unsafe or unacceptable manner, the Engineer may prohibit blasting and order the rock to be excavated by other means.

If the flow of traffic is to be interrupted during blasting operations, the Contractor shall secure approval of his schedule for such interruptions and his proposed methods for safeguarding the public and property.

Excessive blasting will not be permitted. Overbreakage and the backfilling thereof shall be at the Contractors expense. Any material outside the approved cross section limits which may be shattered or loosened because of blasting shall be removed by the Contractor at his own expense. All rock slopes with loose material shall be scaled by workmen and all loose material removed.

Backfilling of overbreakage shall be carried out as directed, using approved soil or crushed materials or other special aggregate, as shown on the Drawings. Undrained pockets shall not be left in the surface of the rock.

Following blasting, cleaning and sealing rock slopes, the face, benches and back of the slope shall be inspected for potential failure planes and the necessary remedial measures shall be taken, as approved by the Engineer.

Excavation of Unsuitable Material

Where excavation to finished grades and cross sections exposes unsuitable material in the subgrade, slopes or ditch inverts, etc. the Engineer may require the Contractor to remove the unsuitable material and backfill the excavated areas using approved material. The Contractor shall conduct his operations in such a way that necessary cross section measurements are taken before such backfill is placed.

Unsuitable material shall be disposed of as directed. Wasted unsuitable material shall not be deposited on any cropland.

When the Contractor is directed to excavate unsuitable material below the surface of the original ground in fill areas, other than that required for clearing and grubbing, the depth to which unsuitable material shall be removed will be determined by the Engineer. The Contractor shall schedule the excavation so that cross sections are taken before and after materials has been removed.

Slopes, Subgrade and Ditches

All excavated slopes, subgrade and ditches shall be finished true to lines, grades and cross sections as shown on the Drawings.

Slopes, except in solid rock or other material which require special treatment, shall be trimmed to slopes not steeper than the specified slope angles and rounded at top and bottom

to a smooth profile to blend in with the adjacent terrain. Material shall not be loosened beyond the specified slope lines. High cut areas shall continuously be monitored by an engineering geologist or a geotechnical engineer.

In cuts where earth overlays a rock formation, slopes shall be benched in an approved manner.

Ditches of all types shall be excavated and trimmed neatly in conformity with the specified grades and cross sections. All projecting rock, stumps, roots or similar shall be removed. Ditches include side ditches, furrow ditches, irrigation ditches, wadi relocations, etc.

Where the subgrade is composed of rock as defined in Section 2.07-"Subgrade Construction", it shall be undercut to a depth of 200 mm below top of subgrade to allow for subsequent placing and compaction of the leveling subgrade layer in accordance with Section 2.07-"Subgrade Construction".

The subgrade in cut, where the soil is unsuitable for retention as the subgrade layer, shall be subexcavated to a depth of 200 mm below top of subgrade to allow for subsequent placing and compaction of the subgrade layer. If the material of the subgrade is suitable for retention as subgrade layer then it shall be scarified to the required depth, watered and compacted in accordance with Section 2.07-"Subgrade Construction".

The Engineer will periodically check all or any part of the Works, to determine conformance to the correct lines, grades and elevations. Tolerances on finished subgrade elevations and on elevations of the surface at the underside of the subgrade layer, shall be as specified in Section 2.07 -"Subgrade Construction".

Unstable Materials Outside Right-of-Way

Materials outside the right-of-way or ditch slopes which, in the opinion of the Engineer, are potentially unstable and liable to slide or encroach into the right-of-way or into the ditches, shall be excavated and disposed of as specified for unsuitable material, unless it is approved for use as embankment fill.

Disposal of Unsuitable and Surplus Materials

Unsuitable and surplus materials disposed of elsewhere than within the right-of-way shall be spread, leveled and shaped as directed so as to present a neat and tidy appearance. No materials shall be disposed of in such a way as to adversely affect natural drainage courses or to cause damage to the Road or adjacent public or private property.

If approved by the Employer, Government land can be used for disposal to the maximum extent practicable. If private land is used for disposal, the Contractor shall secure the consent of the landowner or tenant and, if necessary, and at his own expense, pay for the use of such land. The use of cropland for disposal purposes will not be permitted.

2.03.03 MEASUREMENT

All excavated material of whatever type (except for unauthorized undercut below top of subgrade) shall be measured as "Unclassified Excavation" which shall be deemed to include all materials encountered of any nature, including silts, clays, sand, gravel and granular materials and fractured, jointed and solid rock, and unsuitable material.
Unclassified Excavation shall be measured by cubic meter of material excavated, hauled

away and either wasted, stockpiled, or deposited on or in vicinity of Road embankment areas, including the proper formation of embankments trimming of slopes, preparation and completion of the roadway, subgrade and shoulders. Measurements shall be of volumes computed from the cross sections and the original ground elevations taken jointly by the Consultant and the Contractor before clearing and grubbing operations. Unclassified excavation for temporary diversions shall not be measured for direct payment, but shall be considered as Subsidiary Works the cost of which will be deemed to be included in the Contract prices for the Pay Items.

Excavation of Unstable Material (from areas outside the right-of-way) shall be measured by cubic meter of material excavated, hauled away and disposed of as directed, completed and accepted. Measurements shall be of volumes computed from surveyed cross sections of original and final ground elevations. When cross sectioning is impractical in the opinion of the Engineer, approval may be given to measure volumes in the vehicles removing such excavated material.

Ditch Excavation and excavation of unstable material are considered part of the unclassified excavation.

Rock blasting, backfilling of overbreakage, the trimming and grading of cut slopes, ditches and of other below-subgrade surfaces drainage of excavation areas, obliteration of disused roadways and other ancillary excavation Works shall not be measured for direct payment but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract prices for Pay Items.

PAY ITEM		**UNIT OF MEASUREMENT**
(1)	Unclassified Excavation	Cubic meter (m^3)
(2)	Excavation of Unstable Material Outside right-of-way	Cubic meter (m^3)

SECTION 2.04 BORROW EXCAVATION

2.04.01 SCOPE

These Works shall consist of excavating suitable material from borrow pits, channels and designated borrow areas and hauling to locations for highway embankments or to stockpiles all as and where shown on the Drawings, or as approved by the Engineer.

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

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

2.04.02 LOCATION OF BORROW PITS

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

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

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

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

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

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

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

2.04.03 BORROW MATERIAL

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

B. The Contractor shall submit representative samples of materials from each of the proposed borrow pits or borrow areas. A minimum of three sets of tests shall be required from each borrow area for each type of material. Testing shall conform with the relevant requirements of Part I of specifications Section 4- "Quality Standards and Control" clause No. 4-6-2. Source Tests.. No borrow material shall be brought to the site or used in the Works before its approval.

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

2.04.04 MEASUREMENT

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

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

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

SECTION 2.05 PRESPLITTING ROCK CUTS

2.05.01 SCOPE

These Works shall consist of presplitting rock cuts to produce a uniform plane of rupture so that the resulting backslope will be reasonably even with no overhang or protrusions, in close conformity to the lines and slopes shown on the Drawings and shall not be altered by subsequent blasting and excavation operations.

Presplitting involves the establishment of a free surface or shear plane by the controlled use of explosives and blasting accessories in appropriately aligned and spaced holes.

2.05.02 CONSTRUCTION

Faces of all cut slopes 1:2 (H:V) or steeper, exceeding 5 m in height and which require blasting to excavate, shall be formed by "presplitting" unless otherwise directed. Presplitting techniques for forming the faces of other formations, which could be excavated by means not requiring blasting, may be ordered by the Engineer.

Presplitting shall be by a line of drill boreholes of 50 mm to 100 mm diameter at uniform intervals along the staked slope line. Except for required offsets, hole alignment shall be such that at no point does the hole deviate more than 300 mm from the staked slope line. Localized irregularities of surface variations that do not constitute a safety hazard or an impairment to drainage courses or facilities will be accepted.

Where the depth of cut to be presplit exceeds 10 m, the cut shall be drilled, blasted, and excavated in 2 or more lifts, unless otherwise approved by the Engineer. When 2 or more lifts of drilling are required, the staked slope line for the top lifts shall be set back from the slope line of the underlying lift a distance of 0.5 m to permit operation of drilling equipment for each succeeding line of drilled holes. Where benching is required, primary blasting holes shall not be drilled to an elevation lower than the presplit line holes

The distance between the closest line of primary blasting holes and the line of presplit holes shall be determined during the blasting test. The distance and primary blasting charge shall allow for proper fragmentation but overbreakage behind the presplit line will not be permitted, and in no case shall the distance be less than one meter.

Prior to starting drilling operations for presplitting, the Contractor shall submit a layout plan outlining the position of all drill holes, depth of drilling, type of explosives to be used, loading pattern, and sequence of firing. The drilling and blasting plan is for record purposes only and shall not absolve the Contractor of his responsibilities in respect of proper drilling and blasting procedures.

The Contractor shall drill, blast and excavate short test sections, not exceeding 30 m in length in each geological formation, to determine the controlled blast method, hole spacing, and charge best suited to the material encountered. The Contractor shall utilize a 0.75 m presplit hole spacing for the initial test section. In order to obtain the desired rock fracture, necessary adjustments shall be made and approval obtained before proceeding with full scale drilling and blasting operations.

Only standard cartridge explosives prepared and packaged by explosive manufacturing firms or other authorities shall be used in slope holes. These may consist of fractional portions of standard cartridges to be fixed to the detonating cord in the field or solid column explosives jointed and fixed to the detonating cord in the field. Ammonium nitrate, fuel oil type explosives shall not be used in the holes drilled for controlled blasting along the slope line.

A 15 m minimum horizontal length of finished presplit rock slope depth shall be produced prior to any primary blasting.

Prior to detonation of any charge, the Engineer shall be notified and kept informed of all activities and movements of traffic within and adjacent to the area where the Works are being performed.

The Engineer may order discontinuance of the presplitting operations when the rock formation is of such character that, in his opinion, no advantage is apparent.

Methods other than presplitting, which will assure cleanly sheared rock faces and control of overbreak, may be used only if approved. Such approval may be withdrawn by the Engineer at any time if subsequent results are found to be unsatisfactory.

2.05.03 MEASUREMENT

The 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 the Pay Items.

SECTION 2.06 EMBANKMENT CONSTRUCTION

2.06.01 SCOPE

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

2.06.02 MATERIALS

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

TABLE 2.6.1: SOIL SUITABLE FOR EMBANKMENT

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

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

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

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

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

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

the requirements stated in Table 2.6.2.

Table 2.6.2: ROCK SUITABLE FOR EMBANKMENT

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

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

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

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

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

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

2.06.03 CONSTRUCTION

A. General

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Trial Embankment Sections

If shown on the drawings, or as required by the Engineer, a trial embankment shall be constructed. The trial section shall be at least 2 lanes wide by 100 m long at approved locations or adjacent to the Site. Compaction and other equipment used, shall be as specified and listed in the Contractor Equipment Schedule and approved Program of work.

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

TABLE 2.6.3

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

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

C. Foundation Preparation

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

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

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

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

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

D. Embankment Construction

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

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

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

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

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

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

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

2.06.04 EARTH FILL RETAINING SYSTEM "TERRE ARMEE"

- The system is composed of major elements:
- Earth fill
- Reinforcement
- Concrete facing

The three elements have to meet special criteria in order to be accepted for use in this system. The Contractor is to propose his design calculations for the proposed system using actual selected fill material obtained from the site excavations.

A. Reinforced Earth Fill

- Reinforced earth fill materials used with this system shall be Suitable backfill materials as defined in Clause 403.09.1 of these Specifications and shall also have the following criteria:

- Angle of internal friction of saturated material shall exceed 25° if the reinforcement used is high tensile steel, and 22° if the reinforcement used is mild steel.

  Method for test shall be as per the French Recommendations of the French Ministry of Transport.

- Water content shall not exceed the optimum water content for compaction.

- The Resistivity of the fill material shall exceed 1000 Ohm-centimeter for fill above water, and 3000 Ohm-Centimeter for fill in non-salty water.

- The P.H. of the material shall be between 5 and 10.

- Soluble salt content: in particular chlorides and sulfates shall not exceed:

[Cl^-] <200mg/kg }
[$S04^-$] <100mg/kg } for fill above water

[Cl^-] <100mg/kg }
[$S04^-$] <500mg/kg } for fill in non-salty water

- Organic material: No organic material shall be accepted in the fill.

B. Reinforcement

- Mild steel, galvanized or not, is the most commonly used. However, high tensile steel is also used. The reinforcement shall be in conformity with the required characteristics defined by SETRA in "Les Ouvrages en terre armee -Recommendations et Regles de l'Art".

C. Reinforced Concrete Facing

- Reinforced concrete facing shall be precast and vibrated. The concrete shall be of f'c = 300kg/cm^2, and the reinforcement shall be as defined by the manufacturer, and supported by calculations.

2.06.05 TESTING

General

A.1 The Engineer shall test the compaction of embankment materials in accordance with these Specifications to ensure that adequate compaction or consolidation has been achieved. All such tests shall be fully documented by the Contractor, in an approved manner.

A.2 In the case of cohesionless, free draining rock-soil materials, where maximum density tests fail to produce a well defined moisture - density relationship, the relative density test shall be used, alternatively an electronic compaction meter or any other approved test equipment shall be provided by the Contractor and used to determine the degree of compaction achieved.

A.3 To determine the degree of compaction for embankment consisting of rock fill, average differential settlement values shall also be determined from surveys of an adequate number of grid point elevations as and when directed, at the commencement of, during and after embankment construction.

A.4 If it is required to determine the modulus of soil reaction by the Plate Bearing test, this shall be undertaken using the method given in AASHTO T222-81 (1986).

A.5 When filling and compaction to final grade level are achieved, pressure meter tests or other approved in-situ tests shall be undertaken, if required by the Engineer. The testing shall be at the locations and to the depths indicated by the Engineer on site.

Standards of Compaction for Soil and Granular Materials

B.1 The following compaction standards shall apply to embankment materials other than predominantly rock materials. The "maximum density" of soil type materials shall be the modified maximum density determined in accordance with AASHTO T 180 (Method D). The "relative density" shall be the relative density determined in accordance with ASTM D4254, which identifies the state of compactness of the material with respect to its loosest and densest state. The relative density shall be the standard to which the field density is referred for comparison in the case of cohesionless, free draining granular materials.

B.2 Soil type materials shall be compacted to at least 90% modified maximum density for the full depth of embankment. The 600 mm of embankment material immediately below the subgrade layer shall be compacted to at least 95% modified maximum density. Moisture content shall be within plus or minus 2% of optimum at the time of compaction.

B.3 Cohesionless, free draining granular materials (of 75 mm maximum size and with not more than 15 % passing 0.075 mm (No. 200) sieve shall be compacted to at least 70 % of relative density for the full depth of embankment. The 600 mm depth of such

material immediately below the subgrade layer shall be compacted to at least 75% of relative density.

B.4 When in-situ tests are undertaken the results of the pressure meter test or other approved in-situ test shall prove the following minimum fill characteristics:

- Bearing capacity of 2 kg/cm^2
  Safety Factor of 2.5
- Maximum settlement 2.5 cm

The Engineer may reject the work if the criteria for bearing capacity and settlement are not satisfied. In this case the Contractor shall remove all rejected work and replace at his own cost

B.5 Minimum soil tests required during the construction of subgrade and/or embankment are:

- One sample for CBR, classification (AASHTO M 145), and laboratory (Moisture - density) or relative density compaction from each source prior to use. Each sample shall represent not more than 5000m3.

- One sample for classification representing not more than 3000 m^3 of the material in use.

- For every completed layer, one field density shall be determined each 1500 m2 or 100 linear meters whichever is less. Testing shall be in accordance with ASTM D1556 or ASTM D2167.

Degree of Compaction for Rock Materials

C.1 To ensure proper compaction of rockfill embankments, the contractor shall be required to conduct compaction tests using equipment and materials available in order to determine the best compaction control criteria.

C.2 A rockfill test section shall be placed on a firm surface approved by the Engineer, and the material and layer thickness shall conform to the requirements of these Specifications.

C.3 The test section shall be of sufficient dimensions to permit the establishment of at least twenty leveling points on a 5 meter (5 m) square grid, and no fewer than 3 points on any one line and no point less than three meters from the edge of the layer. The Engineer shall approve the arrangement of the leveling points.

C.4 Compaction shall then commence with a minimum of three passes of a vibratory roller. Leveling points are then established. Short lengths of painted steel bars hammered flush with the surface of the rockfill have been found suitable for this purpose. A level reading is taken at each leveling point on top of a moveable 30 cm square flat steel plate. A hole drilled in the center of the plate will enable a visual check to be made that the plate is located centrally over the bar each time.

C.5 Further readings are taken at the leveling points after two additional passes with the roller. If the average settlement is less than half of one percent (0.5%) of the average compacted layer thickness, or as determined by the Engineer, the rockfill compaction test is complete.

C.6 If the average settlement is more than half of one percent (0.5%), two additional passes of the roller are required and the leveling procedure repeated. If the average settlement is now less than half of one percent (0.5%), the test is complete. If not, this step is then repeated.

C.7 The total number of passes of the rolling equipment necessary to obtain the required result will establish the minimum number of passes to be used on the rock embankments. The contractor shall then use this simplified procedure that is, the equipment, rolling pattern and number of passes, during the construction of rock embankments. However, in no case shall the number of passes be less than five (5).

C.8 This verification procedure shall be conducted for each change of material and at least once each week during the initial stages of construction until a reliable rolling pattern is established. The frequency verification procedure can then be reduced as approved by the Engineer.

C.9 Documentation of the rockfill compaction tests shall be maintained in the project records.

Monitoring Settlement of Rockfill

On completion of the embankment, the contractor shall carry out precise leveling of the crest of the embankment. This shall consist of leveling transverse sections (a minimum of live points) at a maximum spacing of 30 m along the embankment. These shall be referenced to a stable approved datum. Leveling shall be carried out at suitable time intervals until the average rate of settlement over a period of one month does not exceed 0.1 mm per day. No permanent pavement construction will be permitted until the specified criteria are achieved.

2.06.06 MEASUREMENT

Earth Fill Retaining System shall be measured by the linear meter stating the height of wall.

Payment shall be at the rate included in the Bill of Quantities which shall include full compensation for the design (including drawings, calculation sheets, and other related and required documents to be submitted for the review and approval of the Engineer). The rate shall also include for excavation for the complete earth retaining structures system including excavation required for the soil reinforcing bars. Rate shall also include for furnishing all materials required for the proper execution of this type of earth fill retaining structure (including fabricating reinforced concrete facing, reinforcement and tie strips, fasteners, joint fillers and incidentals), full compensation for the construction of the wall foundations, put in place the reinforcing strips, and erect the panel elements to the lines and grade shown on shop drawings approved by the Engineer. The cost of backfilling and compacting with approved fill materials, as specified with this system, shall be as stated under “Structural Excavation and Backfill” section.

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

B. The volume of Embankment displaced by pipe culverts, box culverts and associated end walls, bridge piers and abutments, shall be deducted from the measured volume of

embankment. No deduction shall be made for pipes less than 500 mm in diameter and associated end walls.

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

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

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

PAY ITEM	**UNIT OF MEASUREMENT**
(1) Reinforced Earth Fill	Linear Meter (m)

SECTION 2.07 SUBGRADE CONSTRUCTION

2.07.01 SCOPE

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

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

2.07.02 MATERIALS

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

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

2.07.03 CONSTRUCTION

Subgrade in Cut

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

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

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

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

Subgrade in Embankment

The 200 mm minimum depth of embankment immediately below top of subgrade shall consist of selected, approved subgrade material. The material shall be spread in one layer over the full width of the top of embankment, brought to a uniform moisture content within the specified range and compacted to 100% AASHTO T 180 (Method D) maximum density.

Surface Tolerances

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

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

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

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

Maintenance of Finished Subgrade

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

2.07.04 MEASUREMENT

A. Subgrade layer in fills in rock cut or in soil cut of unsuitable material is not measured separately but is included as part of the Embankment.

B. Subgrade layer preparation in soil cut of suitable material is not measured separately but is considered subsidiary to other items of the Works.

SECTION 2.08 STRUCTURAL EXCAVATION AND BACKFILL

2.08.01 SCOPE

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

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

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

2.08.02 EXCAVATION

A. General

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

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

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

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

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

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

due to weather, equipment, and other causes during periods when the excavations are left open.

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

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

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

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

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

B. Temporary Support System

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

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

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

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

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

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

C.3 Unless shown otherwise on the Drawings, the bottom of all excavations shall be

covered with a 75 mm minimum depth of lean (blinding) concrete class 110/25 to serve as a working platform.

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

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

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

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

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

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

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

D. Excavation for box culverts, ducts and miscellaneous structures

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

D.2 Foundation material supporting the bedding or structure shall be AASHTO M 145 Class A-l-a, A-l-b or A-2-4 compacted to 95% AASHTO T 180 maximum density. If the natural material does not meet the classification requirements, it shall be sub-excavated 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 sub-excavated and replaced with material meeting the specified requirements.

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

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

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

2.08.03 BACKFILLING

A. General

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

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

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

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

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

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

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

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

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

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

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

A.9 Minimum tests required during backfilling operations to verify material are for each abutment, footing etc.
- One Proctor test
- One Gradation of Materials and at change of material or its source
- One Plasticity Index and field density for all compacted layers.

B. Backfilling for Bridges, Underpasses and Overpasses

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

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

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

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

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

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

C. Backfilling for Box Culverts, and Miscellaneous Structures

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

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

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

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

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

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

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

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

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

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

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

2.08.04 MEASUREMENT

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

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

C. Structural Excavation for box culverts less than one sq.m in external cross section and structural excavation for pipe culverts, underdrains (subsoil drains), pits, catchbasins, manholes, inlets, energy dissipators, slope protection Works, fence posts, guardrail posts, lighting columns, sign posts, signal supports and all other minor structures, shall not be measured for direct payment, but shall be considered as subsidiary Works the costs of which will be deemed to be included in the Contract Prices for Pay Items.

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

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

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

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

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

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

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

SECTION 2.09 EXCAVATION AND FILLING FOR PIPE TRENCHES

2.09.01 EXCAVATION FOR PIPE TRENCHES

A. Excavating

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

Trench width: (up to 300 mm above crown of pipe) is not to exceed the following:
- For pipes not exceeding 65 mm diameter: 300 mm
- For pipes over 65 mm and not exceeding 600 mm diameter: nominal diameter + 600 mm
- For pipes over 600 mm diameter: nominal diameter + 1000 mm.

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

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

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

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

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

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

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

Formation for beds generally:

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

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

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

2.09.02 BACKFILLING FOR PIPE TRENCHES

A. Filling materials

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

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

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

B. Workmanship: Backfilling

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

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

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

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

C. Restoration of surfaces

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

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

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

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

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

2.09.03 MEASUREMENT

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

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

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

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

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

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

Excavation in any material encountered,

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

Excavation at any level and to any depth,

Excavating curved on plan,

Allowance for working space,

Increase in bulk for excavating,

Excavating below water table and dewatering as necessary,

Keeping excavations free from water,

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

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

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

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

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

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

Filling over-excavation,

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

Compaction of secondary backfill (main backfill) material,

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

PAY ITEMS		UNIT OF MEASUREMENT
(1)	Trench Excavation for Gravity Pipes	Cubic meter (m^3)
(2)	Trench Excavation for Pressure Pipes	Cubic meter (m^3)
(3)	Soil Support System in Place for Pipe Trench Excavation	Square meter (m^2)

SECTION 2.10 STABILIZATION OF CUT SLOPES

2.10.01 SCOPE

A. These Works shall consist of stabilization of cut or natural slopes in soil or rock by one or combination of the following methods: grouting, shotcreting or guniting, rock bolting, rock anchoring, or wire netting.

B. Before any of the works is commenced, the Contractor shall submit a detailed Method Statement to the Engineer for his approval. The Method Statement shall include adequate details concerning the materials, work procedures, means and methods and frequency of testing for grouts and anchors; intended by the Contractor, to carry out the work and achieve the specified requirements.

2.10.02 MATERIALS

A. Cement Grout

Grout for use in rock grouting of slopes, rock bolting and rock anchors, shall normally consist of a mixture of cement and water only. Fine sand aggregate passing No. 16 sieve may be added, if approved, for grouting of large holes, etc.

Admixtures and filler free from chlorides may be used only if approved.

Cement, sand and water shall conform with the requirements of Section 5.01 -"Concrete and Concrete Mixes and Testing". Sulfate resisting and rapid hardening cements shall be used only if specified and approved.

The compressive strength of 100mm cubes made of grout shall be not less than 170 kg/sq. cm at 7 days. Cubes shall be cured in a moist atmosphere for the first 24 hours and subsequently under water.

Grout mixes shall have good fluidity and low sedimentation or bleeding in the plastic state, good durability and density with low shrinkage in the hardened state, in order to bond with the side of boreholes and to provide protection for bolts and anchors, etc. Mix proportions shall be as specified for the various applications of grout, and grouting trials shall be undertaken if directed.

All materials shall be proportioned by weight.

B. Rock Bolts Generally

B.1 All bolts, required to provide support for excavated or natural rock faces, shall be deformed high tensile steel bars conforming with the relevant requirements of Section 5.03 - "Steel Reinforcement and Fixing" or other type in accordance with Drawings.

B.2 Rock bolts can be continuously threaded or threaded to allow extension to be fitted as required. One end of the bolts shall be threaded for a tensioning locking nut, sufficient to ensure that a 10 to 50mm thread length extends beyond the locking nut. The thread on the bolt shall be ISO metric coarse series to BS 4190. The washer shall be flat mild steel plate 150 by 150 by 8mm thick with free fit holes. Nuts shall conform to BS 490

and washers shall conform to BS4320.

B.3 Rock bolts may consist of tensioned or untensioned dowel bars anchored by resin or grout or mechanically anchored.

B.4 Protection against corrosion shall be as shown on Drawings.

C. Resin-Anchored Rock Bolts

C.1 The point resin anchor is formed using a cartridge system. The remaining length of the bolt is grouted with cement if required by the Engineer. The grout may be injected after the installation of the bolt and anchor, or the resin and cement grout may be placed in the hole and the bar pushed through the cement grout into the resin.

D. Mechanically Anchored Rock Bolts

D.1 These shall be of the expansion shell type and full details of the type of bolt and anchorage to be used shall be submitted for approval prior to installation. If approved, mechanical anchorage bolts shall be used in accordance with the manufacturer's instructions as approved or modified by the Engineer who may require mechanically anchored rock bolts to be cement grouted.

D.2 If the Engineer so directs, rock bolts shall be de-bonded along the length of bar which is not required for anchorage purposes by means of a suitable plastic sheath preventing the formation of a bond between the grout and the bar.

D.3 If untensioned dowel bars are used, all voids shall be completely filled with grout.

D.4 If resin-anchored rock bolts are used, tests shall be carried out to ensure that the resin is not adversely affected by the cement grout.

E. Rock Anchors

E.1 Rock anchors required to provide support for excavated or natural rock faces, and at tunnel portals, shall consist of steel tendons in excess of 10m in length and shall conform to AASHTO M204: "Uncoated Stress Relieved Wire for Prestressed Concrete".

E.2 Corrosion protection shall be as shown on the Drawings.

F. Sprayed Concrete and Mortar

F.1 Sprayed concrete (Shotcrete) is a mixture of water, cement, sand and aggregate, impelled through a nozzle without interruption by means of a purpose made machine onto the area of placement. Sprayed concrete (Shotcrete) with cube compressive strength of 25 MPa with an aggregate smaller than 12 mm particle size shall be used.

F.2 Sprayed mortar (Gunite) is a mixture of water, cement and sand, impelled through a nozzle without interruption by means of a purpose - made machine onto the area of placement. Sprayed mortar (Gunite) with cube compressive strength of 25 MPa with sand of maximum particle size 7mm shall be used.

F.3 Water - Reducing, Non - Chloride Accelerator Admixture: ASTM C494, Type E, and

containing not more than 0.1 percent chloride ions.

Products: subject to compliance with requirements, provide one of the following:

"Accelquard 80"; Euclid Chemical Co.
"Pozzolith High Early"; Master Builders Technologies
"Lubricon NCA"; Cormix

F.4 For concrete and mortar ingredients and related inserts conform to the requirements of Sections 5.01 - "Concrete and Concrete Mixes and Testing" and 5.04 - "Forms, Formwork and Falsework".

F.5 For reinforcement conform to the requirements of Section 5.03 - Steel Reinforcement and Fixing.

G. Wire Netting

G.1 All wires shall be mild steel conforming to BS 1052, having a minimum nominal diameter of 2.7mm. The maximum mesh shall be 100mm x 80mm, the wire shall be hot-dip galvanized in accordance with ASTM A 767, Class II (610g Zinc/m2, 2.0 oz. Zinc psf), after fabrication and bending.

G.2 The hexagonal wire mesh netting shall be triple twisted and suitably woven to produce a flexible uniform net pattern, free of any damage. Both longitudinal sides of the netting sheets shall be edged with a wire of equivalent standard to that of the netting but greater in diameter. The lacing-wire used for fixing adjacent netting sheets shall also be of equivalent standard.

H. Geogrid

H.1 For Rock Slopes:

1. The reinforcing element shall be a geogrid manufactured in accordance with a Quality Management System which complies with the requirements of BS EN ISO 9001:2000.

2. The reinforcing element shall be a geogrid manufactured from high density polyethylene sheet, oriented in two directions so that the resulting ribs shall have a high degree of molecular orientation which continues through the area of the integral node.

3. The ribs of the reinforcing element shall be of rectangular cross section in both the longitudinal and transverse directions with a typical minimum rib thickness of 1.7mm. The geogrid aperture size shall be approximately 58mm x 58mm.

4. The Quality Control Strength [expressed as the lower 95% confidence limit in accordance with ISO 2602:1980 (BS 2846: Part 2:1981)] shall be 15.0 kN/m with peak strain of about 19.0% and 16.0% in the longitudinal and transverse directions respectively at that load, when tested in accordance with BS EN ISO 10319:1996.

5. The typical strength of the nodes between the longitudinal and transverse ribs shall be not less than 95% of the Quality Control Strength in both longitudinal and transverse directions.

6. The reinforcing element shall be inert to all chemicals naturally found in soils and shall have no solvents at ambient temperature. It shall not be susceptible to hydrolysis, shall be resistant to aqueous solutions of salts, acids and alkalis, shall be non-biodegradable and shall have a minimum of 2% finely divided carbon black, as determined by BS 2782:Part 4:Method 452B:1993, well dispersed in the polymer matrix to inhibit attack by ultra violet light.

H.2 For Grass Slopes

1. The erosion control mat shall be manufactured in accordance with a Quality Management System which complies with the requirements of BS EN ISO 9001:2000.

2. The erosion control mat shall be manufactured from polyethylene and be multi-layered, three dimensional and with layers which are heat bonded where they touch.

3. The erosion control mat shall be manufactured to a typical thickness of 16mm (± 2 mm) or 18 mm (± 3 mm), with a unit weight of 0.23kg/m2 or 0.43kg/m2.

4. The longitudinal tensile strength [expressed as a lower 95% confidence limit in accordance with ISO 2602:1980 (BS 2846:Part 2:1981)] shall be 1.6 kN/m or 3.2 kN/m when tested in accordance with BS EN ISO 10319:1996
   Typical tensile strength at 10% strain shall be 0.5 kN/m or 1.3 kN/m.

5. The erosion control mat shall be inert to all chemicals naturally found in soils and shall have no solvents at ambient temperature. It shall not be susceptible to hydrolysis, shall be resistant to aqueous solutions of salts, acids and alkalis and shall be non-biodegradable. It shall contain finely divided carbon black to inhibit attack by ultraviolet light.

2.10.03 CONSTRUCTION

A. Rock Grouting

A.1 Rock grouting is the injection under pressure of grout to consolidate areas of fractured rock. Grouting shall normally proceed from the bottom of the rock slope upwards.

A.2 Details of methods to be adopted and materials to be used shall be submitted for approval before proceeding with any pressure grouting. The Contractor shall ensure that, at all times, grouting Works are under the direct control of skilled and experienced operatives. The Engineer may vary the methods, materials and grouting pressures if, in his opinion, the conditions dictate a change of technique. All holes to be grouted shall be numbered, as directed and grouting operations shall take place in the following order:

- Drilling of Holes
- Washing of Holes
- Water Testing
- Pressure Grouting

A.3 The hole spacing shall normally be 1.6m to 5.0m with additional holes as required to intersect individual weaker areas. Hole depth shall be limited to the range 3-10m and

hole diameter shall be within the range 38-78mm, drilled with either rotary or rotary-percussive drilling equipment. Water or air flush may be used unless otherwise directed by the Engineer.

A.4 Holes shall be jetted using a water flow, under such pressure as may be directed. The injection of water shall be followed by injection of air under pressure, these operations alternating until air bubbles appear at an adjacent hole. All other holes shall be capped and water forced under pressure into the first hole, until unwanted material from fissures washes out from the uncapped hole. This process shall continue until no more fine material is removed, or until directed. The outlet hole shall then be capped and the other holes opened. The sequence shall be repeated until connections between all holes have been established and all fine material removed. After washing, all holes shall be capped.

A.5 Holes shall be water tested in stages or as the Engineer may require. For stage testing, a twin packer and nozzle pipe system shall be used. Water testing equipment shall be capable of ensuring steady pressures and a delivery of water of 100 ltr./min at the required pressure. The equipment shall include all necessary tanks, gauges and water meters. Water shall be pumped at the proposed grouting pressure into the hole to be tested and the flow measured for 5 or 10 minutes as directed. The Contractor shall keep a record of the water flow expressed in ltr./min for each stage tested. Additional testing may be required as the grouting operation proceeds.

A.6 All grout mixes shall be prepared using high speed, high shearing action mixers to ensure uniform consistency. When storing mixed grout for short periods, prior to pumping, only purpose made agitator tanks shall be used. Where clay or bentonite are incorporated in the grout, separate mixing tanks shall be provided in which the bentonite-water mix can be prepared and kept agitated until required.

A.7 Ram type pressure pumps shall be used for grouting. Precise control of pump pressure and delivery over the whole range of pressures and volumes are required. Valves shall be readily accessible for ease of maintenance. All hoses and piping should be of small diameter to ensure high velocity flow without segregation. Injection may be carried out by either the single line or circulating system. Each borehole shall be provided with a short standpipe threaded at its outer end to accept a manifold with a pressure gauge, relief valve and valve enabling delivery from the pump to be cut off from the hole. Pressure gauges shall also be provided at pumps.

A.8 Once grouting has commenced, it shall be continued without interruption until completion. Grouting shall commence with a mix of 8:1 water: solids ratio. The mix shall be thickened progressively until pressure begins to build up. In case pressure build up occurs too quickly, the mix may be thinned again. The final injection shall utilize a 1.5:1 mix. If no pressure build up occurs with a 1.5:1 mix, sand may be mixed with the grout, provided that the sand: cement ratio does not exceed 2:1 by weight. When the desired pumping pressure is achieved, with extremely low grout flows, final injection shall take place with a neat 1:1 cement mix.

A.9 Grouting can be considered complete when the absorption of grout at the required pressure is less than 2 ltr./min over a period of 10 minutes.

A.10 Grouting shall proceed with caution until experience of the ground conditions has been gained. Thereafter, if conditions allow, injection shall proceed at high pressure to

achieve maximum flow from the start of injection. Grout pressure, as measured at the mouth of the hole, shall correspond to 0.4 bar/m depth of hole for those areas where the strata to be treated have no structures in the vicinity. In the vicinity of structures the pressure shall be 0.25 bar/m depth. Uplift gages shall be installed and continuously monitored as grouting proceeds.

A.11 In case the required grouting pressure is not attained using a sand-cement mix, grouting shall be suspended and the hole washed. After several hours, grouting may proceed again using the sand-cement mix until the desired pressure is achieved. Should there be any grout communication between two holes occurs, both holes shall be grouted concurrently or the initial hole grouted whilst the second hole is capped. When injection is interrupted before it is complete, the hole shall be washed using not less than 500 Ltr. of clean water.

A.12 After grout consumption has reached the limits previously specified, the Engineer will require additional holes to be core drilled. The diameter of the retrieved grouted rock cores shall not be less than 50 mm. Three representative samples for each 3 m of core shall be taken and unconfined compression tests shall be carried out on each core sample. The mean strength of each group of cores shall not be less than 3 MN/sq.m. If this value is not reached then additional grouting of the rock shall be performed until further tests indicate that the strength of grouted rock cores achieves 3 MN/sq.m. For every 8 treatment holes or at the Engineer's discretion, at least one hole shall be cored and the cores tested as outlined above. In the core drilled hole the Engineer may require a water test to be carried out.

A.13 Complete details of drilling, water testing and grouting operations including pressures, mixes and grout takes, shall be recorded on daily progress sheets. A graphical record of such results shall be compiled and copies of all progress sheets and records shall be submitted promptly for approval.

B. Rock Bolting Procedures

B.1 After drilling holes of the required diameter and depth, and after inspection and approval of the holes and their locations, rock bolts shall be installed and anchored by various approved means as described below, depending upon the type of rock bolts being installed.

B.2 Grouting Equipment shall be of a type capable of producing a grout of colloidal consistency by means of high local turbulence while imparting only a slow motion to the body of the grout. The injection equipment shall be capable of continuous operation with little variation of pressure and shall include a system for re-circulating the grout while actual grouting is not in progress. Compressed air shall only be used if approved. Equipment shall have a delivery pressure not exceeding 1 MN/sq.m. All baffles to the pump shall be fitted with 1.2mm sieve strainers. All equipment and piping shall be thoroughly washed with clean water after every series of operations and more frequently if directed. Intervals between washings shall not exceed 3 hours.

B.3 Mixing of grout shall proceed by water being added to the mixer first, followed by the cement. When these are thoroughly mixed any admixture or sand shall be added. Mixing shall continue for at least 2 minutes until a uniform consistency is obtained. The water: cement ratio of the mix shall not exceed 0.45 by weight. Mixing by hand will not be permitted.

B.4 Grout shall be injected continuously and in such manner as to avoid causing segregation of the grout. The method of injection shall ensure complete filling of the

boreholes and complete immersion of the bolt in the grout. The volume of the spaces to be filled by the injected grout shall be compared with the quantity of grout injected. Grout shall be allowed to flow from the free end of the borehole until its consistency is equivalent to that of the grout injected. The opening shall then be firmly closed. Injection tubes shall be sealed off under pressure until the grout has set.

B.5 The compressive strength of 100mm cubes made from the grout shall exceed 170 Kg/sq.cm at 7 days. Cubes shall be cured in a moist atmosphere for the first 24 hours and subsequently in water.

B.6 Polyester resin gel and cure times shall be suited to the working temperature and method of installation of the bolt. The main resin and filler content shall be enclosed in an outer sheath or skin and the catalyst shall be enclosed in a separate container within the main sheath. The resin and catalyst shall be mixed by rotating the bolt by means of a power tool for such time and at such speed as will ensure the thorough intermixing of the two constituents.

The viscosity of the resin shall be such that complete disintegration of the resin sheath is achieved and the pieces of sheath material do not have a detrimental effect on the final strength of the anchorage.

B.7 Expansion shells for mechanical anchorage, shall be of an approved type and shall be installed in accordance with the manufacturer's instructions as approved or modified by the Engineer. Where such bolts are used in close proximity to a rock face where blasting is taking place, the security of the anchorages shall be checked after blasting and the bolts re-tightened or replaced, if necessary in a new hole.

B.8 Each hole shall be drilled straight and each bar shall lie centrally in the hole and not be in contact with the rock. The diameter shall be 10mm greater than the bolt diameter if grouted with cement. For resin anchored bolts, the hole size shall be determined according to the anchorage or cartridge size and in accordance with the manufacturer's recommendations. Allowance shall be made for the hole size to be slightly greater than the bit size. Tolerance on the diameter of hole shall be plus or minus 2 mm. The hole shall be thoroughly flushed and cleaned after drilling.

B.9 The rock surface around each hole shall be trimmed flat in a plane normal to the axis of the rock bolt to ensure an even bearing surface for the cover plate. Where this procedure is not possible, a conical aligning seating shall be used. Epoxy mortar packing between the bearing plate and rock shall be used where directed.

B.10 Anchored rock bolts shall be tensioned by either applying a specified torque to the nut or by using a hydraulic jack. The Engineer shall instruct the Contractor as to which method is to be used in particular cases.

B.11 Where the torque method of tensioning is used, the required tension shall be agreed by the Engineer and tests shall be carried out to establish the applied torque required to achieve this load. Care shall be taken to ensure that the threads on the bar and nut are clean and free from obstructions.

B.12 Where tension is to be applied by hydraulic jack, the Engineer may require tests to establish the jack gauge calibration. In calculating the initial load to be applied, loss of tension due to the transfer of load to the locking nut and washer shall be allowed for.

B.13 Permanent load measuring instruments shall be incorporated in selected rock bolts as directed and the tension in these bolts shall be monitored. Monitoring shall be carried out at hourly intervals for the first 4 hours, then at 4-hour intervals up to the first 24 hours, then at daily intervals up to 20 days after tensioning or at such other times as may be directed.

B.14 Where the Engineer directs that the lengths or part of the length of a rock bolt shall be debonded from the surrounding grout, this debonding shall be achieved by means of a plastic sheath closely fitting around the steel bolt.

B.15 All relevant data shall be recorded and presented in an approved form. In case, the Engineer is not satisfied that the anchorage of the bolt is adequate, the Contractor shall take approved remedial measures to ensure adequate anchorage.

C. Pull Out Tests for Anchored Bolts

C.1 Before commencement of any section of Works requiring rock bolts, pull out trials shall be carried out at the Contractor's expense, to measure the ultimate load carrying capacity of all types of bolts to be used. Pull out tests shall be carried out according to ASTM Standard method D4435 or BS equivalent.

C.2 Trials shall be carried out in rock of a similar nature to that in which the rock bolts will be used. The deformation of rock bolts and the load shall be continually monitored until failure. A minimum of 4 tests on each type of bolt to be used shall be performed. Details of proposed procedures shall be submitted for approval before commencement of the trials. The anchorage must be capable of carrying twice the specified working load.

C.3 These tests will be used to assess the suitability of proposed anchorage systems in the particular location where the bolts are to be used. Where rock conditions change, such that anchorage characteristics are affected, further trials shall be carried out as directed.

C.4 During construction approximately 5% of all bolt types shall be tested to twice the specified working load. In case significant failures are obtained in the tests results, the Contractor shall carry out further tests and shall take approved remedial measures as directed by the Engineer.

C.5 A protective barrier (wire netting) shall be erected around the testing equipment to protect and safeguard against any injury to any personnel involved in the testing works and any other measures as deemed necessary by the Engineer.

D. Pull Out Tests for Untensioned Bolts

D.1 The efficiency of grouting shall be checked by pulling out the bolts after such time as will ensure that the cement grout or mortar remains bonded to the bolt when the bolt is withdrawn from its hole. A total of 10% of all untensioned bolts shall be tested in this way. The grouted boreholes shall then be cleaned out and bolts free from hardened grout reinstalled to the Engineer's satisfaction.

D.2 If, in the Engineer's opinion, an unacceptably high percentage of the initial 10% selection of bolts are not fully grouted along their length, the Engineer will require further tests to be carried out.

E. Rock Anchoring Procedures

E.1 Care shall be taken to avoid mechanically damaging, work hardening or heating tendons while handling. All tendons shall be stored clear of the ground and protected from the weather, from any other materials and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity. In no circumstances shall tendons after manufacture be subjected to any welding operation, or on Site heat treatment or metallic coating such as galvanizing.

E.2 When tendons have been stored on Site for a prolonged period, the Engineer may require tests to show that the quality of the tendons has not been significantly impaired by either corrosion, stress-corrosion, loss of cross-sectional area or changes in any other mechanical characteristics.

E.3 All tendons shall be free from loose mill scale, loose rust, oil, paint, grease, soap or other lubricants, or other harmful matter at the time of incorporation in the rock anchor. Cleaning of tendons shall be carried out either by wire brushing or by passing through a pressure box containing carborundum powder. Solvent solutions shall not be used for cleaning without approval.

E.4 Low relaxation and normal relaxation wire shall be in sufficiently large diameter coils to ensure that the wire pays off straight. In cases where, in the opinion of the Engineer, straight as-drawn wire is not essential, wire in small diameter coils corresponding to the diameter of the blocks in the drawing machine may be used.

E.5 Prestressing strand, however manufactured, shall be in sufficiently large diameter coils to ensure that the strand pays off straight.

E.6 Prestressing bars as delivered shall be straight. Any small adjustments for straightness necessary on Site shall be made by hand under the supervision of the Engineer. Bars bent in the threaded portion will be rejected. Any straightening of bars shall be carried out cold.

E.7 All cutting to length and trimming of ends shall be by high speed abrasive cutting wheel, friction saw or any other mechanical method approved by the Engineer. In rock anchor systems, the cutting action shall be not less than one diameter from the anchor, and the heating effect on the tendon shall be kept to a minimum.

E.8 The tendon or tendons shall be accurately located and maintained in position. Spacers are to be used to keep the tendons in their correct position in the borehole.

E.9 The tendon or tendons shall terminate at the back of the hole in the rock secured in a ribbed steel cylindrical anchorage block or be grouted into place over the 'anchorage length' defined for the working load required. The end of the borehole shall be filled with a polyester resin or cement mortar. The length of anchorage shall be sufficient to take the load on the tendons with a safety factor of 2. The remaining length of tendon, (the free length) shall be encased in a corrosion-protected grease-packed, plastic debonding sheet.

F. Tensioning Tendons

All wires or strands stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number and the coil number or numbers of the steel used. Cables shall not be kinked or twisted, and individual wires and strands shall be readily identifiable at the end of the member. No strand that becomes unraveled shall be used.

A tendon when tensioned contains a considerable amount of stored energy, which, in the event of any failure of the tendon, anchorage or jack, may be released violently. The Contractor shall ensure that adequate precautions are taken during and after tensioning to safeguard persons from injury and equipment from damage which may be caused by the sudden release of this energy.

Hydraulic jacks are to be used for tensioning tendons. The tensioning apparatus shall meet the following general requirements:

The means of attachment of the tendon to the jack shall be safe and secure.

Where two or more wires or strands are stressed simultaneously, care shall be taken that they are of approximately equal lengths between anchorage points at the datum of load and extension measurement. The degree of variation shall be small compared with the expected extension.

Tensioning shall be such that a controlled total force is imposed gradually and no dangerous secondary stresses are induced in the tendons, anchorage or concrete.

The force in the tendons during tensioning shall be measured by direct reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. Facilities shall be provided for the measurement of the extension of the tendon and of any movement of the tendon in the gripping devices. The load-measuring device shall be calibrated to an accuracy within plus or minus 2% and checked at frequent intervals agreed with the Engineer. Elongation of the tendon shall be measured to an accuracy within 22% or 2 mm, whichever is more accurate.

Complete records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge, or load-cell readings and the amount of pull-in at each anchorage. Anchorage of the tendons at the rock face end of the borehole shall conform to BS 4447.

The form of anchorage system shall facilitate the even distribution of stress in the concrete bearing pad.

Split wedge and barrel-type anchors shall be of such material and construction that, under the loads imposed during the tensioning operation, the strain in the barrel will not allow such movement of the wedges to reach the limit of their travel before causing sufficient lateral force to grip the tendon, or before the limit of travel of the wedges causes an excessive force in the tendon.

If proprietary forms of anchorage are used, the anchoring procedure shall be in accordance with the manufacturer's instructions and recommendations and as approved by the Engineer.

All bearing surfaces of the anchorages of whatever form shall be clean prior to the tensioning operation.

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

After tendons have been anchored, the force exerted by the tensioning apparatus shall be decreased gradually and steadily so as to avoid shock to the tendon or the anchorage.
Provision shall be made for the protection of anchorages against corrosion.

G. Grouting for Rock Anchors

G.1 The space in the borehole around the tendons shall be grouted with a cement grout such that the void shall be completely filled.

G.2 Grouting shall be carried out as soon as practicable after the tendons have been stressed.

G.3 Grouting procedures, injection of grout and strength of grout shall be as specified for Rock Bolting.

H. Testing of Rock Anchors

H.1 Before commencement of any part of the permanent anchorage works, two trial anchors shall be installed and tested to ensure that they can carry the specified load with a safety factor of 2. anchor pull tests shall be performed according to ASTM D4435 Standard method or BS equivalent

H.2 Load/elongation curves shall be plotted and interpreted by the Contractor and presented with all relevant data in a form approved by the Engineer.

H.3 If either of the trial tests show that the anchor has a safety factor of less than 2, then the anchorage length and formation shall be modified and two further tests shall be carried out.

H.4 All such trial tests and retests shall be at the Contractor's expense.

H.5 Nail Testing

Perform both verification and proof testing of designated test nails. Perform pre-production verification tests on sacrificial test nails at locations shown on the Plans or listed herein. Perform proof tests on production nails at locations selected by the Engineer. Required nail test data shall be recorded. Do not perform nail testing until the nail grout and shotcrete facing have cured for at least 72 hours and attained at least their specified 3-day compressive strength. Testing in less than 72 hours will only be allowed if the Contractor submits compressive strength test results, for tests performed by a qualified independent testing lab, verifying that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strengths in the lesser time.

1. Proof Test Nail Unbounded Length

   Provide temporary unbounded lengths for each test nail. Isolate the test nail bar from the shotcrete facing and/or the reaction frame used during testing. Isolation of a test nail through the shotcrete facing shall not affect the location of the reinforcing steel under the bearing plate. Accepted proof test nails may be

incorporated as production nails provided the temporary test unbounded length is fully grouted subsequent to testing. Submit the proposed test nail isolation methods, methods for providing an unbounded test length and methods for grouting the unbounded length subsequent to testing to the Engineer for review and approval in accordance with the Submittals section. Where temporary casing of the unbonded length of test nails is provided, install the casing in a way that prevents any reaction between the casing and the grouted bond length of the nail and/or the stressing apparatus.

2. Testing Equipment

Testing equipment shall include dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The load cell is required only for the creep test portion of the verification test. Provide description of test setup and jack, pressure gage and load cell calibration curves in accordance with Submittals section.

Design the testing reaction frame to be sufficiently rigid and of adequate dimensions such that excessive deformation of the testing equipment does not occur. If the reaction frame will bear directly on the shotcrete facing, design it to prevent cracking of the shotcrete. Independently support and center the jack over the nail bar so that the bar does not carry the weight of the testing equipment. Align the jack, bearing plates, and stressing anchorage with the bar such that unloading and repositioning of the equipment will not be required during the test.

Apply and measure the test load with a hydraulic jack and pressure gage. The pressure gauge shall be graduated in 50-psi increments or less. The jack and pressure gauge shall have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel shall be sufficient to allow the test to be done without resetting the equipment. Monitor the nail load during verification tests with both the pressure gauge and the load cell. Use the load cell to maintain constant load hold during the creep test load hold increment of the verification test.

Measure the nail head movement with a dial gauge capable of measuring to 0.001 inches. The dial gauge shall have a travel sufficient to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the nail and support the gauge independently from the jack, wall or reaction frame. Use two dial gauges when the test setup requires reaction against a soil cut face.

3. Pre-production Verification Testing of Sacrificial Test Nails

Pre-production verification testing shall be performed prior to installation of production nails to verify the Contractor's installation methods and nail pullout resistance. Perform pre-production verification tests at the locations and elevations shown on the Plans or herein and per Nail Installation Section 3(c), unless otherwise approved by the Engineer. Perform a minimum of 2 verification tests in each different soil/rock unit and for each different drilling/grouting method proposed to be used, at each wall location. Verification test nails will be sacrificial and not incorporated as production nails. Bare bars can be used for the sacrificial verification test nails.

Develop and submit the details of the verification testing arrangement including the method of distributing test load pressures to the excavation surface (reaction frame), test nail bar size, grouted drillhole diameter and reaction frame dimensioning to the Engineer for approval in accordance with Submittals section. Construct verification test nails using the same equipment, installation methods,

nail inclination, and drillhole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer and shall be provided at no additional cost. Payment for additional verification tests required due to differing site conditions, if determined by the Engineer, shall be per the Contract unit price.

Test nails shall have both bonded and temporary unbonded lengths. Prior to testing only the bonded length of the test nail shall be grouted. The temporary unbounded length of the test nail shall be at least 3 feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 bars. The Contractor shall provide larger verification test bar sizes, if required to safely accommodate the 10-foot minimum test bond length and testing to 2 times the allowable pullout resistance requirements, at no additional cost.

The verification test bonded length LBV shall not exceed the test allowable bar structural load divided by 2 times the allowable pullout resistance value. The following equation shall be used for determining the verification test nail maximum bonded length to be used to avoid structurally overstressing the verification test nail bar size:

LBV = C fY AS / 2 Qd , or 10 feet, whichever is greater.

LBV = Maximum Verification Test Nail Bonded Length (feet)

C = 0.9 for Grade 60 bars

fY = Bar Yield or Ultimate Stress (psi)

(Note: fY = 60 ksi for Grade 60 bars)

AS = Bar Steel Area (in2)

2 = Pullout resistance safety factor

Qd = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during verification testing shall be determined by the following equation:

DTL = Design Test Load (lbs) = LBV x Qd

LBV = As-built bonded test length (ft)

Qd = Allowable pullout resistance (lbs/ft. pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

MTL = 2.0 x DTL = Maximum Test Load (lb)

Verification test nails shall be incrementally loaded to a maximum test load of 200 percent of the Design Test Load (DTL) in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

VERIFICATION TEST LOADING SCHEDULE

LOAD	HOLD TIME
AL (.05 DTL max.)	1minute
0.25 DTL	10minutes
0.50 DTL	10minutes
0.75 DTL	10minutes
1.00 DTL	10minutes
1.25 DTL	10minutes
1.50 DTL (Creep Test)	60 minutes
1.75 DTL	10minutes
2.00 DTL(Max.Test Load)	10 minutes

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 5 percent of the Design Test Load (DTL). Dial gauges should be set to "zero" after the alignment load has been applied.

Each load increment shall be held for at least 10 minutes. The verification test nail shall be monitored for creep at the 1.50 DTL load increment. Nail movements during the creep portion of the test shall be measured and recorded at 1 minute, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes. The load during the creep test shall be maintained within 2 percent of the intended load by use of the load cell.

4. Proof Testing of Production Nails

Perform proof testing on 5 percent (1 in 20) of the production nails in each nail row or minimum of 1 per row as designated by the Engineer. A verification test nail successfully completed during production work shall be considered equivalent to a proof test nail and shall be accounted for in determining the number of proof tests required in that particular row.

Production proof test nails shall have both bonded and temporary unbonded lengths. Prior to testing only the bonded length of the test nail shall be grouted. The temporary unbonded length of the test nail shall be at least 3 feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. Production proof test nails shorter than 4 meters in length may be constructed with less than the minimum 10-foot bond length with the unbonded length limited to 3 feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 bars.

The proof test bonded length LBP shall not exceed the test allowable bar load divided by 1.5 times the allowable pullout resistance value, or above minimum lengths, whichever is greater. The following equation shall be used for sizing the proof test nail bonded length to avoid overstressing the production nail bar size:

LBP = C fY AS / 1.5 Qd , or above minimum lengths, whichever is greater.

LBP = Maximum Proof Test Nail Bonded Length (ft)

C = 0.9 for Grade 60 bars

fY = Bar Yield or Ultimate Stress (psi)

(Note: fY = 60,000 psi for Grade 60 bars)

AS = Bar Steel Area (in2)

1.5 = Pullout resistance safety factor

Qd = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during proof testing shall be determined by the following equation:

DTL = Design Test Load (lb) = LBP x Qd

LBP = As-built bonded test length (ft)

Qd = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

MTL = 1.5 x DTL = Maximum Test Load (lb)

Proof tests shall be performed by incrementally loading the proof test nail to a maximum test load of 150 percent of the Design Test Load (DTL). The nail movement at each load shall be measured and recorded by the Engineer in the same manner as for verification tests. The test load shall be monitored by a jack pressure gauge with a sensitivity and range meeting the requirements of pressure gauges used for verification test nails. At load increments other than maximum test load, the load shall be held long enough to obtain a stable reading. Incremental loading for proof tests shall be in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

PROOF TEST LOADING SCHEDULE

LOAD	HOLD TIME
AL (.05 DTL max.)	Until Stable
0.25 DTL	Until Stable
0.50 DTL	Until Stable
0.75 DTL	Until Stable
1.00 DTL	Until Stable
1.25 DTL	Until Stable
1.50 DTL (Max. Test Load)	See Below

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 5 percent of the Design Test Load (DTL). Dial gauges should be set to "zero" after the alignment load has been applied.

All load increments shall be maintained within 5 percent of the intended load. Depending on performance, either 10 minute or 60 minute creep tests shall be performed at the maximum test load (1.50 DTL). The creep period shall start as soon as the maximum test load is applied and the nail movement shall be measured and recorded at 1 minutes, 2, 3, 5, 6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 1 mm, the maximum test load shall be maintained an additional 50 minutes and movements shall be recorded at 20 minutes, 30, 50, and 60 minutes.

5. Test Nail Acceptance Criteria

   a. For verification tests, a total creep movement of less than 2 mm per log cycle of time between the 6 and 60 minute readings is measured during creep testing and the creep rate is linear or decreasing throughout the creep test load hold period.

   b. For proof tests, a total creep movement of less than 1 mm is measured between the 1 and 10 minute readings or a total creep movement of less than 2 mm is measured between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.

   c. The total measured movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.

   d. A pullout failure does not occur at the maximum test load. Pullout failure is defined as the load at which attempts to further increase the test load simply result in continued pullout movement of the test nail. The pullout failure load shall be recorded as part of the test data.

   Successful proof tested nails meeting the above test acceptance criteria may be incorporated as production nails, provided that (1) the unbonded length of the test nail drillhole has not collapsed during testing, (2) the minimum required drillhole diameter has been maintained, (3) the specified corrosion protection is provided, and (4) the test nail length is equal to or greater than the scheduled production nail length. Test nails meeting these requirements shall be completed by satisfactorily grouting up the unbonded test length. Maintaining the temporary unbonded test length for subsequent grouting is the Contractor's responsibility. If the unbonded test length of production proof test nails cannot be satisfactorily grouted subsequent to testing, the proof test nail shall become sacrificial and shall be replaced with an additional production nail installed at no additional cost.

I. Application of Sprayed Concrete and Mortar

I.1 Cut out and replaced any sprayed concrete which in the opinion of the Engineer is not approved.

I.2 Clean and wet all surfaces thoroughly with a strong blast of air and water, immediately prior to the application of sprayed concrete.

I.3 Control the thickness and the alignment of the sprayed material by either guide wires, mortar spotting or plastic studs, to indicate depth. Drill through the concrete lining to establish the thickness of the lining at points selected by the Engineer. Build up each layer of sprayed concrete or mortar by making several passes of the nozzle over the working area. Emerge the sprayed concrete or mortar from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any reason, the nozzle man shall direct it away from the work until it again becomes constant.

I.4 The distance of the nozzle from the work shall be between 600mm and 1500mm. It shall be, as a general rule, aimed perpendicular to the application surface. Commence application for vertical or near vertical surfaces, at the bottom. Embed completely the reinforcement, at least, in the first layer.

I.5 Layer thickness is governed mainly by the requirement that the concrete or mortar should not sag. Where thick layers are applied it is important that the top surface be maintained at approximately a 45 degree slope.

I.6 Where necessary a layer of sprayed concrete or mortar may be covered by succeeding layers, but it shall first allowed to take its initial set. All laitance, loose material and rebound must first be removed. Remove any laitance, which has taken final set by grit blasting. Finally clean and wet the surface using a strong blast of air and water. The time between application of successive layer shall not exceed 24 hours. A longer break may be accepted if it can be shown by tests that sufficient bond can be achieved.

I.7 Under no circumstances shall rebound material be worked back into the construction. Keep the work continually free of rebounded material, by the continuous use of a high pressure air jet or any other necessary means.

I.8 Damp cure sprayed concrete or mortar for at least 7 days.

I.9 Provide suitable screening of the nozzle and the application surface during windy and draughty conditions.

I.10 Keep the spraying equipment in good condition by cleaning frequently. This shall be done at least once per shift. The spraying nozzle shall be in such condition that an even and continuous flow of material is obtained. Change nozzle cover as soon as excessive wear is found in the cover. The arrangement for the addition of water at the nozzle, if used, must give a uniform wetting of the material. If the dry mix process is used, add liquid admixtures, if approved, with the mixing water at the nozzle. In case dry admixture is used, add it into the dry mix at the latest possible time. In either case, employ accurately calibrated and adjustable mechanical means to dispense the admixture in the correct approved proportions.

I.11 The capacity of the compressor plant and water supply shall be large enough to ensure a constant and sufficiently high pressure. The water pressure should be somewhat higher than the air pressure. Manometers should be provided to measure the air and water pressure.

I.12 Provide good lighting, rigid and sufficiently wide working platforms in area where shotcreting is taking place.

I.13 Carry out shotcreting in a sequence and according to a program to be approved by the Engineer.

I.14 Protect properly surfaces which are not to be coated and keep them free from sprayed concrete.

I.15 Avoid spraying through the reinforcement as the reinforcement can make hollows and arching effect, which hinder the production of a homogeneous concrete layer. Fix reinforcement as late as possible. If a number of reinforcement layers are used then they shall be fixed and concreted one at a time. When shooting through bars is unavoidable, hold the nozzle closer than usual and at a slight angle in order to permit better encasement, and facilitate the removal of rebound. Clean reinforcement of any previously deposited rebound material which may prevent a proper bond.

I.16 Construction joints shall be tapered to a thin edge over a width of approximately 300mm, unless specifically instructed by the Engineer. No square joints are allowed. Clean and wet the entire joint thoroughly prior to the placement of adjacent sprayed material.

I.17 The reinforcing mesh shall be made up from 5mm diameter steel bars. Weld the bars to form a 150mm square grid and fix it firmly to the rock by an approved means such that it is rigidly held during the subsequent application of sprayed concrete. Ties, anchors and supports shall be of a material approved by the Engineer.

I.18 The method of fixing shall be such that sprayed concrete can be compacted soundly behind the reinforcement at all points.

I.19 The minimum cover of mesh reinforcement to the rock surface is to be 25mm. The minimum cover to mesh reinforcement from the required finished surface of the sprayed concrete is to be 20mm.

I.20 Sprayed concrete or mortar surfaces are not to be trowelled, screeded or disturbed in any way unless specified otherwise.

I.21 Make the profile of the finished surface even. Fill any area of excessive overbreak with sprayed concrete, or other approved cavity filler, to bring the finished surface level with the general profile of the surrounding finished sprayed concrete or mortar.

I.22 Safety: if the exposed rock profile is considered by the Engineer to be unsafe, then ensure that the personnel manning the sprayed concrete operation are protected from falling rock. In this respect the Contractor is advised to consider the use of a remote controlled-sprayed concrete machine.

J. Wire Netting

J.1 Wire netting is to be used to secure loose rock on the cut slopes it may be used in conjunction with rock bolts and sprayed concrete. The netting is to be secured to the rock face in a manner approved by the Engineer.

K. Geogrid

K.1 For Rock Slopes

In order to provide a reasonably flat surface for the grid the branches of larger bushes and trees shall be removed. Rows of 15mm fully-bonded rockbolts shall be then installed both behind the crest of the slope and along the base of the slope. The rockbolts shall penetrate at least 1m into solid chalk. Eye nuts shall be then screwed onto the tops of the bars.

A steel cable shall be passed through the eye nuts and at the same time, laced through the apertures of the grid. The steel cable shall be then tensioned using a turnbuckle and anchor bolts at each end. The top and bottom of each roll of grid shall be then folded around the cable and laced with HDPE braid. This will achieve secure fixings at the top.

Adjacent rolls widths shall be overlapped and stitched to form secure vertical joints.

K.2 For Grass Slopes

1. Prepare the slope to be treated by trimming the profile.
2. Place 50-70mm of topsoil on the prepared slope (this is optional depending on the soil type and uniformity of the prepared slope).
3. Unroll the mat down the face of the slope flat side down, lapping adjacent strips by a minimum of 100mm.
4. Fixings (either Pegs or approved mild steel pins) should be at around 1m centres (depending on the slope angle) along the laps.
5. Bury the top and bottom ends of each strip at the shoulder and the toe, respectively, in shallow trenches typically 450mm wide by 250mm deep.
6. Sow grass seed into the mat.
7. Brush friable soil into the full depth of the mat.
8. Re-sow the slope and apply (optional) fertilizer.
9. Lightly tamp the soil surface.

Omit steps 6 to 9 for planted slopes. The soil-filled mats can be slit longitudinally to accommodate planting.

2.10.04 MEASUREMENT

2.10.04.1 Permanent Nails

The rates shall include the following items:

A. Rock Grouting of Slopes including grouting materials furnished, injected, completed, and accepted.

B. Boreholes for rock grouting of slopes, drilled, cleaned out, completed, and accepted.

C. Rock Bolts as per category furnished, installed including borehole drilling, grouted, debouned if required, completed, and accepted.

D. Rock Anchors: all anchors of each specified capacity, furnished, installed including borehole drilling, tensioned, completed, and accepted.

E. Nail testing: Specified verification test nails will be measured on a unit basis for each verification test successfully completed. Failed verification test nails or additional verification test nails installed to verify alternative nail installation methods proposed by the Contractor will not be m

F. Jetting of fractured rock, water testing of boreholes, debounding of rock bolts, trial belts and trial rock anchors, testing and monitoring of rock bolts, and rock anchors, grouting of rock belts and rock anchors, 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.

2.10.04.2 Shotcrete

The rates shall include the following items:

A. Shotcrete (concrete) or gunite (mortar) furnished, applied, complete and accepted.

B. Wire netting and reinforcing mesh furnished, installed, completed and accepted.

2.10.04.3 Geogrid

The rates shall include the following items:
Geogrid furnished, installed, completed and accepted

PAY ITEMS	UNIT OF MEASUREMENT
(1) Permanent Soil Nails	Linear Meter (m)
(2) Verification Test Nails	Number (Nr)
(3) Shotcrete	Square Meter (m^2)
(4) Geogrid	Square Meter (m^2)

SECTION -3-

SUBBASE AND BASE COURSES

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SECTION 3.01 MATERIALS FOR SUB-BASE AND BASE COURSES

3.01.01 SCOPE

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

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

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

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

3.01.02 GENERAL

A. Sources and Production

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

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

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

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

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

B. Stockpiling

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

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

C. Sampling and Testing

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

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

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

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

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

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

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

3.01.03 GRANULAR MATERIAL FOR SUB-BASE

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

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

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

Table 3.1.1: Gradation of Granular Material by Class

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

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

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

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

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

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

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

3.01.04 AGGREGATE FOR BASE COURSES

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

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

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

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

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

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

Table 3.1.2: Gradation of Base Course Aggregate by Class

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

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

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

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

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

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

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

3.01.05 STABILIZING AGENTS

A. Cement as Stabilizing Agent

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

B. Bitumen as Stabilizing Agent

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

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

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

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

C. Lime as Stabilizing Agent

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

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

3.01.06 MEASUREMENT

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

SECTION 3.02 GRANULAR SUB-BASE COURSE

3.02.01 SCOPE

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

3.02.02 MATERIALS

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

3.02.03 SUBGRADE SURFACE PREPARATION

A. The subgrade shall have previously been constructed in accordance with the requirements of Section 2.07 - "Subgrade Construction" and properly maintained and kept well drained thereafter.

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

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

3.02.04 EQUIPMENT

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

3.02.05 CONSTRUCTION OF TRIAL SECTIONS

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

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

3.02.06 CONSTRUCTION

A. Stockpiling of Granular Material

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

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

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

B. Mixing and Spreading

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

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

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

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

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

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

B.7 Neither hauling nor placement of material will be permitted when, in the judgment of the Engineer the weather or surface conditions are such that hauling operations will

cause cutting or rutting of the subgrade or cause contamination of the sub-base material.

C. Compaction

C.1 The Contractor shall plan the sequence of operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If the Contractor delays placing of succeeding layers of material to the extent that additional water is required to prevent raveling or excessive drying the application of such water shall be carried out as directed and at the Contractor's expense.

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

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

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

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

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

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

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

D. Tolerances

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

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

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

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

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

E. Maintenance of Completed Sub-base

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

3.02.07 TESTING

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

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

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

3.02.08 MEASUREMENT

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

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

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

SECTION 3.03 AGGREGATE BASE COURSE

3.03.01 SCOPE

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

3.03.02 MATERIALS

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

3.03.03 SURFACE PREPARATION

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

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

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

3.03.04 EQUIPMENT

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

3.03.05 CONSTRUCTION OF TRIAL SECTIONS

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

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

3.03.06 CONSTRUCTION

A. Stockpiling of Aggregate Materials

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

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

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

B. Mixing and Spreading

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

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

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

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

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

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

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

C. Compaction

C.1 The Contractor shall plan the sequence of operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If the Contractor delays placing of succeeding layers of material to the extent that additional water is required to prevent raveling or excessive drying, the application of such water shall be carried out in an approved manner and at the Contractor's expense.

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

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

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

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

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

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

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

D. Tolerances

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

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

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

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

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

E. Maintenance of Completed Base

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

3.03.07 TESTING

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

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

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

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

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

3.03.08 MEASUREMENT

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

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

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

SECTION -4-

BITUMINOUS CONSTRUCTION

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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 graded bitumens, cutback bitumens, emulsified bitumens, modified bitumens, and rejuvenating agents for use in bituminous courses and surface treatments.

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

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

4.01.02 AGGREGATE MATERIALS GENERALLY

A. Sources and Production

A.1 The Contractor shall have satisfied himself as to the location, suitability and quantity of materials available; extent of work necessary to obtain the material available, the work required to open the quarry and to crush, screen and wash (if necessary) the materials; and the length of haul to the Site.

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

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

A.4 Approval of the crushing and screening plants and other equipment shall in no way relieve the Contractor of his responsibilities in respect of producing aggregate which conform to the Specifications and in the quantities required for the completion of the Works on time.

B. Stockpiling

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

B.2 Stockpiling procedures shall not result in degradation or segregation of the stockpiled

material, or introduction of foreign materials into the stockpile. Heights of aggregate stockpiles shall not exceed 5 m.

C. Sampling and Testing

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

C.2 The Contractor shall submit to the Engineer, 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 in 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 locations, extent of deposits and quantities of materials which will conform to the Specifications when properly processed. Any special tests that may be required by the Engineer shall be carried out by the Contractor, in his own laboratory, or an outside laboratory, approved by the Engineer. All testing as carried out by the Contractor shall in no way obviate the need for further testing by the Engineer. Approval of specific sources of materials shall not be construed as final approval and acceptance of materials from such sources.

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

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

4.01.03 AGGREGATES FOR BITUMINOUS PAVING MIXES

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

B. Coarse aggregate shall be the fraction of crushed aggregate material retained on 4.75 mm (No. 4) sieve. Fine aggregate shall be the fraction of crushed aggregate material passing 4.75 mm (No. 4) sieve. Mineral filler shall be added when the combined grading of coarse and fine aggregates is deficient in material passing 0.075 mm (No. 200) sieve.

C. The material from hot bins passing the number 40 sieve (0.425 mm) when tested in accordance with AASHTO T90 shall be non plastic. In addition the material from cold bins should not have PI larger than 4.

D. Aggregates shall not contain gypsum more than 1 % and the coarse fraction of the aggregate shall not contain more than 5% chert.

E. Aggregates shall be of uniform quality, free from decomposed stone, organic matter, shale.

F. The percentage by weight of friable particles, clay lumps, and other deleterious matter shall not exceed 1% as determined by AASHTO T 112.

G. Aggregate particles shall be clean, hard, durable and sound. Crushing shall result in a product such that, for particles retained on 4.75 mm (No. 4) sieve, at least 90 % by weight shall have 2 or more fractured faces.

H. The flakiness index and the elongation index test should be conducted in accordance with BS 812, the following are maximum limits :

	Wearing Course	Binder & Bituminous Base Course
Flakiness Index F.I	25	30
Elongation Index E.I	25	30

I. Aggregates shall be washed if directed, 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.

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

K. Combined coarse and fine aggregates for bituminous mixes, including mineral filler, when tested in accordance with AASHTO T 27 and T11, shall conform to the gradations shown in Table 4.1.1.

Table 4.1.1: Gradation of Aggregates for Bituminous Mixes

SIEVE SIZE		PER CENT PASSING	
		Base Course	**Wearing Course**
1"	(25.0 mm)	100	----
3/4"	(9.0 mm)	65-100	100
3/8"	(9.5 mm)	47-72	56-80
No. 4	(4.75 mm)	30-56	35-56
No. 10	(2.00 mm)	19-36	22-36
No. 40	(0.425 m)	8-20	8-20
No. 200	(0.075 mm)	2-8	2-8

L. The loss in weight of aggregate after 500 revolutions when tested in accordance with AASHTO T 96 shall not exceed 35 %.

M. When tested for soundness in accordance with AASHTO T 104 the coarse aggregate (retained on No. 4 sieve) shall not show signs of disintegration and the loss by weight after 5 cycles shall not exceed 10% in the case of the sodium sulfate lest and 12 % in the case of the magnesium sulfate test.

N. When tested for resistance to stripping in accordance with the AASHTO T- 182 at least 95 % coated particles should be achieved.

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. Wadi gravels shall not be used for seal coats suitability of suggested crushed stone fines for use in slurry seal shall be demonstrated prior to use.

B. Aggregates shall not contain crystalline or amorphous gypsum (expressed as SO3) more than 1 % 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 Index and Elongation Index tested in accordance with BS-812 shall not exceed 25 % for each of flakiness and elongation index . The percentage by weight of clay lumps & friable particles as determined by AASHTO T 112 shall not exceed 3 %. Light weight aggregate of specific gravity of 2 or less shall not exceed 3 % as determined by AASHTO T 113.

E. If necessary, aggregates shall be washed or processed by any alternative approval 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, when tested in accordance with AASHTO T 27 and T11, shall conform to the gradations given in Table 4.1.2.

Table 4.1.2: Gradation of Aggregates for Seal Coats

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

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

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

A. Type and Grade

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 will 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 if necessary, 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 an approved sampling device which shall be built into the tank or recirculating or discharge line in such a manner that a sample can be drawn during circulation or discharge.

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 should be clean and stable and provided with cover and shelter from excessive temperatures.

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

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

C.4 If the bitumen is delivered to the site in metal drums, on arrival the drums shall be inspected for:

- Perforations
- Rusting
- Melting

Other defects that would directly cause pollution or chemical changes to the bitumen.

Any drum(s) showing any of these defects shall be rejected at the discretion of the Engineer.

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

D. Heating of Bitumen

D.1 Heating equipment shall be of an approved type. Any method of agitation or heating that introduces free steam or moisture into the bitumen will not be approved During the process of its manufacture, conveyance, storage, or construction use, bitumen of whatever type shall not be heated to temperatures more than10 degrees C above the maximum application temperature specified for the respective type of bitumen nor above 170 degrees C, whichever is the lower. Materials heated in excess of these temperatures will be rejected and shall 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 insure proper and continuous circulation of the bitumen during the entire operating period. Suitable means shall be provided, either by steam or oil jacketing, or other insulation, for maintaining the required temperature of bitumen, weigh buckets, spray bars, and other containers.

D.3 Thermometers of approved type and adequate range (calibrated in 2 degrees 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 with the requirements of part 1 of specifications Section 4-6 “Samples and Approvals”.

4.01.06 BITUMEN PRODUCTS

A. Penetration Graded Bitumen

A.1 The various grades of penetration graded bitumen Asphalt cement shall conform generally with the requirements of AASHTO M 20 as given in Table 4.1.3

Table 4.1.3: PROPERTIES OF PENETRATION GRADE BITUMEN

	Penetration Grade					
	40 -50		60 - 70		85 - 100	
	Min	Max	Min	Max	Min	Max
Ductility at 25°C (cm)	100	-	100	-	100	-
Penetration at 25°C (0.1 mm)	40	50	60	70	85	100
Softening Point (° C)	50	58	48	56	45.8	48
Specific Gravity at 25°C	1.01	1.06	1.01	1.06	1.0	-
Loss on heating 163°C	-	0.8	-	0.8	-	1.0
Penetration of residue % of original	58	-	54	-	50	-
Solubility in Trichlorethylene (% wt)	99	-	99	-	99	-
Ash content % wt	-	1.0	-	1.0	-	1.0
Flashpoint (Cleveland Open Cup.) (°C)	250	-	250	-	225	-

A.2 Sampling and testing shall be in accordance with the AASHTO standard method listed in AASHTO M 20.

A.3 Penetration bitumen application temperature range shall be so that appropriate viscosity range for each application is achieved . If however the viscosity curve arc not available the values given in table 4.1.4 shall be generally considered as a guidance.

Table 4.1.4: BITUMEN GRADE

	40/50	60/70	80/100
Application Temperature °C	150-170	145-165	140-160

B. Bitumen Modifier

B.1 An approved modifier shall be incorporated in all penetration graded bitumens whenever specified immediately prior to the time of use unless otherwise shown on the Drawings. The modifier (catalyst) shall serve to polymerize the bitumen by converting the benzylic carbon groups into ketones.

B.2 The modified bitumen shall demonstrate significantly reduced temperature susceptibility and/or improved adhesive qualities. The workability of the modified bitumen shall be unchanged from that of unmodified bitumen.

B.3 The mixing and preparation of Modified Bitumen shall be carried out in accordance with the manufacturers instructions, and with the approval of the Engineer.

C. Rapid-Curing (RC) Cutback Bitumen

C.1 RC cutback shall conform with the requirements of AASHTO M 81, which covers Grades RC-70, RC-250, RC-800, and RC-3000 and are listed in Table 4. 1.5.

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

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

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

D. Medium-Curing (MC) Cutback Bitumen

D.1 MC cutback shall conform with the requirements of AASHTO M 82, which covers Grades MC-30, MC-70, MC-250, MC-800 and MC-3000 and are listed in Table 4.1.6.

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

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

MC Cutback Grade	Spraying Temp °C
MC - 30	21 - 63
MC - 70	45 - 80
MC - 250	70 - 110
MC - 800	95 - 125
MC - 3000	110 - 145

E. Slow-Curing (SC) Cutback Bitumen

E.1 SC cutback shall conform with the requirements of ASTM D 2026 which covers Grades SC-70, SC-250, SC-800, and SC-3000, and are shown in Table 4.1.7.

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

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

MC Cutback Grade	Spraying Temp °C
SC - 70	45 - 80
SC - 250	70 - 110
SC - 800	95 - 125
SC - 3000	110 - 145

F. Emulsified Bitumens Generally

F.1 Selection and use of emulsified bitumens shall generally be in accordance with the recommendations in AASHTO R5 or in NF T 65-011, subject to the following requirements.

F.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.

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

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

F.5 All emulsified bitumens shall adhere firmly to the surface of the mineral aggregate or the road 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.

G. Anionic Emulsified Bitumen

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

Table 4.1.5: PROPERTIES OF R.C. CUTBACK BITUMEN

	RC – 70		RC - 250		RC - 800		RC - 3000	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Kinematic Viscosity at 60 °C centistokes	70	140	250	500	800	1600	3000	6000
Flash Point (Tag, open-cup) degrees °C	-	-	27	-	27	-	27	-
Water, percent	-	0.2	-	0.2	-	0.2	-	0.2
Distillation test:								
Distillate, percentage by volume of total distillate to 360 °C								
to 119°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	55	-	65	-	75	-	85	-
Tests on residue from distillation:								
Absolute viscosity at 60 °C poises	600	2400	600	2400	600	2400	600	2400
Ductility, 5 cm/min at 25 °C cm	100	-	100	-	100	-	100	-
Solubility in Trichloroethylene, percent	99.	-	99.	-	99.	-	99.	-
Spot test with:								
Standard naphtha	Negative for all grades							
Naphtha-xylene solvent - percent xylene	Negative for all grades							
Heptane-xylene solvent, - percent xylene	Negative for all grades							

Table 4.1.6: PROPERTIES OF M.C. CUTBACK BITUMEN

	MC - 30		MC – 70		MC - 250		MC - 800		MC - 3000	
	Min.	Max	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Kinematic Viscosity at 60 °C centistokes	30	60	70	140	250	500	800	1600	3000	6000
Flash Point (Tag, open-cup) degrees °C	38	-	38	-	66	-	66	-	66	-
Water, percent	-	0.2	-	0.2	-	0.2	-	0.2	-	0.2
Distillation test: Distillate, percentage by volume of total distillate to 360 °C										
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	50	-	55	-	67	-	75	-	80	-
Tests on residue from distillation:										
Absolute viscosity at 60 °C poises	300	1200	300	1200	300	1200	300	1200	300	1200
Ductility, 5 cm/min cm	100	-	100	-	100	-	100	-	100	-
Solubility in Trichloroethylene, percent	99.	-	99.	-	99.	-	99.	-	99.	-
Spot test with:										
Standard naphtha	Negative for all grades									
Naphtha-xylene solvent - percent xylene	Negative for all grades									
Heptane-xylene solvent, - percent xylene	Negative for all grades									

Table 4.1.7: PROPERTIES OF S.C. CUTBACK BITUMEN

	SC - 70		SC - 250		SC - 800		SC - 3000	
	Min	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Kinematic Viscosity at 60 °C centistokes	70	140	250	500	800	1600	3000	6000
Flash Point (Cleveland open-cup) °C	66	-	79	-	93	-	107	-
Distillation test:								
Total distillate to 360°C, volume %	10	30	4	20	2	12	-	5
Solubility in trichloroethylene %	99.	-	99.	-	99.	-	99.	-
Kinematic viscosity on distillation residue at 60°C, St	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	-	0.5	-	0.5	-	0.5	-	0.5
Water, %								

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

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

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

G.3 Emulsified bitumen spraying temperature range shall be so that appropriate viscosity for each application is achieved, if however the viscosity curves are not available these values, generally considered as guidance, shall be 25 - 65 degrees C (except for Grade RS-2 where the range shall be 50-75 degrees C). The temperature range for pugmill mixing for medium and slow setting types shall be 15-65 degrees C.

H. Cationic Emulsified Bitumen

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

Table 4.1.9: PROPERTIES OF CATIONIC EMULSIFIED BITUMEN

	Slow-Setting CSS-1	
	Min.	Max.
Tests on emulsions:		
Viscosity, Saybolt Furol at 25°C, s	200	100
Storage stability test, 24-h, %	1	
Particle charge test	Positive	
Sieve test, %		
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 trichlorocthylene %	97.5	

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

H.3 Emulsified bitumen spraying temperature range shall be so that appropriate viscosity for each application is achieved if however the viscosity curve are not available these values generally considered as guidance shall be 25-65 degrees C (except for Grade GRS-2 where the range shall be 50-75 degrees C). The temperature range for pugmill mixing for medium and slow setting types shall be 15-65 degrees C.

4.01.07 MEASUREMENT

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

SECTION 4.02 BITUMINOUS PRIME AND TACK COATS

4.02.01 SCOPE

These Works shall consist of furnishing and applying MC cutback or emulsified bitumen prime coat to a previously constructed subgrade, sub-base or aggregate base course, highway shoulders, or concrete pavement, and furnishing and applying emulsified bitumen as a tack coat to a previously constructed bituminous base or wearing surface to provide bond for a superimposed bituminous course; all 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. Generally MC 70 shall be used unless otherwise specified.

B. Emulsified Bitumen (Prime Coat)

Emulsified bitumen (for prime coats) shall be slow or medium Grades as appropriate and as specified in Section 4.01- "Materials for Bituminous Construction" or as required by the Engineer.

C. Emulsified Bitumen (Tack Coat)

Emulsified bitumen (for tack coats) shall be slow or medium or rapid setting Grades as appropriate and as specified in Section 4.01-"Materials for Bituminous Construction", or as required by the Engineer.

4.02.03 EQUIPMENT

Equipment used for emulsified bitumen, heating cutback bitumen, spraying cutback and emulsified bitumen, and for application of blotting material to prime coats, shall conform with the requirements of part 1 of specifications Section 4-4 -"Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

4.02.04 CONSTRUCTION OF TRIAL SECTIONS

A. The Engineer may, if he deems necessary, require 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 m 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.

4.02.05 APPLICATION PROCEDURES

A. General

A.1 All equipment used for surface cleaning, heating bitumen (if required) and application of prime and tack coats, shall be adequate for the purposes intended and shall be approved before use.

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

A.3 Application of prime coats and tack coats shall be performed only when the surface to be treated is sufficiently dry for tack coat and sufficiently moist for prime coat, and when the atmospheric temperature is above 10 oC for the application of tack coat, 15 oC for the application of prime coat. There should be no fog, rain, strong winds, dusty conditions, or dust storms.

A.4 Surfaces of all structures, curbs, gutters and other highway appurtenances shall be protected in an approved manner 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 scheduling priming or subsequent paving after priming, the surface tolerances and compaction of the granular course shall be reverified and deficient areas corrected or replaced in an approved manner 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, any surface defects repaired and the coat re-applied at the Contractor's expense. Traffic control measures shall conform with the relevant requirements of Section 6. 10-"Maintenance of Traffic and Detours".

B. Prime Coat Application

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

B.2 Heating of MC cutback bitumen and its temperature at the time of application shall conform with 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 including 200 mm widths outside the edges of the pavement line; top of embankment slopes to pavement lines,

and between curbs or gutter edges for bridge checks.

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

Range of Application Rates for Prime Coat

Type of Surface	**Kg/m2**
- Untreated subgrade surfaces, shoulders sub-base and base courses	0.75 - 2.0
- Bridge wearing surfaces, concrete pavements	0.1 - 0.4
- 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 (MC-70) cutback, or other grade if ordered by the Engineer, shall be applied at the rate selected by the Engineer, using approved type pressure distributors operated by skilled workmen. The spray nozzles and spray bar shall be adjusted and frequently checked so that uniform distribution is ensured. Spraying shall cease immediately upon any clogging or interference of any nozzle, and corrective measures taken before spraying is resumed.

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

B.8 Application of prime at the junction of spreads shall not be excessive. Any excess shall be removed from the surface and any skipped areas or recognized deficiencies shall be corrected by use of 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 approved material.

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) on clean dry surface and the rate shall be as ordered 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 with the relevant requirements of Section 4.03 "Bituminous Courses". Where slow setting emulsified bitumen (SS or CSS Type) is used for tack coat, it shall not normally require heating except in temperatures below 20 degrees C.

C.3 The rate of application shall be approved by the Engineer and after trial tests are carried out it shall be between 0.2 and 0.6 kg/m2. depending on whether RC cutback or emulsified bitumen is used and the surface condition of the bituminous course on which the tack coat is to be sprayed. The Engineer may alter the previously established

rates of application during 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 application shall not proceed so far in advance of the following course that it dries out completely.

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

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

4.02.06 MEASUREMENT

A. Bituminous Prime Coat shall be measured by the square meter of the areas primed at the appropriate rate specified by the Engineer. Bituminous prime coat for temporary diversions 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.

B. Bituminous tack coat shall be measured by the square meter of the areas tacked at the appropriate rate specified by the Engineer.

C. Surface preparation, protective measures to avoid staining or damage to appurtenances, blotting of prime coats when required, and cleaning stains and repairing damage caused by equipment, etc. shall not be measured for direct payment, but shall be considered as subsidiary 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) Bituminous Prime Coat	Square meter (m^2)
(2) Bituminous Tack Coat	Square meter (m^2)

SECTION 4.03 BITUMINOUS COURSES

4.03.01 SCOPE

A. These Works shall consist of the general requirements for furnishing materials, mixing at a central mixing plant, and spreading and compacting various bituminous concrete and other bituminous mixes, including installation of reinforcing fabric when specified, all as and where shown on the Drawings.

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

4.03.02 MATERIALS

A. Bituminous plant mixes shall generally be composed of coarse mineral aggregate, fine mineral aggregate, mineral filler or cement if required, and penetration graded bituminous with mix additives if specified, cutback bitumen or emulsified bitumen appropriate to the type of bituminous course to be constructed.

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

4.03.03 JOB MIXES AND PROJECT MIXES

A. At least 30 days prior to the date the Contractor intends to begin production at the mixing plant and after receiving approval of the aggregates, and after the delivery to the Site of the bitumen specified, the Contractor shall submit for approval his proposed Job Mix Formula.

B. The Job Mix Formula shall stipulate a single combined grading of all aggregate and filler materials showing the specific % by weight passing each sieve size and the specific % by weight 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 with the Marshall method of mix design and relevant procedures contained in Asphalt Institute Manual MS-2. 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 any) in such proportions as to produce a Job Mix which is within the limits of the specified gradation and bitumen content ranges and which meets the Marshall 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 directed, shall be 170 degrees C.

E. 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.

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.

G. In order to meet the requirements, an approved additive such as Portland cement, hydrated lime or liquid antistrip agent, maybe required 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 2-3% by weight of the aggregates and shall be added at the cold feed in dry or slurry form as directed. Liquid antistriping agent, if needed will normally be required in the approximate range of 0.6-1% by weight of the bitumen, or according to the manufacturers specifications.

H. Upon receipt of approval of the Job Mix Formula, the Contractor shall adjust his mixing plant to proportion the individual aggregates, mineral filler and bitumen to produce a final project mix within the limits given in Table 4.3.1 with respect to the Job Mix gradations:

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

Sieve Designation (square openings)	Specified Tolerances
9.5 mm (3/8 in.) and above	+ or - 5.0 %
4.75 mm (No. 4)	+ or - 4.0 %
2.00 mm (No. 10)	+ or - 4.0 %
0.425 mm (No. 40)	+ or - 4.0 %
0.18 mm (No. 80)	+ or - 4.0 %
0.075 mm (No. 200)	+ or - 1.0 %
Bitumen Content	to be recommended by designer
Temperature of Mix on discharge	+ or - 5°C

I. Any deviation from these limits shall be made only with the approval of the Engineer.

J. Conformance to gradation requirements will 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 will 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 reapproved 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 in no way relieve the Contractor of responsibility for producing project mixes meeting the specified requirements.

4.03.04 EQUIPMENT

A. General

Plant and equipment for mixing, transporting, spreading and compacting bituminous mixes, shall conform with the requirements of part 1 of specifications, Section 4-4 - "Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

B. Mixing Plant

B.1 Bituminous mixes shall be produced in an approved type batch mixing plant of adequate size with a minimum capacity of not less than 80 ton/hr and a mixer capacity of not less than 750 kg batch. The plant shall conform with the relevant requirements 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 town, or whenever they are required by law.

B.4 The cold feed system shall be of continuous belt feed type or other approved system It should be easily modified to allow hydrated lime slurry to be added to the mix prior to heating, and dry powdered lime 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 will only be considered in special circumstances. In such cases, 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 if not new and the manufacturer's specifications, shall be submitted for approval 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, on a weekly basis and also whenever suspect, the following key operational aspects of the mixing plant:

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

B.8 The Contractor shall furnish, for 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 Asphalt Institute Specification and Manuals MS-2, MS-3, MS-4, MS-8 and MS-22 shall be furnished by the Contractor for use by the Engineer's supervisory staff and, in addition, one copy of each as appropriate shall be issued to each of the Contractor's senior staff involved in bituminous course 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 approved type, 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 assembly with devices for heating the screed, and shall be capable of spreading and finishing the various courses of bituminous plant mix to the proper thickness and in lane and shoulder widths applicable to the typical cross sections shown on the Drawings, and in incremental widths down to 2.4 m minimum and up to 8 m maximum.

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

C.3 The paver shall be equipped with a receiving hopper having sufficient capacity for a uniform spreading operation The hopper 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 assembly 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. Speed shall be fully adjustable between 3 m/min and 6 m/min.

C.6 The automatic controls shall consist of an automatic linkage arrangement such that, through the process of automatically 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 m in length.

C.7 If during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities that are not satisfactorily corrected by scheduled operations, the use of such equipment shall be discontinued and other satisfactory spreading and finishing equipment shall be provided by the Contractor.

C.8 The Contractor shall make available, for reference by the Engineer, the manufacturer's instruction and operating manuals for each paver intended for use.

4.03.05 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 m long at approved locations close to the Site. Each trial section shall be laid using the same materials, proposed 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 methods and organization proposed.

D. If the trial section meets the required specification, the job Mix Formula will be approved.

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

4.03.06 MIXING PROCEDURES

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

B. Immediately after heating, the aggregates shall be screened into at least 3 sizes and conveyed into 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, 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. Just prior to bitumen entering the mixer, bitumen modifier (catalyst) or antistripping additive, if required, shall be thoroughly mixed with the bitumen which shall then be introduced into the pugmill mixer in the proportionate amount 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 other wise directed, the bitumen temperature shall be as given in Table 4.3.2.

Table 4.3.2:

Type and Grade of Asphalt	Viscosity (centistokes)	Max. Temperature °C Immediately after discharge from Pugmill
85 - 100 pen.	170 + 20	160
60 - 70 pen.	170 + 20	165
40 - 50 pen.	170 + 20	170

E. Any mix subjected to higher temperature 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 shal1 be determined by the Contractor in the presence of the Engineer. This time shall be determined 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 will be determined by the following formula or other approved methods: Mixing time (sec) = Pugmill dead capacity (kg) divided by pugmill output (kg/sec).

4.03.07 SURFACE PREPARATION

A. When the bituminous mix is to be placed on a prepared subgrade, subbase, 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.

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 and refilled with the specified bituminous mix.

D. Prior to placing of the bituminous mix on an existing bituminous surface when required, a tack coat as specified in Section 4.02 - "Bituminous Prime and Tack Coats" shall be applied to 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.

4.03.08 DELIVERY, SPREADING AND FINISHING

A. Delivery of Mix to Site

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

A.2 Hauling equipment for aggregates and bituminous mixes shall consist of vehicles having dump bodies suitable for dumping materials in a windrow or in spreader boxes. The bodies shall be so constructed that their volume measurement 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 equipement for hot bituminous mixes shall have tight clean smooth metal beds which are periodically thinly coated with a time 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 if permitted by the Engineer in special circumstances.

A.4 The dispatching of the hauling vehicles to the Site shall be so scheduled that all material delivered is placed at least 90 minutes before sunset to allow sufficient time for compaction unless the use of artificial light is approved. 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 discharge temperature at the mixing plant. The minimum temperature for the commencement of breakdown rolling is 120°C. Mix loads of temperature less than 120°C shall not be accepted and the load shall be disposed of and another load used. If there is 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 weight and net weight of each load for each vehicle and dates and time of loading.

B. Setting Out and Reference Lines

B.1 The Contractor shall survey the centerline profile and crown of the existing surface or base and determine a reference grade line which will be submitted 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 m maximum spacing unless there is noticeable sag in the line or the pavement surface, in which case the maximum spacing shall be 4 m.

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 will normally be required, if the paver is equipped with adequate automatic superelevation control.

C. Spreading and Finishing

C.1 Bituminous mixes shall be laid only when the air temperature is at least 5 degrees C or above when the existing surface is free from moisture, and when the weather is not foggy, rainy, dusty or excessively windy (particularly at low temperatures).

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 may be spread and finished by approved hand methods only where the Engineer determines that machine methods are impracticable. Hand methods include heated hand tampers of at least 10 kg weight and approved type mechanical (vibratory) tampers.

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 mix 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 shall be constructed. Paving shall not recommence until the Engineer is satisfied that paving will proceed without interruptions.

C.7 Contact surfaces of curbing, 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, it is found that the spreading and finishing, equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities that are not satisfactorily corrected by 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 Unless otherwise directed by the Engineer, 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 m. Longitudinal joints shall be offset at least 150 mm.

C.11 Bituminous mix shall be spread in one or more layers so that, after rolling, the nominal thickness of each layer of the compacted bituminous material does not exceed 2 to 3 times maximum size of aggregate. This maximum thickness may be increased slightly when such increase is more appropriate to total pavement thickness and provided the Engineer determines that such 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 geometrics, the surface tolerance specifications, and shall not be visually discontinuous or abrupt in appearance.

C.13 Side roads, entrances and laybys 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 be such as to ensure thorough and continuous bond between the old and new material.

D.2 Before placing 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. 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 will be smooth and tight.

D.3 The Contractor shall schedule paving operations so as to minimize the exposure of the leading lane of longitudinal joints prior to the completion and compaction of the joint. As a minimum, the leading lane shall not be laid in advance of the adjacent trailing lane by more than one half day of paving, and in no case shall the leading lane be more than 0.5 km ahead of the trailing lane without approval. In the event of failure to conform with these requirements, the Engineer may temporarily 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, if approved, 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 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 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 is permitted to roll over the end of the new material, the line shall be located back of the rounded edge 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 asphalt 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 if necessary, 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 occur.

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 must 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 tire 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 tire pressures are maintained at all times in conformity with such charts or tabulations. The maximum allowable tolerances shall be plus or minus 35 kN/sq.m (5 psi).

E.5 Rollers should move at a slow but uniform speed, generally with the drive roll or wheels nearest the paver. Recommended speeds are shown in Table 4.3.3 (km/hr).

Table 4.3.3: 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, when it is required to change direction, the vibration should be turned off before the roller is stopped, and turned on after motion in the new direction begins.

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 trips 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 will not be permitted.

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

E.11 The initial or breakdown rolling shall be followed by intermediate rolling involving 3 coverages with pneumatic-tired rollers unless otherwise specified. Tire contact pressure shall be as approved.

E.12 Finishing rolling shall then be carried out by means of tandem power steel rollers unless otherwise designated. 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 equal to or greater than 97 % of the average Marshall bulk specific gravity 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 in any way defective in finish or density, or which does not conform in all other respects with the specified requirements shall be removed, replaced with suitable material and properly finished.

4.03.09 SAMPLING AND TESTING

A. Sampling and testing shall conform with the relevant requirements of part 1 of specifications, Section 4-6 "Samples and Approvals", and Table 4.3.4.

Table4.3.4 TESTS FOR BITUMINOUS PAVEMENTS (Minimum Required)

Work item	(A) Test as Source of material	Frequency for all tests mentioned under (A)	(B) Test at road site	Frequency for all tests mentioned under (B)
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	Test for each source - When materials quality changes - As requested		
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	Test for each source - When materials quality changes - As requested		
4-3 Asphalt mix design each layer (At batching plant)	1- Complete mix design in accordance with American Asphalt Institute (MS2) 2- Loss of stability	- For each project - When materials quality changes - When results are not consistent with the mix design results - As requested		

Work item	(A) Test as Source of material	Frequency for all tests mentioned under (A)	(B) Test at road site	Frequency for all tests mentioned under (B)
4-4 Asphalt for each layer	At Batching plant 1- Stability 2- Flow 3- Extraction (binder content and gradation) 4- Air voids 5- Voids in mineral aggregates 6- Daily Marshall density	- Test each 3 working days - Test for each batching plant - As requested	Behind spreader 1- Stability 2- Flow 3- Extraction (binder content and gradation) 4- Air voids 5- Voids in mineral aggregates 6- Daily Marshall density	- Test each working day - Test for each batch - As requested
	7- Loss of Stability	- Once a week - As requested	7- Road density and thickness (after final compaction)	- Test each 200 lin.m, per lane and for each layer - As requested
			Stability	- As requested

B. The Marshall bulk specific gravity shall be determined in accordance with AASHTO T 166. The Marshall specimens shall be prepared from the same material used in 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 designated by the Engineer who may require additional tests to determine limits of areas deficient in density, or for recheck.

D. Samples for in situ bulk specific gravity determinations shall be taken in sets of 2 from each pavement location. Minimum frequency of sampling for each bituminous layer shall be one set/lane/500 m, with a minimum of one set per day of placing bituminous layers.

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

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

4.03.10 SURFACE TOLERANCES

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

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

C. When the finished surface is tested with a 3 m long straightedge, placed parallel to, or at right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 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, if approved, by adding new material and recompacting and finishing to the specified standard or increasing the thickness of the succeeding course.

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

4.03.11 DETERMINATION OF THICKNESS OF COURSES

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, will be considered deficiencies in the final (wearing) course.

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

C. Thickness of bituminous courses shall be determined by average caliper measurement of cores, rounded upwards to the nearest mm.

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

E. One core shall be taken from each section by the Contractor at approved locations 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 will 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 m shall be taken and used together with the first core to determine the average thickness of such 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 m intervals parallel to the centerline in each direction from the affected location until, in each direction, a core is taken which is not deficient by more than 20 mm. Exploratory cores for deficient thickness will not be used in average thickness determinations.

H. Any deficiencies in the total thickness of bituminous courses shall be subject to a proportional reduction in the volume of final (wearing) course measured for payment. Alternatively, the Contractor shall construct all at his own expense, a wearing course overlay, if practicable in the judgment 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 will be made.

4.03.12 MEASUREMENT

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

B. Bituminous Prime shall be measured as prescribed in Section 4.02 -"Bituminous Prime and Tack Coats". No measurement or payment will be made for Bituminous Tack Coat which shall be considered subsidiary to the "Bituminous Courses"

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

D. Establishment of the Job Mix Formula, surface preparation, construction of joints, hand painting of contact surfaces, remedial treatment of surface irregularities, cutting of cores and slabs for testing or measurement purposes, reinstatement of core and slab areas of pavement, rolled down longitudinal bituminous edge strips, additional thickness of bituminous course in excess of the specified thickness, 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.

SECTION 4.04 BITUMINOUS BASE COURSE

4.04.01 SCOPE

These Works shall consist of furnishing materials, mixing at a central mixing plant, and spreading and compacting bituminous base course on an approved sub-base course or subgrade, as and where shown on the Drawings.

4.04.02 MATERIALS

A. All materials shall conform with 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.

C. When an approved modifier (catalyst) 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. The Job Mix for bituminous base course shall conform to the following composition limits as shown in Table 4.4.1.

Table 4.4.1: JOB MIX REQUIREMENTS FOR BITUMINOUS BASE COURSE

Marshall Stability at 60°C (kg)	700
Flow (mms)	2 - 3.5
Voids in Mineral Aggregate (VMA)	12(min)
Air voids (%)	4 - 8

C. After the job mix formula has been established and approved, all mixes furnished shall conform to it within the stated tolerances.

D. 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 with 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 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 surface upon which the bituminous base course mix is to be laid, shall be appropriate to the type and condition of such surface and shall conform with 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 with the following particular requirements.

B. Rollers

B.1 Initial breakdown rolling shall be carried out by use of 2 dual-drum vibrating steel-wheeled vibrating rollers each of minimum weight 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 by use of at least 2 self-propelled, tandem pneumatic smooth-tired rollers each capable of exerting contact pressures of up to 690 kN/sq.m (100 psi) and ballast - adjustable to ensure uniform wheel loadings.

B.3 Final rolling shall be carried out by use of , 2-axle tandem steel-tired rollers each of minimum weight 10,000 kg, capable of exerting contact pressures of up to 65 kg/cm (350 lb/in).

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 replacement, in the event of breakdown of the operating roller.

C. Standard of Compaction

The compacted density of the bituminous base course shall be equal to or greater than 97% of the average Marshall bulk density for each day's production.

4.04.09 SAMPLING AND TESTING

Sampling and testing shall conform with the relevant requirements of Section 4.03 - "Bituminous Courses", and Table 4.3.4.

4.04.10 SURFACE TOLERANCES

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

B. The tolerances on elevations of finished bituminous base course surface shall be not greater than plus 10 mm to minus l0 mm.

C. When the finished surface is tested with a 3 m long straightedge7 placed parallel to, or at right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 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 with the following particular requirements.

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

C. In any case where the bituminous base course will not be covered by superimposed binder or wearing courses, the base course shall be deemed to be the final (wearing) course for the purposes of determining the proportion of wearing course volume measured for payment or for the purposes of any overlay ordered to correct deficiencies.

4.04.12 MEASUREMENT

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

B. Where Bituminous Base Course is intended to serve as a wearing course, any deficiencies in thickness shall, unless an overlay is constructed at the Contractor's expense, result in a proportion only of the base course volume being measured for payment. Proportions shall be determined in accordance with the thickness deficiencies presented in Section 4.03 -“Bituminous Courses".

C. Bituminous prime coat shall be measured as prescribed in Section 4.02 -“Bituminous prime and Tack Coats ”.

D. Tack coat and other incidental items shall not be measured for direct payment, as prescribed in Section 4.03 -“Bituminous Courses ”.

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

SECTION 4.05 BITUMINOUS BINDER AND WEARING COURSES

4.05.01 SCOPE

A. Bituminous wearing coarse 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 course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross sections shown on the plans or as indicated by the Engineer.

B. Each course layer shall be constructed to the depth, typical section or elevation required by the drawings and shall be rolled, finished and approved prior to acceptance.

4.05.02 AGGREGATE

A. Aggregates shall consist of crushed stone or crushed gravel with or without sand or other inert finely divided mineral aggregate. The portion of materials retained on the No. 8 sieve shall be defined as coarse aggregate, the portion passing the No. 8 sieve and retained on the No. 200 sieve as fine aggregate, and the portion passing the No. 200 sieve as mineral filler.

B. Coarse Aggregate

B.1 Coarse aggregate shall consist of sound, tough, durable particles, free from adherent coatings of clay, organic matter, and other deleterious substances. It shall show no more wear than 30% when tested in accordance with ASTM C 131, nor shall the sodium sulphate soundness loss exceed 12 %, or the magnesium soundness loss exceed 18 %, after five cycles, when tested in accordance with ASTM C 88.

B.2 Crushed aggregate shall contain at least 75% by weight of crushed pieces having two or more crushed fractured faces. The area of each face shall be equal to at least 75% of the smallest mid-sectional area of the piece. When two fractures are contiguous, the angle between the planes of fracture shall be at least 30 degree to count as two fractured faces.

B.3 The aggregate shall not contain more than 8% by weight of flat or elongated pieces. A flat particle is one having a ratio of width to thickness greater than three, an elongated particle is one having a ratio of length to width greater than three.

B.4 If so instructed by the Engineer or detailed elsewhere in the Contract Documents and Drawings coarse aggregate shll consist wholly or partly of unweathered basalt rock meeting all the requirements of B1 to B3 above.

C. Fine Aggregate

C.1 Fine aggregate shall consist of clean, sound, durable, angular particles produced by crushing stone or gravel that meets the requirements for wear and soundness specified for coarse aggregate. The aggregate particles shall be free from coatings of clay, silt and other deleterious substances and shall contain no clay particles. The fine aggregate, including any blended filler, shall have a plasticity index of not more than 4% when tested in accordance with ASTM D 424, and a liquid limit of not more than 25% when tested in accordance with ASTM D 423.

C.2 If necessary natural sand may be used to obtain the target gradation of aggregate blend or workability. Beach sand shall not be used in any asphalt mix. The amount of sand to be added shall be adjusted to produce mixtures conforming to the requirements of this section. If it is necessary to add natural sand, the percentage shall be kept below 15% of the weight of the mix).

D. Sampling and Testing

All aggregate samples required for testing shall be provided by the Contractor. ASTM D 75 shall be used for sampling coarse and fine aggregate, and ASTM C 183 for sampling mineral filler. All tests for initial aggregate selection necessary to determine compliance with requirements specified herein shall be made by the Contractor and will be observed and supervised by the Engineer. No aggregate shall be used in the production of mixtures without prior approval.

E. Sources of Aggregates

Sources of aggregates shall be selected well in advance of the time the materials are required in the works. An inspection of the producer's operation will be made by the Engineer. The Engineer's approval is required for all sources of aggregates. When new sources are to be developed, the Contractor shall indicate the sources and shall submit a plan for operation 30 days in advance of starting production. Approval of the source of aggregate does not relieve the Contractor in any way of the responsibility for delivery at the job site of aggregates which meet the specified requirements.

F. Samples of Aggregates

Samples of aggregates shall be furnished and tested by the Contractor at the start of production and at intervals during production of bituminous mixtures. The intervals and points of sampling will be specified by the Engineer. The samples will be the basis of approval of specific batches of aggregates to fulfil the quality requirements of this section. Sampling of aggregates shall be in accordance with AASHTO T2.

4.05.03 REQUIRED CHARACTERISTICS OF THE BASALT

The skid resistance is provided by the texture of the surface of the wearing course. The texture is the result of the protruding stones -macro texture of the surfacing- and the 'roughness' of the stones -micro texture of the aggregate.

The macro texture is measured as 'texture depth'.

The micro texture is the result of the size and nature of the crystals of the minerals of the stone.

Long lasting skid resistance requires that macro and the micro textures are long lasting characteristics, prevailing over the service life of the wearing. course.

To maintain the macro texture the aggregate has to resist abrasion; this characteristic is measured by the Los Angeles Abrasion test. Long lasting texture depth is provided by hard aggregate, i.e. aggregate with a low aggregate abrasion value [AAV].

To maintain the micro texture the aggregate has to resist polishing; this characteristic is measured by the Polished Stone Value test. Long lasting rough micro texture is provided by polish resistant aggregate, i.e. aggregate with a high resistance to polishing [PSV].

Both tests are carried out in the Central Laboratory.

The following values shall be specified for the basalt material to be used, and compliance with these ranges is always required:

- **Los Angeles Abrasion: characteristic value < 22%; absolute < 25%**
- **Polished Stone Value: characteristic value > 65; absolute > 60**

4.05.04 FILLER

If additional filler is necessary, it shall meet the requirements of ASTM D 242.

4.05.05 BITUMINOUS BINDER MATERIAL

A. The type, grade, controlling specifications and maximum mixing temperatures for the bituminous binder materials are as follows:

Penetration grade:	40-50
Specification ASTM:	D 946
Maximum mixing temperature ^{o}C:	170

B. 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.

C. Unless otherwise shown on the Drawings bitumen for surface course construction shall be 40/50 penetration grade bitumen.

4.05.06 COMPOSITION OF MIXTURE

The asphalt plant mix shall be a mixture of aggregate, filler (if required) and bituminous binder. The aggregate fractions shall be sized, uniformly graded, and combined in such proportions that the resulting mixture meets the overall grading requirements of the job mix formula.

4.05.07 JOB MIX FORMULA

A. Analysis of air voids in the mix:
Air voids shall be calculated in accordance with the procedure given in the Asphalt Institute Manual, MS2.

The design range of air voids (3 to 5%) is the level desired.

The laboratory compactive effort is to be selected for the expected traffic demand. The design air voids range will normally be achieved if the mix is designed at the correct

compactive effort and the percentage air voids after construction is about 8 percent. Some consolidation with traffic is expected and desired.

Mixtures that ultimately consolidate to less than three percent air voids can be expected to rut and shore if placed in heavy traffic locations.

Similarly, problems can occur if the final air voids content is above 5% or if the pavement is constructed with over eight percent air voids initially.

Brittleness, premature cracking, ravelling and stripping are all possible under these conditions.

The overall objective is to limit adjustments of the design asphalt content to less than 0.5 percent air voids from the median of the design criteria (four percent – Table 1).

B. No asphalt mixture for payment shall be produced until a job mix formula has been approved by the Engineer. The job mix formula shall specify a combination of aggregates including filler and bitumen (plus bitumen modifier if any) in such proportions as to produce a job mix which is within the limits of the specified gradation and bitumen contents ranges and which meets the Marshall 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 directed, shall be 170 degrees C. The formula shall be submitted in writing by the Contractor to the Engineer at least 10 days prior to the start of paving operations and shall indicate the definite percentage of each sieve fraction of aggregate, the percentage of bitumen, and the temperature of the completed mixture when discharged from the mixture. All test data used to develop the job mix formula shall also be submitted. The job mix formula for each mixture shall be in effect if approves and unless modified in writing by the Engineer. Should a change in sources of materials be made, a new job mix formula shall be established before the new material is used.

C. All the tests required by this section shall be performed in an independent laboratory approved by the Engineer.

D. The bituminous mixture shall be designed using procedures contained in Chapter 5, Marshall Method of Mix Design, of the Asphalt Institute's Manual Series No. 2 (MS-2), sixth edition, and shall meet the requirements of tables 1 and 2.

E. The Contractor shall prepare a series of test specimens for a range of different binder contents so that the test data show a well-defined curve. Tests should 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.

F. To provide adequate data, triplicate test specimens shall be prepared for each binder content mix to be tested.

G. The mineral aggregate shall be of such a size that the percentage composition by weight, as determined by laboratory screens, will conform to the gradation or gradations specified in table 3, when tested in accordance with ASTM Standard C 136 (dry sieve only). The percentage by weight for the bituminous material shall be within the limits specified.

H. Table 1. Marshall Design Criteria

Test	Value
Number of blows	75 (Heavy traffic)
Stability, minimum in newtons	8,000
Flow, in mm	2 – 3.5
Percent air voids	3 - 5
Percent voids in mineral aggregate	See table 2
VFA %	65 – 75%
Dust to bitumen ratio	1.2 maximum

I. Table 2: Minimum Percent Voids in Mineral Aggregate

ASTM Sieve	Max. Particle Size mm	Minimum Voids in Mineral Aggregate Percent Design Air Voids		
		3%	4%	5%
1/2"	12.5	13	14	15
3/4"	19.0	12	13	14
1"	25.0	11	12	13
1 1/2"	37.5	10	11	12

J. Table 3: Aggregate - Asphalt Concrete Surface Course

ASTM Sieve	Percentage by weight passing sieves		
Size	1" max.	3/4" max.	1/2" max.
1 1/2"	100	-----	-----
1"	90 - 100	100	-----
3/4"	------	90-100	100
1/2"	56 - 80	-----	90 - 100
3/8"	------	56 - 80	------
No. 4	29 - 59	35 - 65	44 - 74
No. 8	19 - 45	23 - 49	28 - 58
No. 16	------	-------	-------
No. 30	------	------	------
No.50	5 - 17	5 - 19	5 - 21
No.100	------	------	------
No. 200	1 - 7	2 - 8	2 - 10
Cement %	4.5 - 7.0	5.0 - 7.5	5.5 - 8.0

Bitumen content shall be calculated by weight of total mixture.

J.2 The compacted thickness of any layer should be at least 2 to 2.5 times the nominal size of the aggrgate band for wearing course or as directed by the Engineer.

In considering the total grading characteristics of a bituminous paving mixture, the amount passing the No. 8 (2.36 mm) sieve will result in pavement surfaces having comparatively fine texture, while coarse gradings approaching the minimum amount passing the No. 8 sieve will result in surfaces with comparatively coarse texture.

K. The gradations in table 3 represent the limits which shall determine the suitability of aggregate for use from the sources of supply. The selection of any of the gradations shown in table 3 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 3/4" unless otherwise directed by the Engineer.

L. The aggregate, as finally selected, shall have a gradation within the limits designated in table 3 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.

M. The job mix tolerances shown in table 4 shall be applied to the job mix formula to establish a job control grading band. However, the limits of the master grading band as specified in table 3 will still apply if application of the job mix tolerances results in a job control grading band outside the master grading band.

N. Table 4: Job Mix Formula Tolerances (based on a single test)

Material	Tolerance Plus or Minus
Aggregate passing No.1/2" (12.5 mm) and Larger seive	± 8%
Aggregate passing No.3/8" and No. 4 seives	± 7%
Aggregate passing Nos. 8, 16, No. sieves	± 6%
Aggregate passing Nos. 30 and 50 sieves	± 5%
Aggregate passing No. 200 sieve	± 3%
Bitumen %, weight % by total mix	0.50%
Temperature of mix.	11 ^{o}C

O. The aggregate gradation may be adjusted within the limits of table 3 as directed, without adjustments in the contract unit prices.

P. 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.

Q. Tests on Marshall specimens shall be made at least twice daily to retain job control. The mixture shall comply with the requirements of table 1 & 2 when tested in accordance with the Marshall method procedures contained in chapter 5 of the Asphalt Institute's Manual Series No. 2 (MS-2) sixth edition. Failure to meet the design criteria will be cause for the Engineer to halt production until the problem is identified and corrected.

R. 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.

4.05.08 GENERAL PROCEDURES - TESTING

4.05.08.1 General Procedures

A. The overlay may include a leveling course to correct the contour of the old pavement, followed by a uniform course to provide the needed thickness.

The leveling course will be of a variable thickness used to eliminate irregularities in the contour of an existing surface prior to superimposed treatment or construction.

All depressions of 25mm or more should be overlaid with a leveling course and compacted ahead of the surfacing operation. All surfaces, both horizontal and vertical, that will be in contact with the new asphalt surface must be thoroughly cleaned.

Cleaning flat surfaces is usually done with rotary brooms, but washing or flushing may be necessary to remove dirt. A tack coat should be applied to the milled pavement and to all vertical faces.

B. After the area to be overlaid has been properly prepared, including trimming of edges, thoroughly cleaned, and applying the correct prime coat or tack coat, there remains only the placing and compacting of the mix. Segregation should be prevented.

To make the joint, the quantity of material placed in the area should be sufficient to ensure that, after compaction, the new surface will not be below that of the adjacent pavement. We have to produce a smooth riding surface. If proper equipment and procedures are used the surface of the joint shall be at the same grade as the adjacent pavement. If light compaction methods are used, however, the surface of the completed new pavement should be slightly higher than the pavement. Traffic will compress the new pavement further.

C. Levelling Courses:

C.1 Purpose of the Levelling Course

Placing a leveling course is an operation employed where the road surface is so irregular that it exceeds the leveling capabilities of the paver. The paver is usually effective on irregularities of lengths not longer than 1.5 to 2 times the wheel base of the machine. Beyond these lengths, a grade control device is necessary.

Generally, irregularities no longer than 12 or 15m can be handled with a traveling string line device and automatic screed control on the paver.

The existing centerline profile, as determined by preliminary measurements and observations, should be reviewed and evaluated. Based on this information, the decision should be made on the portions of the project, where it is necessary to undergo the leveling course operation.

C.2 Spreading with a Motor Grader

Long wheel base motor graders having smooth-tread tires often are used for spreading hot-mix asphalt in leveling courses. In laying the leveling course with a blade, the

principal advantage offered by the longer wheel base of the grader is the elimination of excessive trumps, sags, and irregularities in the subgrade or old pavement on which the mix is being placed. Another benefit realized is a rough textured surfaced on which to place the overlying course.

In placing a course of hot-mix asphalt with a motor grader, a roller is needed to compact the mix closely behind the grader. It is preferable to use a pneumatic tired roller in conjunction with the blade in this type of operation with each pass of the motor grader, the roller should follow immediately compacting the spread that is laid. This operation should progress until the final desired surface evenness is reached.

C.3 Leveling Wedges

Leveling wedges are patches of asphalt plant-mix used to level sags and depressions in an old pavement prior to the surfacing operation. Placing leveling wedges is part of the leveling course operation.

Leveling wedges should be installed in 2 layers if they are from 75 to 150mm in thickness. Wedges thicker than 150mm should be placed in compacted layers of not more than 75mm.

Where wedging of dips and depressions requires multiple layers, the Engineer should have sufficient levels taken to plot profiles, and cross sections accurately. From these plots, the grades of the proposed correction and the linear limits of the successive layers should be determined so that definite stationing for starting and stopping the spreader or motor grader passes can be decided.

4.05.08.2 Test Section

A. Prior to full production, the Contractor shall prepare a quantity of bituminous mixture according to the job mix formula. The amount of mixture should be sufficient to construct a test section and shall be of the same depth specified for the construction of the course which it represents. The underlying grade or pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same type and weight to be used on the remainder of the course represented by the test section.

B. If the test section should prove to be unsatisfactory, the necessary adjustments to the mix design, plant operation, and/or rolling procedures shall be made. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications. When test sections do not conform to specification requirements, the pavement shall be removed and replaced at the Contractor's expense. Full production shall not begin without approval of the Engineer.

C. In the event that a test section is incorporated in the final works, it should be placed in an area where it will receive little or no traffic so that marginal quality trail runs can be safely left in place.

4.05.08.3 Sampling And Testing Frequency Schedule

Item			Material		
		Coarse Aggregate	Fine Aggregate	Asphalt Mixture	Bitumen
	Standard	m3	m3	Ton	Ton
* Aggregate & Filler - Grading	AASHTO T-27	100	100		
- Filler content	AASHTO T-11	100	100		
- Specific gravity (Fine)	AASHTO T-84	-	M		
- Specific gravity (Coarse)	AASHTO T-85	M	-		
- Sand Equivalent	AASHTO T-176	-	M		
- Los Angeles (Abrasion)	AASHTO T-96	E	-		
- Sulphate Soundness	AASHTO T-104	E	-		
- Deleterious Materials	AASHTO T-112	E	E		
-Angularity	ASTM D5821	M	-		
-Flackiness Index	BS-812	M	-		
* Butimen - Penetration	AASHTO T-49				M
- Softening point	AASHTO T-53				M
* Bituminous mix - Bitumen Extraction	AASHTO T-164			500	
- Marshall stability	AASHTO T-245			500	
- Bulk Specific gravity	AASHTO T-166			500	
- Grading	AASHTO T-30			500	

M = Monthly
E = Once per year or every time a new source is introduced.

4.05.09 WEATHER LIMITATIONS

A. The bituminous mixture shall not be placed upon a wet surface or when the surface temperature of the underlying course is less than specified in table 5. The temperature requirements may be waived, but only when so directed by the Engineer.

B. Table 5: Base Temperature Limitations

Course Thickness	Base Temperature (minimum) ^{o}C
75 mm or greater	4
greater than 25mm but less than 75mm	7
25mm or less	10

4.05.10 BITUMINOUS MIXING PLANT

A. General

Mixing plants shall be of sufficient capacity (not less than 80 ton/hr with a mixer capacity of not less than 750kg batch) and are in accordance with the specifications as laid down in ASTM D 995. Sufficient storage space shall be provided for each size of

aggregate and the different sizes shall be kept separated until they have been delivered to the cold elevator. The plant yard and storage yard shall be neat and tidy.

B. Inspection of Plant

The Engineer or his authorized representative shall have access, at all times, to all parts of the mixing plant for checking adequacy of equipment, verifying weights, proportions, and character of materials, and checking the temperatures maintained in the preparation of the mixtures.

4.05.11 HAULING EQUIPMENT

Trucks used for hauling bituminous mixtures shall have tight, clean, smooth metal beds. To prevent the mixture from adhering to them, the beds shall be lightly coated with a minimum amount of paraffin oil, lime solution, or other approved material. Each truck shall have suitable cover to protect the mixture from adverse weather, when necessary, so that the mixture will be delivered to the site at the specified temperature, truck beds shall be insulated and covers shall be securely fastened.

4.05.12 BITUMINOUS PAVERS

A. Bituminous pavers shall be self-contained, power-propelled units with an activated screed or strike-off assembly, heated if necessary, and shall be capable of spreading and finishing courses of bituminous plant-mix material which will meet the specified thickness, smoothness, and grade. Pavers used for shoulders and similar construction shall be capable of spreading and finishing courses of bituminous plant-mix material in widths shown on the drawings.

B. The paver shall have a receiving hopper of sufficient capacity to permit a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed. The screed or strike-off assembly shall effectively produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

C. The paver shall be capable of operating at forward speeds consistent with satisfactory laying of the mixture.

D. The paver shall be equipped with an automatic grade control system capable of automatically maintaining the screed elevation as specified herein. The control system shall be automatically actuated from either a reference line or surface through a system of mechanical sensors or sensor-directed mechanisms or devices which will maintain the paver screed at a predetermined transverse slope and at the proper elevation to obtain the required surface.

E. The controls shall be capable of working in conjunction with any of the following attachments:

1) Ski-type device of not less than 9m in length or as directed by the Engineer.
2) Taut strangling (wire) set to grade.
3) Short ski or shoe.

4.05.13 ROLLERS

Rollers may be of the vibratory, steel wheel, or pneumatic-tired type. They shall be in good condition, capable of reversing without backlash, and operating at slow speeds to avoid displacement of the bituminous mixture. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density without detrimentally affecting the compacted material.

4.05.14 PREPARATION OF BITUMINOUS MATERIAL

The bituminous material shall be heated to the specified temperature in a manner which will avoid local overheating and provide a continuous supply of the bituminous material to the mixer at a uniform temperature. Any method of agitation or heating that introduces free steam or moisture into the bitumen will not be approved. During the process of its manufacture, conveyance, storage, or construction use, bitumen of whatever type shall not be heated to temperatures more than 4 degrees C above the maximum application temperature specified for the respective type of bitumen nor above 170 degrees C whichever is the lower. Materials heated in excess of these temperatures will be rejected and shall not be used in the works. The temperature of the bituminous material delivered to the mixture shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles.

4.05.15 PREPARATION OF MINERAL AGGREGATE

The aggregate for the mixture shall be dried and heated to the temperature designated by the job formula within the job tolerance specified. The maximum temperature and rate of heating shall be such that no permanent damage occurs to the aggregates. Particular care shall be taken that aggregates high in calcium or magnesium content are not damaged by overheating. The temperature shall not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

4.05.16 PREPARATION OF BITUMINOUS MIXTURE

A. The aggregates and the bituminous material shall be measured or gauged and introduced into the mixer in the amount specified by the job mix formula.

B. The combined materials shall be mixed until a complete and uniform coating of the particles and a thorough distribution of the bituminous material throughout the aggregate are secured. Wet mixing time shall be approved by the Engineer for each plant and for each type of aggregate used. Normally, the mixing time after introduction of bituminous material should not be less than 30 seconds. For continuous plants, the minimum mixing time shall be determined by dividing the weight of its contents at operating level by the weight of the mixture delivered per second by the mixer.

$$\text{Mixing time (in seconds)} = \frac{\text{Pugmill dead capacity in kg}}{\text{Pugmill output in kg per second}}$$

4.05.17 TRANSPORTING, SPREADING, AND FINISHING

A. The mixture shall be transported from the mixing plant to the point of use and deliveries shall be scheduled so that spreading and rolling of all mixture prepared for

one day's run can be completed during daylight, unless adequate artificial lighting is provided. Hauling over freshly placed material shall not be permitted until the material has been compacted, as specified, and allowed to cool to atmospheric temperature.

B. Immediately before placing the bituminous mixture, the underlying course shall be cleared of all loose or deleterious material with power blowers, power brooms, or hand brooms as directed.

C. Penetration bitumen application temperature range shall be so that appropriate viscosity range for each application is achieved. If however the viscosity curve are not available the values given in table 6 shall be generally consider as a guidance moisture content of the mix shall not exceed 1%.

Table 6

BITUMEN GRADE

	40/50
Application Temperature ^{o}C	150-170

D. Upon arrival, the mixture shall be spread to the full width by an approved bituminous paver. It shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness and shall conform to the grade and contour indicated. The speed of the paver shall be regulated to eliminate pulling and tearing of the bituminous mat. Unless otherwise directed, placing shall begin along the centerline of areas to be paved on a crowned section or on the high side of areas with a one-way slope. The mixture shall be placed in consecutive adjacent strips having a minimum width of 3 m, except where edge lanes require strips less than 3m to complete the area.

E. Transverse joints in one layer shall be offset by at least 60 cm from transverse joints in the previous layer. Transverse joints in adjacent lanes shall be offset a minimum of 3m.

F. One areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread, raked, and luted by hand tools.

4.05.18 COMPACTION OF MIXTURE

A. After spreading, the mixture shall be thoroughly and uniformly compacted without delay and while the temperature of the mat is not less than 120 ºC with power rollers. Rolling of the mixture shall begin as soon after spreading as it will bear the roller without undue displacement or hair checking using steel wheeled rollers and pneumatic rubber tyred rollers of 10 tons minimum capacity. Rolling shall be initiated with the drive wheel towards the paving machine at a speed of between 3 & 6 Km per hour. The sequence of rolling the first paving lane should be to first roll the lower edge (with reference to the transverse slope) of the lane and then to roll the upper edge. The interior of the lane should then be rolled from the lower side towards the upper edge with overlapping roller paths. On adjoining paving lanes rolling shall begin by overlapping the joint (with the previous lane) by 150 to 200mm and then rolling the outside edge of the new lane. The interior should be with overlapping wheel paths. Alternate paths of the roller shall be of slightly different lengths.

B. The speed of the roller shall, at all times, be sufficiently slow to avoid displacement of the hot mixture. Any displacement occurring as a result of reversing the direction of the roller or from any other cause shall be corrected at once by raking and applying fresh mixture.

C. Sufficient rollers shall be furnished to handle the output of the plant. Rolling shall continue until all roller marks are eliminated, the surface is of uniform texture and true to grade and cross section, and the required field density is obtained.

D. To prevent adhesion of the mixture to the roller the wheels shall be kept properly moistened, but excessive water will not be permitted.

E. In areas not accessible to the roller, the mixture shall be thoroughly compacted with hot hand tampers.

F. Any mixture which becomes loose and broken, mixed with dirt, or in any way defective, shall be removed and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. Skin patching and handworking shall not be allowed.

4.05.19 JOINTS

A. The formation of all joints shall be made in such a manner as to ensure a continuous bond between old and new sections of the course. All joints shall present the same texture, density, and smoothness as other sections of the course.

B. The roller shall not pass over the unprotected end of the freshly laid mixture except when necessary to form a transverse joint. When necessary to form a transverse joint, it shall be made by means of placing a bulkhead or by tapering the course, in which case the edge shall be cut back to its full depth and width on a straight line to expose a vertical face. In both methods all contact surfaces shall be given a tack coat of bituminous material before placing any fresh mixture against the joint.

C. Cold longitudinal joints shall be cut back over their full length to expose a clean, sound surface for the full depth of the course. All contact surfaces shall be given a tack coat of bituminous material prior to placing any fresh mixture against the joint.

4.05.20 SHAPING EDGES

While the surface is being compacted and finished, the Contractor shall carefully trim the outside edges of the pavement to the proper alignment. Edges so formed shall be bevelled while still hot with the back of a rake or a smoothing iron and thoroughly compacted by tampers or by other satisfactory methods.

4.05.21 ROUTINE TESTS ON MIXTURE

A. Approximately every 2 (two) hours during mixing periods an aggregate sample shall be taken from each hot bin and its grading determined, together with that of the combined grading. This combined grading shall be checked for compliance with the grading of

the approved job control grading band as specified and as directed by Engineer.

B. Additional samples of the mixed materials shall also be taken at the point of mixing at least every four hours and not less than twice daily for making Marshall specimens and their stability, flow, unit weight, and voids shall be determined. Aggregate grading analysis and bitumen content determinations shall be carried out on material taken from the same samples.

C. The result of each analysis shall be submitted to the Engineer within four hours of sampling and any adjustments shown to be required shall be made, with his agreement, immediately.. Until the adjustments have been made and a certificate to this effect has been received by the Engineer, no further deliveries of mixed materials shall be made from the mixing plant in question.

D. Sample quality assurance – quality control schedule.

1- Preproduction, sampling and testing:
   i) Aggregate for mix design
   ii) Mineral filler/additives, if necessary
   iii) Asphalt material from proposed source.

2- Job mix Formula Verification

   i) Aggregate gradation
   ii) Asphalt content
   iii) Air voids, VMA, and voids filled with asphalt
   iv) Marshall properties, where applicable.

3- Mix properties during production

   i) Maximum Theoritical specific gravity
   ii) Bulk specific gravity for air voids.
   iii) Stability and flow.
   iv) Aggregate gradation and asphalt content.

4- In place acceptance testing:

   i) Air void/in place desity
   ii) Thickness
   iii) Smoothness/Ride quality
   iv) Profile

4.05.22 JOB MIX DENSITY

A. The density of compacted bituminous courses of all mixtures designed in accordance with the Marshall Method shall be related to the "Job Mix Density". The "Job Mix Density" shall be obtained by making from samples of the approved "Job Mix ", six standard Marshall specimens, determining the bulk specific gravity of each and comparing them with the mean value of the six.

B. An individual result which differs from the mean by more than 1.5% shall be rejected and provided not more than two results are so rejected the mean of the remaining results shall become the "Job Mix Density".

4.05.23 FIELD DENSITY TESTS

A. Asphalt concrete will be accepted for density on a lot basis. A lot consists of 4,000 m2 for each layer and will be divided into four equal sub lots. One test shall be made for each sub lot.

B. Core samples 100 mm nominal diameter, shall be taken from each finished asphalt layer the day after construction and tested to determine the bulk specific gravity, air voids, degree of compaction and thicknesses of the completed asphalt layer.

Cores shall be cut from each compacted layer at locations designated by the engineer and the test results shall be compared with the results of tests on the loose mix samples from the same location, for quality control purposes.

C. Each lot of compacted pavement will be accepted, with respect to % air voids, when the average in place air voids are equal to or less than 8% of the average voids of the laboratory-prepared specimens, and when no individual determination deviates more than 1.8% from the average in place air voids.

D. Four field density determinations shall be made for each lot. Cores taken from the pavement shall be used to test the field density and air voids. The density of the cored samples shall be determined in accordance with ASTM D 2726 or D 1188, whichever is applicable.

E. The location of sampling sites within a lot's laying area shall be chosen on a random basis. Cores shall be taken in accordance with the requirements of section 3.05.25.

F. Asphalt concrete which does not meet the density requirements shall be cut out and replaced or be subject to reduced payment.

G. The cores shall also be used to determine the course thickness.

H. In lieu of the core method of density determination, acceptance testing may be accomplished with a nuclear device in accordance with ASTM D 2950, subject to approval of the Engineer.

4.05.24 SURFACE FINISH TESTS

A. Tests for conformity with the specified level and grade shall be made by the Contractor immediately after initial compaction. Any variation shall be corrected by the removal or addition of materials and by continuous rolling.

B. The surface shall not vary more than 3mm for the surface course when tested with a 3m straightedge applied parallel with the centreline or 4mm at right angles to the centerline. Except that 3% of the regular measurements may exceed this tolerance by another 2mm.

C. After the completion of final rolling, the smoothness of the course shall again be tested. Humps or depressions exceeding the specified tolerances shall be immediately corrected by removing the defective work and replacing with new material, as directed by the Engineer. This shall be done at the Contractor's

expense. Skin patching will not be permitted.

4.05.25 TOLERANCES IN COURSE THICKNESS

A. The course used for the field density tests shall also be used to determine the course thickness. Additional cores may be required in case of deficiencies in thickness exceeding the tolerances. The asphalt concrete surface course will be accepted for thickness on the same lot basis.

B. Each lot of pavement will be accepted, with respect to thickness, when the average total thickness of the asphalt concrete surface course is within a tolerance of 5mm plus or minus the specified thickness.

4.05.26 SAMPLING PAVEMENT

Samples for determination of thickness and density of completed pavements shall be obtained by the Contractor at no extra cost. The size, number, and locations of the samples will be as directed by the Engineer. Samples shall be neatly cut with a core drill. The Contractor shall furnish all tools, labour, and materials for cutting samples and replacing pavement. The Contractor shall replace the pavement where samples are removed free of charge.

4.05.27 METHOD OF MEASUREMENT

A. The quantity of bituminous wearing course to be paid for shall be the number of cubic meters of surface course used in the accepted works.

4.05.28 BASIS OF PAYMENT

A. General

A1. Payment for bituminous wearing course shall be made at the contract unit price per cubic metre. The price shall be full compensation for furnishing all materials, for all preparation, mixing, and placing of these materials, and for all labour, equipment, tools, and incidentals necessary to complete the item, provided however that the thicknesses are within the tolerances, and the densities as specified and mentioned before.

A2. The quantity of asphalt placed in excess of the tolerances mentioned before, will not be paid for.

B. Price Adjustments for Field Densities or in Place Air Voids

B1. Air voids corresponding to 100% of laboratory density should fall between 3 and 8%.

B2. Air voids tested from in place taken cores should not exceed 8%.

B3. Compaction that falls between the two above items shall be paid 100%, compaction that correspond to 9% air voids shall be paid 75%, other results shall be rejected.

It should be noted that while the comparison between the maximum theoritical density and the in place air voids content is a consistent one, the relationships between the

other two reference density types and in place air voids will shift up or down depending on the actual mix design and compaction criteria used in the specifications (Refer to Figure 8.1 of Chapter 8 in the mix design methods book, sixth Edition, of the Asphalt Institute).

B4. If one or more pay factors are to be used for any given lot, the reduced price shall be determined by successively multiplying the contract unit price by all such pay factors.

B5. Payment will be made under:

bituminous wearing course - per cubic metre.

4.05.29 TESTING AND MATERIAL REQUIREMENTS

The following testing and material requirements form part of this specification:

A. Testing Requirements

ASTM C 29	Unit weight of aggregate
ASTM C 88	Soundness of aggregates by use of sodium sulphate or magnesium sulphate
ASTM C 117	Materials finer than No. 200 sieve by washing
ASTM C 127	Specific gravity and absorption of coarse aggregate
ASTM C 128	Specific gravity and absorption of fine aggregate
ASTM C 131	Resistance to abrasion of small size coarse aggregates by use of the Los Angeles Machine
ASTM C 136	Sieve or screen analysis of fine and course aggregates
ASTM C 183	Sampling hydraulic cement
ASTM D 75	Sampling Aggregates
ASTM D 423	Liquid limit of soils
ASTM D 424	Plastic limit and plasticity index of soils
ASTM D 1075	Effect of water on cohesion of compacted bituminous mixtures
ASTM D 1188	Bulk specific gravity of compacted bituminous mixtures using paraffin-coated specimens
ASTM D 1559	Resistance to plastic flow of bituminous mixtures using Marshall apparatus
ASTM D 2172	Quantitative extraction of bitumen from bituminous paving mixtures
ASTM D 2726	Bulk specific gravity of compacted bituminous mixtures using saturated surface-dry specimens
AASHTO T 30	Mechanical analysis of extracted aggregate
The asphalt Institute's Manual No. 2 (MS-2)	Mix design methods for asphlat concrete

B. Material Requirements

ASTM D 242	Mineral filler for bituminous paving mixtures
ASTM D 946	Asphalt cement for use in pavement construction
ASTM D 3381	Viscosity-graded asphlat cement for use in payment construction.

C. Plant Requirements

ASTM D 995	Requirements for mixing plants

SECTION 4.06 BITUMINOUS SEAL COATS - SURFACE DRESSINGS

4.06.01 SCOPE

A. These Works shall consist of the furnishing of materials and one or more applications of cutback bitumen and cover material or a single application of emulsified bitumen or spreading emulsified bitumen slurry to previously prepared base course or wearing course surfaces 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 sand aggregate or as specified.

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

4.06.02 MATERIALS

A. Bitumen

A.1 Bitumen for SBSD and DBSD (Surface Dressing) applications shall be Rapid-Curing RC-800 Grade conforming with the relevant requirements of Section 4.01 -"Materials for Bituminous Construction", and AASHTO M-81.

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

B. Aggregates

B.1 Cover aggregates shall consist of screenings of crushed stone or crushed gravel. Aggregate for slurry seals shall consist of crushed stone or gravel 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, an applying and spreading slurry seals, shall conform with the requirements of part 1 of specifications, Section 4-4 "Contractor's Plant and Equipment" and with the Contractor's approved Work Program.

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 m long, at approved locations 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 us 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.

4.06.05 RATES OF APPLICATION

A. Application rates for cutback and emulsified bitumen and for the various cover aggregate gradations, will 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: APPLICATION RATES

Types of seal coat	Approx. rate of application	
	Aggregate (Kg/m^2)	**Binder (Kg/m^2)**
Coarse agg. seal coat	12.5- 20.0	1 .00- 1.80
Medium agg. seal coat	10.0-1 5.0	0.90- 1.80
Slurry seal	Generally 5-6 Kg/m^2 for the mix	

B. The Engineer may 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 favorable weather conditions as determined by the Engineer. The atmospheric temperature shall be above 15 degrees C and the weather shall not be foggy, rainy, dusty or unduly windy.

A.2 Generally, where the seal coat is to carry traffic prior to final sweeping, speed signs shall be erected to control the speed of traffic. Provision for traffic control shall be in accordance with the relevant requirements of Section 6. 10 - "Maintenance of Traffic and Detours".

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, 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, which results in deterioration of the surface, the Engineer may order appropriate repairs or corrective treatment prior to seal coating.

B.2 When coatings are applied to existing pavement surfaces, all pavement repairs shown on the Drawings shall first be completed. Where applicable, the positions of traffic markings shall be surveyed and recorded to enable their accurate replacement after the seal coatings 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. If required, the surface shall be slightly dampened with a light application of water immediately prior to application of bitumen.

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

C. Heating of Bitumen

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

D. Spreading Slurry Seal

D.1 Spreading of slurry seal shall be by means of an approved type spreader box which shall be capable of spreading at least one traffic lane width. It shall have flexible rubber or similar strips fastened on each side to prevent loss of slurry and shall have baffles incorporated in the box to ensure uniform application. A rear, flexible strike-off blade of adjustable type shall also be provided.

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

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 bitumen cutback or emulsified bitumen for fog and 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 designated by the Engineer.

E.2 A strip of building paper or heavy polyethylene sheeting, at least one m 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 be moving forward at proper application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected immediately as directed.

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. Under no circumstances shall operations proceed in such a manner that the bitumen will be allowed to chill, set up, dry, or otherwise impair retention of the cover 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 as well as verification of application rates designated by the Engineer.

E.6 Distribution of bitumen shall be so regulated and sufficient material left in the distributor at the end of each application, that there will be a uniform distribution across the spray bar. In no case shall the distributor be allowed to expel air with the bitumen, thereby 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, aggregates shall be washed prior to use in order to eliminate or reduce any dust coating 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 will 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 tires of the hauling units or aggregate spreader do not come in contact with the uncovered bitumen surface.

F.4 Where adjacent spreads are to be made, the first aggregate spread shall not extend closer than 150 mm to the edge of bitumen application. The adjacent spread or bitumen shall overlap this 150 mm and complete aggregate coverage shall be achieved on the second spread promptly upon completion of the first spread to ensure a smooth riding surface.

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

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

G. Rolling and Brooming

G.1 Aggregate shall not be spread more than 150 m 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 these requirements shall be made good as directed, 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, etc.). 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 may order the alternative use of pneumatic-tired 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-tired 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 and in such a manner that embedded aggregate particles will not be dislodged. This brooming shall result in uniform distribution of loose screenings over the surface which shall then be re-rolled using pneumatic-tired 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.

G.9 Excess (surplus) screenings shall be salvaged and stockpiled or disposed of as directed.

H. Maintenance and Protection of Sealed Surfaces

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

H.2 Each coat of SBSD and DBSD shall be maintained and protected from traffic 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, the surface shall be finally swept, using a rotary broom, to remove loose screenings. Surplus screenings shall be stockpiled or disposed of as directed.

H.4 Adequate traffic control (including speed control measures) shall be taken during the maintenance periods, in accordance with the relevant requirements of Section 6.10 - "Maintenance of Traffic and Detours".

4.06.07 TOLERANCES AND RECORDS

A. The Contractor shall be responsible for ensuring 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 bitumen tanker contents 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 locations, width and lengths of the respective runs.

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 accepted, be subject to a 10% reduction in quantity or area measurements as appropriate.

E. Applications of cutback bitumen varying by more than 5% but less than 10%, after temperature adjustment, above the specified rate of application shall, if accepted, 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, at the Contractor's expense.

G. The Contractor shall maintain, on a daily basis, complete records of the volumes and tonnage of each type of aggregate delivered to the Site and used in each section of the Works for seal coat 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 applications have been carried out. No measurements will be made of bitumen applications which are not supported by adequate, verifiable records.

4.06.08 MEASUREMENT

The quantity of seal coat to be paid for shall be the number of square meters for each application as entered in the Bill of Quantities. No separate payment shall be made for bituminous material, or cover aggregates.

PAY ITEM	UNIT OF MEASUREMENT
(1) Single Bituminous Surface Dressing	Square meter (m^2)
(2) Double Bituminous Surface Dressing	Square meter (m^2)
(3) Bituminous Slurry Seal Coat	Square meter (m^2)

SECTION 4.07 BITUMINOUS LEVELING COURSE

4.07.01 SCOPE

These Works shall consist of furnishing materials mixing at a central mixing plant and spreading and compacting bituminous wearing course on an existing pavement surface as and where shown on the Drawings or directed.

4.07.02 MATERIALS

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

B. Unless otherwise shown on the drawings materials shall conform with the requirements of Section 4.05 - "Bituminous Binder and Wearing Courses".

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".

B. The Job Mix for bituminous leveling shall conform with the requirements of Section 4.05 - "Bituminous Binder and Wearing Courses".

4.07.04 EQUIPMENT

Plant and equipment for mixing, hauling, placing and compacting bituminous leveling course materials shall conform with 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 and in accordance with the relevant requirements of Section 4.03 - "Bituminous Courses".

4.07.06 SURFACE PREPARATION

A. Damaged pavement surfaces shall, where directed, be repaired by patching prior to receiving the bituminous leveling course. The extent of patching shall be as shown on the Drawings or as directed.

B. Areas of existing pavement to be patched shall be cut out to neat lines to a depth ordered by the Engineer, thoroughly cleaned, and the exposed edges of pavement painted or sprayed with a thin coat of rapid setting of emulsified bitumen in accordance with the relevant requirements of Section 4.02 - "Bituminous Prime and Tack Coats". The cut out pavement shall be patched with bituminous material as shown on the Drawings or as directed and conforming with the relevant requirements of Section 4.01 - "Materials for Bituminous Construction".

C. Patching shall be carried out in accordance with the relevant requirements of Section 4.03 - "Bituminous Courses".

D. Patching shall be carried out in layers not exceeding 80 mm in thickness. Each layer shall be thoroughly compacted by means of approved pneumatic tampers prior to placing the succeeding layer. Each layer shall be protected from damage and all dirt or foreign material shall be removed before placing subsequent layers. The final layer shall be rolled with a heavy roller. Each layer shall be approved prior to placement of subsequent layers.

E. All cut-out pavement material and surplus patching material shall be removed from the site and disposed of by the Contractor prior to placing the leveling courses.

F. In areas where leveling courses are required, as shown on the Drawings or directed, the Contractor shall take cross sections of the existing pavement after completing any patching. The cross sections will be taken at intervals of 12.5 meters or as directed. When the survey is approved, the Engineer will determine and inform the Contractor of the locations, grades and thicknesses of leveling courses to obtain the desired surface.

G. Prior to placing the 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 with the relevant requirements of Section 4.05 - "Bituminous Binder and Wearing Courses".

B. In areas where a specific grade and super elevation 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 pits or small isolated areas, a mobile reference line or alternative control system may be approved.

4.07.08 SAMPLING AND TESTING

A. Sampling and testing of leveling courses shall conform with the relevant requirements of Section 4.03 - "Bituminous Courses", and Table 4.3.3.

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

4.07.09 SURFACE TOLERANCES

Surface Tolerances for leveling courses shall conform with the relevant requirements for Binder Courses in Section 4.04 - "Bituminous Base Course".

4.07.10 DETERMINATION OF THICKNESS

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

4.07.11 MEASUREMENT

A. Bituminous leveling courses shall be measured by the cu.m of mix furnished, spread, compacted, completed and accepted. Measurements shall be based on the areas and thicknesses shown on the Drawings or as directed.

B. Patching shall be measured by the cu.m of mix furnished, spread, compacted, completed and accepted. Measurements shall be based on the areas and thicknesses shown on the Drawings as directed.

C. Bituminous Tack Coat shall not be measured or paid as prescribed in Section 4.02 - "Bituminous Prime and Tack Coats".

D. All other incidental items shall not be measured for direct payment, as prescribed in Section 4.03 - "Bituminous Courses".

PAY ITEM	UNIT OF MEASUREMENT
(1) Bituminous Leveling Course	Cubic meter (m^3)

SECTION 4.08 NOT APPLICABLE

SECTION 4.09 NOT APPLICABLE

SECTION 4.10 PAVEMENT REPAIRS AND TRENCH REINSTATEMENT WORKS

4.10.01 SCOPE

These Works shall consist of removing defective bituminous pavement, preparing surfaces to receive repairs, crack sealing, furnishing materials, placing and finishing new pavement, as and where shown on the Drawings or directed. The contractor shall be responsible for all traffic management during the execution of the works.

4.10.02 MATERIALS

A. All pavement materials shall conform with the relevant requirements of Section 3.01 - "Materials for sub-base and Base Courses" and Section 4.01 - "Materials for Bituminous Construction".

B. Subgrade materials shall conform with the relevant requirements of Section 2.07 - "Subgrade Construction ".

4.10.03 EQUIPMENT

All plant and equipment shall conform with the relevant requirements of part 1 of specifications, Section 4-4 -"Contractors Plant and Equipment".

4.10.04 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 asphaltic 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.

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

4.10.05 PLACING AND FINISHING REPAIR MATERIALS

A. Cracks of 3 mm width or wider shall be filled with clean, coarse sand then saturated with 1:1 diluted emulsified bitumen or as directed. Cracks shall be filled to the road surface.

Any excess bitumen shall be removed with a squeegee and the bitumen surface shall be sprinkled liberally with coarse sand.

B. 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 with the requirements of Section 2.07 - "Subgrade Construction" and to the satisfaction of the Engineer.

C. 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 with the relevant requirements of Section 3.02 - "Granular Sub-Base Courses" or Section 3.03 - "Aggregate Base Courses" and shall be to the grading shown on the Drawings or specified by the Engineer.

D. 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 bituminous surfaces shall be lightly painted with emulsified bitumen, all in accordance with the requirements of Section 4.02- "Bituminous Prime and Tack Coats".

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

F. New utility trenches shall be backfilled to the details shown on the Drawings, or ordered, including any surrounds, haunching or protective materials. Construction of subgrade and pavement shall be as for pavement repairs.

G. No excavated areas shall remain open overnight.

4.10.06 SAMPLING AND TESTING

Testing of repair materials shall conform with the relevant requirements of Section 4.03 - "Bituminous Courses", and Table 4.3.3. Sampling shall be as ordered by the Engineer.

4.10.07 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 with the relevant requirements of Section 4.04 - "Bituminous Base Course" and Section 4.05 - "Bituminous Binder and Wearing Courses".

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

4.10.08 MEASUREMENT

A. Sealing of cracks shall not be measured for direct payment unless otherwise specified.

B. Pavement repairs shall be measured by the sq.m of repair, prepared, filled, compacted, completed and accepted. Measurement shall be of the areas shown on the Drawings or ordered.

C. Trench reinstatements shall be measured by the sq.m of reinstatement prepared, filled, compacted, completed and accepted. Measurement shall be of the areas shown on the Drawings or ordered. New utility trench construction will not be measured under this item.

D. No separate measurement will be made for excavation, prime or tack coats or pavement materials.

E. Aggregate base course improvement / replacement, where necessary, shall be measured in square meter with a nominal layer depth of 150mm.

F. All other incidental items shall not be measured for direct payment, as prescribed in Section 4.03 - "Bituminous Courses", but shall be considered as susidiary 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) Pavement Repairs	Square meter (m^2)
(2) Trench Reinstatement	Square meter (m^2)
(3) Aggregate Base Course Improvement (or replacement)	Square meter (m^2)

SECTION 4.11 MILLING AND GRINDING

4.11.01 SCOPE

The works shall also include cold milling of the existing asphalt layer to a specified depth at the locations shown on the Drawings. This work shall also consist of grinding asphalt concrete or portland cement concrete pavement and roadway surfaces of structures as shown on the plans and as specified in these specifications. The contractor shall be responsible for all traffic management during the execution of the works.

4.11.02 EQUIPMENT

Grinding shall be performed with abrasive grinding equipment utilizing diamond cutting blades.

Except on structures, the entire area of pavement in locations designated shall be ground.

Existing portland cement concrete pavement not constructed as part of the project shall be ground as follows :

Grinding shall be performed so that the pavement surface on both sides of all transverse joints and cracks has essentially the same depth of texture and does not vary from a true plane enough to permit 2 mm thick shim 80 mm wide to pass under a 1m straight-edge adjacent to either side of the joint or crack when the straightedge is laid on the pavement parallel to centerline with its midpoint at the joint or crack. After grinding has been completed, the pavement shall conform to the straightedge and profile requirements specified in Part 4 (4.03.10).

Abnormally depressed areas due to subsidence or other localized causes will be excluded from testing with the profilograph and 3m straightedge specified in said Section. The accumulated total of all such excluded areas shall not exceed 5 percent of the total area to be ground. Profilograph testing shall end 10 m prior to excluded areas and shall resume 10 m following the excluded areas.

Existing asphalt concrete pavement not constructed as part of the project shall be ground so that the finished surface shall not vary from a true plane enough to permit a 3 mm thick shim 80 mm wide to pass under a straightedge 3 m long when the straightedge is laid on the finished surface parallel with the centerline. The transverse slope of the finished surface shall be uniform to a degree such that 6 mm thick shim 80 mm wide will not pass under a staightedge 3m long when the straightedge is laid on the finished surface in a direction transverse to the centerline and extending form edge to edge of a 3,5 m traffic lane.

Ground areas on structures, approach slabs and the adjacent 15m of approach pavement shall conform to the requirements for smoothness and concrete cover over reinforcing steel specified in Part -5-.

Ground surfaces shall not be smooth or polished and shall have a coefficient of friction of not less than 0.30 as determined by California Test 342.

Residue from grinding operations shall be picked up by means of a vacuum attachment to the grinding machine and shall be picked up by means of a flow across the pavement nor be left on the surface of the pavement.

Residue form grinding portland cement concrete pavement shall be disposed of at the location listed and in the manner specified by the Engineer. Residue from grinding asphalt concrete shall be disposed of outside the highway right of way.

The noise level created by the combined grinding operation shall not exceed 86 dBA at a distance of 15 m at right angles to the direction of travel.

Concrete removal and replacement operations shall be performed in such manner that adjacent concrete pavement and subgrade are not disturbed. In the event material underlying removed concrete pavement is disturbed, it shall be recompacted at the Contractor's expense to a relative compaction of not less than 95 percent.

Concrete pavement removed and replaced in lieu of grinding will be measured an paid for by the meter as grind existing concrete pavement.

If the grinding on a section of concrete pavement has begun and the Contractor thereafter elects to remove and replace the section, in lieu of grinding, no payment will be made for grinding performed on such section prior to replacement.

4.11.03 PREPARATION OF MILLED SURFACE FOR RESURFACING

A. When the new asphalt mix is lo be placed on an existing bituminous surface, the surface shall be cleaned of ail foreign material and broomed free of dust. Any loose, broken or shattered asphalt material along the edges of the existing surface shall be removed and the exposed unbound material, and a sufficient width of the sidewalk adjacent to the edge of the existing surface, shall be shaped, bladed, compacted and broomed to provide a uniform firm subgrade base for the new surface course. Broken, soft, or unstable areas of existing asphalt surface, base or subgrade shall be removed and replaced. The areas shall be excavated to a depth as directed and refilled with the specified asphalt mix. Any cracks encountered in the exposed bituminous surface, shall be prepared as specified in 4.10.4A before laying the new asphalt layer.
Prior to placing of the asphalt mix on an existing asphalt surface when required, a tack coat as specified in Section 4.02 - "Bituminous Prime and Tack Coals" shall be applied lo 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.

B. When the asphalt mix is to be placed on an existing aggregate base course surface, the surface shall be recompacted to 100% maximum dry density (AASHTO Modified Proctor).
In locations where the base course consists of gap-graded aggregate, contains excess fines or moisture or does not comply with the specified base course materials quality and cannot be compacted to the above required density: then it shall be replaced to a depth of 150 mm with suitable aggregate base course material in order to meet the Specifications and the Engineer's approval.

Prior to placing of the asphalt mix on an existing or replaced aggregate base course, a prime coal as specified in Section 4.02 "Bituminous Prime and Tack Coat" shall be applied to the surface at the rate determined by the Engineer. No mixture shall be laid on a prime coat until it has been inspected and approved.

4.11.04 MEASUREMENT

A. Cold milling of the existing asphalt shall be measured in square meters of the milled area to the specified depth. All surface preparation and cleaning works specified above shall be deemed included in this pay item.

B. Refilling the milled area with bituminous wearing course shall be paid separately as specified under section 4.05 " Bituminous Wearing Course".

C. Prime coat (when used) under the new bituminous layers shall also be paid separately as specified under Section 4.02 "Bituminous Prime and Task Coats.

D. The contract price paid per square meter for grind existing concrete pavement shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in grinding the existing pavement and removing and disposing of residue, including furnishing water for washing the pavement, as shown on the plans, as specified in these specifications and as directed by the Engineer.

E. Pavement grinding on existing pavements will be measured by the square meter. The quantity of pavement grinding to be measured for payment will be determined by multiplying the width of the area ground by the length ground.

PAY ITEM	UNIT OF MEASUREMENT
(1) Milling (at a specified depth in cm) of the Existing Asphalt	Square Meter (m^2)

SECTION 4.12 IN SITU BITUMINOUS CURB

4.12.01 SCOPE

A. These Works shall consist of furnishing of materials and constructing in situ bituminous curb as and where shown on the Drawings.

4.12.02 MATERIALS

A. All materials shall conform with the relevant requirements of section 4.01 "Materials far Bituminous Construction".

B. Unless otherwise shown on the Drawings, bitumen for in situ bituminous curb shall be 60/70 penetration graded bitumen.

C. Aggregate shall be hard, clean durable crushed slag or gravel complying with the requirements of BS 594. Nominal size of the aggregate shall not exceed 20 mm, and will normally be 10 mm.

D. The percentage of the binder by mass of the total shall be 6-9 per cent unless otherwise requested by the Engineer,

4.12.03 CONSTRUCTION

A. General

A.1 In situ bituminous curbs shall be laid by an approved machine to the dimensions shown on the Drawings, The curbs shall be closely compacted with regular sides, edges, arrises and chamfers finished to a Hue surface, free from blowholes and drawing.

A.2 Making and placing of in situ bituminous curbs shall comply with the recommendations of BS593 1.

B. Plant and Equipment

B.1 All plant and equipment shall conform with the relevant requirements of Section 4-4 "Contractors 1'lanl and Equipment" of the General Requirements and Section 4.03 "Bituminous Courses".

B.2 The mix shall be laid by a self propelled automatic curber machine or a paver capable of producing a dense, smooth-surfaced curb to true line and level.

B.3 The automatic curber or machine shall meet the following requirements;

- The weight of the machine shall provide required compaction without the machine riding above the bed on which curbing is constructed.
- The machine shall form curbing that is uniform m texture, shape and density.
- The Engineer may permit the construction of curbing by other than the automatic curber or machine, when short sections or sections with short radii are required, or for such other warranted reasons. The resulting curbing shall conform in all respects to the curbing produced by the use of the machine.

C. Job Mix Formula

C.1 Within the above limitations, the Job Mix Formula shall be established by the Contractor in accordance with the procedures and requirements of Section 4.03"Biti!minous Courses".

C.2 Where the curb is immediately close to the carriageway and where there is a high risk from mechanical damage from vehicle impact, a harder grade of binder coupled with the courser range of aggregate content is recommended.

D. Trial Mixes

The Contractor shall make trial mixes and carry out tests using the same plant as will be used in the works as and where directed and in accordance with the relevant requirements of Section 4.03 "Bituminous Courses'".

E. Surface Preparation

E.1 The surface should be dry and cleaned of loose or deleterious material.

E.2 Except in the case of freshly laid bituminous wearing course, a tack coat, complying with the requirements of Section 4.02 "Bituminous Prime and Tack Coats", shall be applied to the surface before the curb is laid. The Contractor shall prevent the spread of tack coat to areas outside the curb area.

E.3 Preparation of the surface upon which the bituminous curb is to be laid and the use of tack coat shall conform with the relevant requirements of Section 4.03 "Bituminous Courses".

4.12.04 MEASUREMENT

A. In Situ Bituminous Curb shall be measured by linear meter (lin.m.) furnished, installed, completed and accepted.

B. Surface preparation and tack coat shall not be measured or paid for as prescribed in Section 4.02 "Bituminous Prime and Tack Coats".

PAY ITEM	UNIT OF MEASUREMENT
(1) In Situ Bituminous Curb	Linear meter (m)

SECTION 4.13 PLANING OF THE EXISTING ASPHALT

4.13.01 SCOPE

A. The works shall consist of cold planning of the top surface of the existing asphalt concrete pavement, where and as shown on drawings or directed by the Engineer in order to obtain the required levels and grades and prepare surface for receiving the subsequent asphalt overlay.

4.13.02 SURFACE PREPARATION

A. When the asphalt mix is to be placed on an existing asphalt surface (after it has been planed), the surface shall be cleaned of all foreign material and bloomed free of dust. Any loose, broken or shattered material along the edges of the existing surface shall be removed and the exposed surface shall be shaped and bloomed to provide a uniform base for the new overlaying course. Broken, soft, or unstable areas of existing asphalt surface, base or subgrade shall be removed and replaced. Cracked surface shall be sealed with approved material before laying new asphalt.

4.13.03 MEASUREMENT

A. Cold Planning of the existing asphalt shall be carried out to a maximum depth of 20 cm. All surface preparation and cleaning works specified above shall be deemed to be part of item 4.05.12.

B. Refilling the planed area with bituminous courses and other pavement materials shall be paid as specified item 4.05.12.

SECTION -5-

CONCRETE, STEEL, AND STRUCTURES

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SECTION 5.01 CONCRETE AND CONCRETE MIXES AND TESTING

5.01.01 SCOPE

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

5.01.02 MATERIALS

A. Cement

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

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

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

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

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

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

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

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

Composition **Properties**

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

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

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

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

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

A.13 Cement remaining in bulk storage at the mill, prior to shipment, for more than 6 months or cement stored in bags in local storage by the Contractor or a vendor for more than 3 months after shipment from the mill, may be retested before use and will be rejected if it fails to meet any of the requirements of these specifications.

B. Aggregates

B.1 Potential aggregate sources shall be examined and particular attention shall be paid to the following aspects of the deposits and the actual or proposed extraction and production arrangements:

Name, location, local national grid reference, type of deposit, potential variability, methods of extraction.

Methods and degree of control exercised over extraction.

Processing methods, types of plant, number of processing stages, standards of maintenance and process control, producer's laboratory facilities and technical staffing.

Stockpiling arrangements, loading and supply arrangements.

Potential variations in end-products due to variations inherent in the deposit and in the existing methods of extraction, processing and stockpiling.

Possible modifications to existing extraction, processing, storage and handling arrangements, and to supervision arrangements to reduce end-product variations.

Possible requirements for supplementary processing on site.

Photographs shall be provided of each of the proposed new sources and related production arrangements. The source photographs should preferably include low level (helicopter) aerial photographs and close-ups of working faces.

B.2 Aggregate deposits shall be sampled and tested in an appropriate and systematic manner to assess their potential variability and to assist in determining appropriate methods of extraction and processing.

B.3 The deposit investigation and sampling programs shall be relevant to each type of deposit and shall be devised and supervised by an experienced approved engineering geologist, after he has made a field reconnaissance of the potential deposit areas, or the existing workings.

B.4 Each size of aggregate shall be sampled at the discharge points on the production plant (i.e. conveyors or hoppers, not stockpiles) at three well spaced intervals during the course of each of three consecutive production days; these samples shall be designated “production samples”.

B.5 In addition, selected samples shall be taken from producer’s stockpiles to represent any readily visible variations in physical characteristics, or appearance, or materials ready for loading, these samples shall be designated “stockpile samples”.

B.6 All samples shall be taken by arrangement with and in the presence of the Engineer, or his representative, and shall be tested as required below.

B.7 Representative portions of the above samples shall be taken for reference purposes and shall be split and retained on site by the Contractor and by the Engineer.

C. Testing Aggregates

C.1 Each production sample shall be tested for the following:

Proportion of natural (uncrushed) material (% by weight) gradings, passing 75mm sieve (U.S. Sieve No.200 to AASHTO M92 or ASTM M81) when tested in accordance to AASHTO T 11 .

Total acid soluble chloride content and total acid soluble sulfate content (% by weight).

Flakiness and elongation indices.

C.2 Representative portions of equal weight shall be taken from each of the production samples of each size of aggregate and then combined to provide composite production samples for each size of aggregate. The composite samples shall be tested as for the individual unless otherwise directed by the Engineer.

Potential Reactivity tests for alkali-silicate and alkali-carbonate reactions: petrographic examination in accordance with ASTM C295, rapid chemical method in accordance with ASTM C289 and rock expansion test in accordance with ASTM C586.

If one or more of the tests in sub-item C.2.1 above are positive then the mortar prism test in accordance with ASTM C227 shall be carried out.

Partial chemical analysis, including insoluble residue (ASTM D3042-84), chloride content, sulfate content and calculated approximate composition.

ASTM Soundness Test C88, using sodium sulfate solution or ASTM Soundness Test C88, using magnesium sulfate solution.

Aggregate Impact Value by the Los Angeles test in accordance with AASHTO T96-83 ASTM C 131 -81, ASTM C535-81.
10% Fine Value to BS 812.

Aggregate Abrasion Value to BS 812..

Specific Gravities and Water Absorption to BS 812 or approved ASTM equivalent

C.3 Stockpile samples shall be examined and tested in as many of the above mentioned respects as are considered relevant by the Engineer.

C.4 The properties of the aggregates shall be such that the Drying Shrinkage of concrete prepared and tested in an approved laboratory in accordance with the United Kingdom Building Research Station Digest No. 35 (Second Series) shall not exceed 0.045 percent.

The Initial Drying Shrinkage of all the proposed concrete mixes prepared and tested in an approved laboratory in accordance with BS 1881 shall not exceed 0.06 percent.

C.5 Aggregate for use in concrete or mortar that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground, shall not contain material that is deleteriously reactive with the alkalis in the cement, or any which maybe additionally present in the aggregates and mixing water or water in contact with the concrete or mortar, in amounts sufficient to cause excessive localized or general expansion of concrete or mortar.

Under no circumstances shall the Contractor use Dacite, Andesite, Rhyolites, Opal Cherts and Tuffs.

Coarse and fine aggregates shall be tested for reactivity potential in accordance with the methods listed above and shall satisfy the various criteria given for innocuous aggregates in the relevant standard.

In case the aggregate source has no previous records and no performance history, potential reactivity should be evaluated using the specified tests. However, if the aggregate has been used in previous works in adjacent location and performed well without showing signs of Alkali reaction, the results of these tests should not be used as the only factor deciding the usage of the aggregate. The Engineer shall then decide on this matter.

The period of the tests is minimum 14 weeks to 26 weeks unless the accelerated test is used instead of the mortar bar test (ASTM C227).

D. Fine Aggregates

D.1 Fine concrete aggregates shall conform to AASHTO M6 and shall consist of natural sand or crushed rock having hard and durable particles or, if approved by the Engineer other inert materials having similar characteristics, 100% passing 9.5 mm sieve and 2% to 10% passing 0.15 mm sieve. It shall not contain harmful materials such as iron pyrites, coal, mica, shale or similar laminated materials such as flat and elongated particles or any materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength, durability and texture of the concrete.

D.2 The Contractor shall, when directed by the Engineer, wash the fine aggregates to remove deleterious substances or for consistency of concrete colour. Such washing shall be carried out using fresh water. The water shall be replaced regularly as deemed necessary to maintain its chloride and/or sulfate content low.

D.3 The total acid soluble sulfate content (BS 812:Part 118 1988) of fine aggregate expressed as sulphur trioxide (S03), shall not exceed 0.40% by dry weight (AASHTO T260-82, BS 812: Part 117). The total acid soluble chloride content expressed as sodium chloride (NaCl) shall not exceed 0.10% by dry weight of fine aggregate. The following additional requirements shall apply to the concrete mix:

Total sulfate content (as S03) of any mix excluding that present in the cement but including any present in the other materials shall not exceed 2.5% by weight of cement in the mix.

Total chloride content (as NaCl) of any mix including any chloride present in the other materials and in the mix water shall not exceed 0.35% by weight of cement in the mix.

D.4 Fine aggregate shall meet the following additional requirements:

Fineness modulus AASHTO M6: ± 0.20% of approved value which shall be not greater than 3.1 or less than 2.3. Sieve analysis to AASHTO T27.

Sodium or magnesium sulfate soundness AASHTO T104: max. 12%, 18% loss respectively.

Content of clay lumps and friable particles, AASHTO T 112-82: 3% max.

Sand equivalent AASHTO T176: min 75% .
Coal and lignite, AASHTO T113-82: 0.5% max.

Organic impurities AASHTO T21-81: not darker than standard colour.

D.5 The amount of hollow shells likely to form voids and present in material retained on a 2.36 mm sieve determined by direct visual separation, shall not exceed 3% by weight of the entire sample.

D.6 When sampled and tested in accordance with the appropriate sections of BS 812 (using BS 410 test sieves) the grading of fine aggregates shall be within the limits of the grading zones given in Table 4 of BS 882. The fine aggregate shall be described as a fine aggregate of the grading zone into which it falls.

D.7 If the fineness modulus varies by more than 0.2 from the value assumed in the concrete mix design, the use of such fine aggregate shall be discontinued until suitable adjustments can be made in the mix proportions to compensate for the difference in gradation.

E. Coarse Aggregates

E.1 Coarse concrete aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel, or crushed stone free from coating of clay or other deleterious substances. It shall not contain harmful or any other materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength and durability of the concrete. If necessary, coarse aggregate shall be washed to remove deleterious substances, or for consistency of concrete colour.

E.2 The total acid soluble sulfate content (BS812: Part 118, 1988) of coarse aggregate expressed as sulphur trioxide (S03), shall not exceed 0.40% by weight (AASHTO T260-82, BS812: Part 117).The total acid soluble chloride contents of coarse aggregates, expressed as sodium chloride (NaCl), shall not exceed 0.05% by weight. These limits are subject to the following overriding requirements:

The total sulfate content (as S03) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix

The total chloride content (as NaCl) of any mix, including any chloride present in the other materials and the mix water, shall not exceed 0.35% by weight of cement in the mix.

E.3 Coarse aggregate shall also meet the following additional requirements:

Sodium or magnesium sulfate soundness AASHTO T104: 5 cycles: max. 12%, 18% loss respectively.

Abrasion, in accordance with AASHTO T96 max 40% loss.

Content of clay lumps and friable particles AASHTO T112-81: max. 1% by weight.

Soft fragments and shale AASHTO M80: max. 5% by weight.

Flakiness index, BS812: 30% max. Elongation index, BS 812:30% max.

Coal and Lignite, AASHTO T113-82: 0.5% max.

E.4 The grading of coarse aggregate shall comply with AASHTO M43.

E.5 The coarse concrete aggregate, when tested according to AASHTO T27,shall meet the following gradation requirements and shall be graded within the limits stated in Table5.1.1.

Table 5.5.1: Limits of Gradation for Coarse Aggregates

AASHTO Sieve Size	mm	Percent Passing by Weight for					
		Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
3'	75	100	-	-	-	-	-
2 ½"	63	-	100	-	-	-	-
2"	50	90-95	95-100	100	-	-	-
1 ½"	37.50	-	-	95-100	100	-	-
1"	25.0	30-65	35-70	-	95-100	100	-
3/4"	19.0	-	-	35-70	-	95-100	100
1/2"	12.5	10-30	10-30	-	25-60	-	90-100
3/8"	9.5	-	-	10-30	-	20-55	40-70
No. 4	4.75	0-5	0-5	0-5	0-10	0-10	0-15
No. 8	2.36	-	-	-	0-5	0-5	0-5
No. 200	0.075	0-1	0-1	0-1	0-1	0-1	0-1

E.6 The type of grading for coarse concrete aggregates shall depend on the maximum size of aggregate, which shal1 not be larger than one-fifth (1/5) of the narrowest dimension between sides of forms, nor larger than two-thirds (2/3) of the minimum clear spacing between reinforcing bars, whichever is least.

E.7 Before batching, all types of coarse aggregate shall be separated into fractions having uniform grading as determined by the Engineer.

E.8 However, the number of fractions and their gradings shall be fixed on the basis of the maximum size of the aggregates in the cement concrete as proposed below:

- For fractions up to 1-1/4":(31.5 mm) between 3/8" and 3/4" (9.5 - 19.0 mm).
- For fractions up 1-1/2" to 3": (37.5-75 mm) between 3/4" and 1-1/4" (19.0 - 31.5 mm)

F. Combined Aggregates

F.1 Combined aggregate is composed of a mixture of coarse aggregates and fine aggregates. They shall be used only in proportions with the prior approval of the Engineer.

F.2 In no case shall materials passing the No. 200 (0.075 mm) sieve exceed 3% by weight of the combined aggregate.

F.3 The combined concrete aggregate gradation used in the work shall be as specified, except that when approved or directed by the Engineer. Grading 7 of Table shall be used for curbs, handrails, parapets, posts and other similar sections or members with reinforcement spacing too close to permit proper placement and consolidation of the concrete.

F.4 Changes from one gradation to another shall not be made during the progress of work, unless approved by the Engineer.

F.5 For the proportion of each fraction of coarse aggregate and for the proportion of fine and coarse aggregate, the combined gradings in Table 512 shall be utilized as a guideline for the mix proportion design as to guarantee the maximum densities of the concrete. Before batching, however, the Engineer or his representative shall check only the compliance of the grading of the fine and coarse aggregate with the requirements of the Specifications, since the grading of each fraction ultimately remains the sole responsibility of the Contractor.

Table 5.1.2: Limits of Gradation for Combined Aggregates

AASHTO Sieve Size	mm	Combined Aggregate Percent Passing by Weight for						
		Grading 1	Grading 2	Grading 3	Grading 4	Grading 5	Grading 6	Grading 7
3"	75	100	-	-	-	-	-	-
2 ½"	63	88-95	100	-	-	-	-	-
2"	50	78-90	85-95	100	100	-	-	-
1 ½"	37.50	66-81	74-86	80-92	93-98	100	-	-
1"	25.0	51-70	56-75	63-80	70-88	87-96	100	-
3/4"	19.0	43-62	47-67	52-72	60-79	73-86	80-96	100
1/2"	12.5	32-53	36-58	41-60	47-66	57-74	61-80	73-86
3/8"	9.5	27-48	30-53	36-54	40-60	48-68	52-72	61-79
No. 4	4.75	19-38	22-42	23-43	28-49	34-55	38-56	43-64
No. 8	2.36	9-27	10-29	12-30	16-36	24-40	25-41	26-46
No.16	1.18	4-19	5-21	6-22	7-25	9-28	11-29	13-33
No.30	0.600	3-15	4-17	4-19	5-21	7-23	8-24	10-28
No.50	0.300	2-11	2-13	2-14	2-15	4-17	5-19	5-21
No.100	0.150	1-7	1-8	1-8	1-9	2-10	2-11	2-12
No.200	0.075	0-3	0-3	0-3	0-3	0-3	0-3	0-3

G. On Site Storage of Aggregates

G.1 Adequate stocks of tested and approved aggregates shall be maintained on site and the capacity of the storage bins for each type and grading of aggregate shall be sufficient to hold the respective quantities required for the maximum amount of concrete which the Contractor is obliged or intends to pour in any continuous operation in one day. Stockpiles shall be built in layers of 1.50 m maximum height and segregation of the aggregates prevented. Different grades of aggregates shall be totally separated by concrete block walls.

G.2 Dense concrete or bituminous slabs shall be laid with sufficient falls to cover all aggregate stockpile areas or bins and shall extend to cover all surrounding areas where aggregates are likely to be discharged or handled. These areas shall be swept and kept clean at all times to ensure that the aggregates are not contaminated by the adjacent ground through trafficking or otherwise, and shall be constructed with adequate drainage for surplus water.

G.3 Windbreaks shall be provided where aggregates might suffer excessive contamination by windblown materials. During periods of heavy rain the bins or compounds shall be covered by tarpaulins or other approved means.

H. Rejection of Aggregates

H.1 The general or localized build up of fines in aggregate stockpiles shall not be allowed and any material which, in the opinion of the Engineer, is so affected will be rejected after testing.

H.2 Aggregates which have suffered segregation or contamination during processing, handling at source, transportation to the site, stockpiling and handling on site, or which otherwise do not conform with requirements of the Specifications, either locally or generally, will be rejected and shall be removed promptly from the site.

H.3 Aggregates which are found to be contaminated during transportation or during stockpiling or during handling shall be promptly removed from the site by the Contractor notwithstanding any prior approval of the source which may have been given by the Engineer.

I. Washing and Processing Aggregate

The Contractor may be required to carry out on site supplementary processing or effective washing of coarse and fine aggregates where the aggregate producer's methods, in the opinion of the Engineer, may not result in end products which consistently comply with all requirements of the Specifications, or where aggregates suffer unacceptable changes during loading at source or during subsequent transportation to the site, or otherwise.

J. Water

J.1 All sources of water to be used with cement whether for mixing or curing of concrete, or compaction of backfill around the concrete structures, shall be approved by the Engineer. If at any time during construction, water from an approved source become unsatisfactory, the Contractor shall provide satisfactory water from other main sources.

J.2 Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt as determined by the Engineer. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of AASHTO T26 and BS 3148. If the specific conductance is less than 1500 microohms per centimeter the total solids content requirement may be waived.

J.3 Non-potable water may be used when potable water is not available provided the impurities do not exceed the values given in Table 5.1.3.

J.4 Mortar prepared with water submitted by the Contractor for approval shall show no marked change in time of set, no indication of unsoundness and a reduction of not more than ten (10) percent in mortar strength when compared with mortar made with water of known satisfactory quality.

J.5 The water used in the mix design shall be the same as the water approved for site use.

J.6 Water used for prestressed concrete structures or for concrete containing or in contact with aluminum fittings or fixtures shall not contain chloride ions.

Table 5.1.3: Maximum Permitted Impurities in Non-Potable Water

Impurity	Max. Concentration (ppm)	Method
Chloride as (Cl-)		
a) Prestressed concrete or concrete in bridge Decks	500	ASTM D5l2
b) Other reinforced concrete in moist environment or containing aluminum embedments or dissimilar metals or with stay in place galvanized metals form	1000	
Sulfates as S04	300	ASTM D5l6
Alkalis as(Na_2O+0.658 K_2O)	600	AASHTO T-26
Total solid	5000	

K. Admixtures

K.1 General: The quantity and method of using admixtures shall be in accordance with the manufacturer's recommendations and in all cases shall be subject to the approval of the Engineer.

K.2 In all cases the Contractor shall provide the following information for the Engineer's approval:

- The quantity to be used, in kilograms per kilogram of cement and in kilograms per cubic meter of concrete.
- The detrimental effects caused by adding a greater or lesser quantity in kilograms per cubic meter of concrete.
- The chemical name(s) of the main active ingredient(s).
- Whether or not the admixture leads to the entraining of air.

K.3 The Contractor shall demonstrate the action of an admixture by means of trial mixes.

K.4 The use of calcium chloride in any form is prohibited.

K.5 Reference may be made to ACI Committee 212 report "Guide for Use of Admixtures in Concrete".

L. Admixture to Produce High Workability

L.1 Concrete for use in certain construction shall contain an approved superplasticising agent when so directed by the Engineer. The superplasticiser shall be stored and used strictly in accordance with the manufacturer's instructions and must be fully compatible with all proposed concrete mix constituents. The optimum dosage of the additive shall be determined by site and laboratory trials to the Engineer's approval. The Contractor shall submit to the Engineer full details of his proposed mix design which must ensure that the minimum strength requirements as specified for the particular use of the concrete are achieved. Only when the Engineer has approved the proposed mix design may such a mix be used in full compliance with the Specifications.

L.2 The Contractor's mixing and transporting plant shall be so designed that accurate metering of the superplasticising agent is possible and so that the additive may be introduced immediately before placing.

L.3 The Contractor's rates for concrete listed in the Bill of Quantities shall include for the use of superplasticisers. The rate shall include for the use of superplasticisers. The rate shall be inclusive for compliance with the Specifications together with all necessary testing and trials for concrete containing superplasticisers.

5.01.03 DEFINITIONS

A. Crushing Strength
The crushing strength of a test cylinder shall be prepared in accordance with AASHTO T23 and AASHTO T126. Alternative standard cubes may be tested in accordance to BS specifications.

B. Average Strength
The mean of the crushing strengths of specimens taken from a sample of concrete

C. Characteristic Strength
The value of the crushing strength below which 5% of the population of all possible strength measurements of the specified concrete are expected to fall.

D. Fresh Concrete
Concrete during the initial period of two hours from the addition of water to the cement.

E. Batch
The quantity of concrete mixed in one cycle of operations of a batch mixer or the quantity of concrete conveyed ready-mixed in a vehicle, or the quantity discharged during one minute from a continuous mixer.

F. Sample
A quantity of concrete taken from a batch whose properties are to be determined.

G. Regular Sampling

The sampling of concrete nominally of the same mix received regularly from the same source.

H. Specimen

Cylinder or cube taken from a sample for testing.

5.01.04 CONCRETE STRENGTH REQUIREMENTS

A. Design Mixes

A.1 Mixes for the classes of concrete shown in Table 5.1.4 shall be designed by the Contractor then specified for use in any part of the Works. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and vibrated in the particular locations required. Unless otherwise approved by the Engineer, the mix designs shall be on the basis of continuously graded aggregates and all mix designs shall be submitted to the Engineer for approval.

A.2 The Cement content in any mix shall not exceed 450 kg/m3.

A.3 The 7-day compressive strengths shall not be less than 75% of the specified 28 day strengths. If the 7 days results are below 75% of the required 28 days strength the Contractor may postpone works related to the suspected concrete until the 28 days results are available and successful or if the Contractor decides to continue work he may do so under his own responsibility and risk.

A.4 The ultimate cylinder compressive strength of concrete shall be determined on test specimens obtained and prepared in accordance with AASHTO T23 and AASHTO T 126 except that six inch by twelve inch cylinders shall be used for all compression tests. Alternatively the Engineer may require ultimate compressive strength of concrete to be determined on test specimen obtained by taking and airing cubes in accordance with BS 1881. The Contractor shall furnish single-use cylinder moulds conforming to AASHTO M205 or when approved by the Engineer re-usable vertical moulds made from heavy gauge metal.

Table 5.1.4: CONCRETE CLASS AND DESIGN MIXES

Class of Concrete	Cylinder Works Strength @ 28 days Kg/cm^2	Equivalent Works Cube Strength @ 28 days kg/cm^2	Maximum Size of Aggregate mm	Minimum Cement Content Kg/m3
110/25 (Blinding)	110	140	25	220
140/25	140	180	25	250
170/60	170	210	60	275
210/50	210	260	50	300
210/25	210	260	25	325
210/20 (B20)	210	260	20	325
250/20 (B25)	250	310	20	350
250/30	250	310	30	350
310/20	310	385	20	375
360/20	360	450	20	425
400/20	400	500	20	425

B. Nominal Concrete Mix

B.1 General

Concrete for use as backfilling for structural excavation shall be either no-fines concrete or cyclopean concrete as directed by the Engineer. The cement: aggregate ratio of such nominal mixes shall be not greater than 1:15 and the minimum cylinder strength at 28 days not less than 50kg/cm2.

B.2 No-Fines Concrete

No-fines concrete shall comply with the grading in Table 5.1.5 and shall be mixed and laid in general conformity with this Section 5.01.

B.3 Cyclopean Concrete

Plums used in cyclopean concrete shall consist of non-reactive broken stone spalls or boulders ranging in size from 200 mm to 300 mm. They shall be free from sharp or angular edges and shall not form more than 30% of the total volume of concrete. They shall be evenly graded and shall be soaked in water prior to incorporation in the mix. Plums shall he evenly distributed in the concrete mix with a minimum cover of 100 mm.

TABLE 5.1.5: GRADING FOR NO-FINES CONCRETE

GRADING OF AGGREGATE Sieve Size	% by Dry Weight Passing
90 mm	100
40 mm	85-100
20 mm	0-20
10 mm	0-5

C. Compliance with Strength Requirements

C.1 General

Cylinders (or cubes) from concrete as mixed for the Work will be tested in accordance with AASHTO T22 (BS 1881 for cubes) after seven (7) days and twenty eight (28) days. Test specimens shall be made and cured in accordance with AASHTO T23. These specimens will be the basis for acceptance of the concrete in the structure.

C.2 Preliminary Tests

Prior to the commencement of any concreting work and subsequently, whenever a change is intended, preliminary tests shall be carried out. From each of three samples of materials, a trial mix shall be made. For each class of concrete, the trial mixes shall represent at least two different water cement ratios. From each trial mix, six cylinders (or cubes) shall be made, three for testing at 7 days, and three for testing at 28 days. The average strength of the cylinders (or cubes) tested for each sample shall be taken as the preliminary cylinder (or cube) strength of the mix.

The Engineer will require the preliminary test to be repeated if the difference in strength between the greatest and the least strength is more than 20 per cent of the average.

The water/cement ratio and slump adopted in the preliminary tests for each class of concrete shall be used in the works concrete. It shall be such that, if selected for use at the Site, the concrete can be worked readily into the corners and angles of the forms and around the reinforcement without permitting the materials to segregate, or free water to collect on the surface.

Preliminary tests shall have these minimum ultimate strengths given in Table 5.1.6.

C.3 Works Tests

During the first four days of the commencement of concreting with any particular mix, two sets of six works cylinders (or cubes) in each set shall be made each day. Three cylinders (or cubes) from each set shall be tested at 7 days, and 3 at 28 days. The above works tests shall be carried out for each class of concrete. Subsequently, the frequency of making sets of test cylinders (or cubes) and the number in each shall be as directed by the Engineer.

Table 5.1.6: PRELIMINARY TESTS FOR STRENGTH

Class of Concrete	Cylinder Strength (kg/cm^2)	Equivalent Cube Strength (kg/cm2)
110/25	170	210
140/25	210	260
170/60	240	300
210/50	290	360
210/25	290	360
210/20	290	360
250/20	325	400
250/30	325	400
310/20	395	490
360/20	440	550
400/20	480	600

The cylinders (or cubes) shall be cured in the same manner and environment as the members they represent. The cylinder (or cube) strength shall be accepted as complying with the specified requirement for work cylinder (or cube) strength if none of the compressive strengths of the cylinders (or cubes) falls below the minimum strengths given in Table 5.1.4 or if the average strength is not less than the specified minimum works cylinder (or cube) strength and the difference between the greatest and least cylinder (or cube) strength is not more than 20 percent of the average.

Alternatively, the criterion of acceptable test results shall be that not more than 5 per cent of works cylinders fall below the specified strength. For this to be fulfilled, the mean strengths of works cylinders (or cubes) less 1.64 times the standard deviation should not be less than the required strength. This calculation shall be made for both 7 and 28 day cylinder (or cube) tests as soon as 24 cylinders (or cubes) have been tested at each age. Thereafter, it shall be repeated as further test results become available at a frequency determined by the Engineer. The number of cylinders (or cubes) considered in each calculation shall be the total number of cylinders (or cubes) of the mix in question tested from the commencement of the Works.

Cores shall be taken in accordance with ACI 318-89, article 5.6.4, and tested in accordance with AASHTO T24. Load testing shall be carried out in accordance with ACI 318-89, chapter 20. The Contractor shall hire an authorized independent laboratory to carry out such tests at no extra cost to the Client.

C.4 The Engineer may make additional test cylinders to ascertain the effectiveness of the methods by which the structure is being cured, and also to determine when the structure may be placed in service. These cylinders shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders from all damage.

C.5 The Contractor shall take every precaution to prevent injury to the test cylinders during handling, transporting and sorting. He will be held solely responsible for any test failure caused by improper handling and transportation, or any other cause which may be detrimental to the test cylinder.

C.6 In order that the test cylinders may be transported from field to laboratory undamaged, the Contractor shall provide a minimum of two (2) approved boxes. [One (1) for the Contractor's use and one (1) for the Engineer's use.] Boxes shall be of such size to receive a minimum of six (6) test cylinders and leave space for sawdust packing around all surfaces of the cylinders. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

C.7 When test cylinders fail to meet minimum strength requiremcnts, the Engineer may require core samples to be taken to determine the acceptability of such structures. The Contractor shall, at his own expense, furnish all equipment required for such core samples.

5.01.05 COMPOSITION OF CONCRETE

A. Mix Proportions

A.1 The Contractor shall consult with the Engineer as to mix proportions at least forty five (45) days prior to beginning concrete work. The actual mix proportions of cement, aggregates, and water shall be determined by the Contractor under the supervision of the Engineer.

A.2 The Contractor shall, in the presence of the Engineer, prepare trial-mixes for each class of concrete required for the project, made with the approved materials to be used in the Work. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the cement content specified and meeting the plasticity requirements and the preliminary test strength requirements specified for the designated class of concrete.

A.3 If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the use of admixtures to maintain the water content within the specified limit shall be permitted. At all times the concrete mix shall satisfy the durability requirements by satisfying the minimum and maximum limits specified of cement and water contents respectively.

A.4 The Engineer will review the Contractor's trial - mixes and break the test cylinders at seven (7) and twenty-eight (28) days. The Engineer will then determine which of the trial mixes shall be used. If none of the trial-mixes for a class of concrete meets the specifications, the Engineer will direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

A.5 The approval of the job-mix proportions by the Engineer, or his assistance to the Contractor in establishing those proportions, in no way relieves the Contractor of the responsibility of producing concrete which meets the requirements specified in these specifications.

A.6 All costs connected with the preparation of trial-mixes and the design of the job mixes shall be borne by the Contractor, except that the Engineer shall not charge the Contractor for laboratory supervision and the breaking of the test cylinders.

B. Design Limits

The following will be designated by the Engineer within the limits of the specifications:

The minimum cement content in sacks per cubic meter of concrete.

The maximum allowable water content in liters per sack of cement, or equivalent units, including surface moisture, but excluding water absorbed by the aggregates.

The ratio of coarse and fine aggregates.

Slump or slumps designated at the point of delivery.

C. Changes to Mix Design

C.1 Changes in mix proportions requested by the Contractor to previously approved mix designs shall only be made after new approval by the Engineer.

C.2 When, in the opinion of the Engineer, cement is being lost due to windy conditions, the Contractor shall add additional amounts of cement as directed by the Engineer. No additional payment will be made for the added cement.

C.3 As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions from time to time if conditions warrant such changes to produce satisfactory results. Any such change may be made within the limits of the specifications at no additional compensation to the Contractor.

C.4 When in the opinion of the Engineer, an adjustment for protection against concrete deterioration due to salty environment is necessary, he may require the cement content be increased ten (l0) per cent over and above that cement content used in the approved trial mix design for non-salty environment. Water content shall be adjusted accordingly to obtain a dense workable mix. All bridge footings and column lengths to the first construction joint above the ground surface for the entire project are subject to this increased cement content. No additional payment will be made for the increase in cement content.

C.5 Failure of the mix to meet specifications determined by the Engineer under items A and B in this sub-section will be grounds for the Engineer to reject the concrete.

C.6 Mortar for laying stone for grouted stone riprap, grouted stone wash checks or grouted stone ditch lining shall be composed of one (1) part of Portland cement and three (3) parts of fine aggregate by volume with water added to make a workable mix of such consistency as to perform properly the functions required for the work being done. Amount of water added shall be approved by the Engineer.

a) Aggregates for masonry mortar shall conform to AASHTO M45.
b) Portland cement shall conform to AASHTO M85, Type I, II or III.

5.01.06 REQUIREMENTS FOR COMBINING MATERIALS

A. Measurement for Proportioning Materials

A.1 Cement: The cement shall be measured in bulk or as packed by the manufacturer, a sack of cement shall weigh 50 kilograms. Measurement shall be accurate to within 3.0 per cent throughout the range of use.

A.2 Water: The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within 2.0 percent throughout the range of use.

A.3 Aggregates: The aggregates shall be measured by weight. The measurement shall be accurate to within (+ or - 2.0% fine, coarse aggregates) throughout the range of use.

A.4 Additives: Additives shall be measured by volume if in liquid form and by weights if solid. The measurement shall be accurate to within 3.0 per cent throughout the range of use.

B. Assembly and Handling of Materials

B.1 Assembly: Aggregates shall be assembled in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient unsegregated materials having proper and uniform moisture content to ensure continuous and uniform operation. Aggregates shall enter the mixer in a manner approved by the Engineer and so as to ensure that no matter foreign to the concrete or matter capable of changing the desired proportions is included. In the event that 2 or more sizes or types of coarse or fine aggregates are used on the same project, only 1 size or type of each aggregate may be used on one continuous pour.

B.2 Stockpiling of Aggregates: All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content, to provide uniform conditions for proportioning plant control and to aid in obtaining concrete that is uniform as to materials and moisture content. The use of equipment or methods of handling aggregates which results in the degradation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles. All equipment used for handling aggregates shall be approved by the Engineer. Stockpiling of aggregates shall be in the manner approved by the Engineer, and in addition, every precaution shall be taken to prevent segregation. Segregation shall be prevented by making no layer higher than 1.5 meters and if 2 or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer. Aggregates shall not be stockpiled against the supports of proportioning hoppers and weighing devices.

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

B.4 **Transporting of Aggregates:** If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being dumped.

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

a) All cement bags shall be marked with the date of manufacture. Additionally, all bags shall be marked with the date of storage so that they can be taken out for use in the same order as they were brought in to storage.

b) Cement bags shall be placed on wooden shelves at least 100 mm above ground and 150 mm clear of walls.

c) Unpacked cement shall not be used six months after manufacture and bagged cement three months after manufacture.

d) No cement shall be used which has been affected by humidity, regardless of the date of manufacture.

e) Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within 1.5 hours.

C. Mixing

C.1 Concrete shall be mixed in quantities required for immediate use. Concrete shall not be used which has developed initial set. Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

C.1.1 If washed sand is used while still wet the mixing time starts with the addition of cement to the aggregate, even if the water required for the mixing has not been added.

C.2 The concrete may be mixed at the site of the Works, in a central-mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements of Sub-Section 5.01 .7 "Ready-Mixed Concrete and Central-Mixed Concrete".

C.3 The coarse aggregate shall first be loaded into the mixer followed by the fine aggregate. Some mix water shall be added to the mix before the cement is loaded into the mixer. Water shall be continually added throughout the mixing. Additives, if required and approved by the Engineer, shall be added according to the manufacturers' instructions. Retarders shall be added within one minute or 25% of the total mixing time whichever is the smaller.

C.4 The manufacturers' instructions shall be followed in respect of overloading the mixer and the selections of the rate of revolutions of the mixer.

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

C.6 After mixing, the concrete shall be homogeneous and comply with the provisions of these specifications. The Engineer may, if the mix fails to produce concrete of the required strength vary the mix time.

D. Central Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

D.1 **Cement:** Means provided for storing cement shall be as approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved cement before starting to manufacture concrete for the Works.

D.2 **Aggregate:** Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregate shall come from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved aggregate before starting to manufacture concrete for the Works.

D.3 **Consistency:** The Contractor shall be responsible for producing concrete that is homogeneous and complies with the provisions of these specifications.

D.4 **Hauling:** Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators, non-agitating trucks having special bodies or other approved containers.

D.5 **Time of Haul:** The time elapsing from the time water is added to the mix until the concrete is deposited in place shall be not greater than:

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

- Thirty minutes when air temperature is 25°C or higher.
- Forty minutes when air temperature is 1 8°C or below.
- Interpolated time between 18°C and 25°C.

For concrete transported by transit mixer or agitators, the time taken for 300 revolutions of the transit mixer or agitator or 20 minutes, whichever is the lesser.

The maximum haul time may be reduced at the Engineer's discretion if the slump changes or there are signs of the concrete beginning to dry.

D.6 **Delivery:** The Contractor when supplying concrete from a central plant shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be such as to provide for the proper handling, placing and finishing of the concrete. The method of delivery and handling the concrete shall be such as it will facilitate placing with a minimum of rehandling and without damage to the structure or the concrete.

Methods of delivery and handling for each site shall be approved, by the Engineer. The Engineer may delay or suspend the mixing and placing of concrete at any site, for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

5.01.07 READY-MIXED CONCRETE AND CENTRAL MIXED CONCRETE

A. General

A.1 "Ready-Mixed Concrete" and "Central-Mixed Concrete" shall consist of a mixture of cement, water and aggregate, without air entraining or water-reducing admixture. When air-entraining or water-reducing or any other type of admixture is required it shall be at the Engineer's discretion. The terms ready-mixed or central-mixed concrete shall include transit mixed concrete and will be referred to hereinafter as ready-mixed concrete.

A.2 Ready-mixed concrete may be used in the construction of all Works, when approved by the Engineer.

A.3 Approval of any ready mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling the materials, the production procedures, the transportation and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

A.4 Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

Mixed completely in a stationary central mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (known as "central-mixed concrete") .

Mixed completely in a truck mixer at the batching plant or while in transit (known as transit-mixed concrete).

Mixed completely in a truck mixer at the point of use following the addition of mixing water (known as truck-mixed concrete).

A.5 Permission to use ready-mixed concrete from any previously approved plant may be rescinded at any time upon failure to comply with the requirements of the Specification.

B. Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of Sub-Section 5.01.2 "Materials".

C. Equipment

Equipment shall be efficient, well maintained, and shall be of the type and number as outlined in the Contractor's Program of Work. Transit mixers and agitator trucks shall comply with the standards specified in ASTM C94. Non-agitating equipment used for transporting concrete shall be water tight and be equipped with gates that will permit controlled discharge of concrete and, when required by the Engineer, be fitted with covers for protection against the weather.

D. Supply

D.1 Where transit mixers are used, the constituent materials shall be mixed dry in the mixer and water added directly before pour and mixed at the speed and number of turns in accordance with the manufacturers' recommendations.

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

D.3 Time of haul shall not exceed the maximum stated in sub-item D.5 of sub-section 5.01.6 of these Specifications.

E. Uniformity Tests

Four samples of fresh concrete shall be taken, two after 15% of discharge from the truck mixer or agitator truck and two after 85% discharge and within 20 minutes. Slump and compaction factor tests shall be carried out including any other tests specified or required by the Engineer.

F. Samples

F.1 Samples for strength test shall be taken as specified in Clause C of subsection 5.01.4 of these Specifications.

F.2 At least six specimens shall be prepared per sample. Three of these shall be tested at 7 days and three at 28 days.

G. Control of Delivery

G.1 Driver of delivery trucks shall be provided with trip tickets, which shall be signed by a responsible member of the central plant staff, for submission to the Engineer. The ticket shall contain the following information.

- Name and address of the Central Plant.
- Serial number of the ticket and date.
- Truck number.
- Class and/or strength of concrete.
- Cement content of the mix.
- Loading time.
- Slump.
- Any other type of relevant information.

G.2 The Engineer may send his representative to the central plant who may:

- Check the batching and mixing.
- Verify loading time.
- Take a copy of the trip ticket.

G.3 The Contractor and/or concrete supplier shall afford the Engineer and/or his representative, without charge, all facilities necessary to take samples, conduct tests and inspect the central plant to determine whether the concrete is being furnished in accordance with these Specifications.

G.4 Concrete delivered in outdoor temperatures lower than 5 degrees C, or if the temperature is expected to drop below 5 degrees C during the curing period, shall arrive at the Works having a temperature of not less than 10 degrees C nor greater than 32 degrees C.

G.5 In supplying ready-mixed concrete the plant shall have sufficient batching and transporting capacity to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall provide for the proper handling placing and finishing of concrete. If the rate of delivery does not provide a continuous concrete operation the Engineer may suspend all or parts of further concrete work until such time as the Contractor provides sufficient additional delivery equipment which in the opinion of the Engineer will provide for a continuous concrete operation.

5.01.08 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 include mass reinforced and prestressed concrete of both in-situ and precast construction of a general nature but do not include specific components of highway structures such as concrete piles concrete parapets and safety barriers precast concrete curbs and tiles etc. which are separately described in other sections of these specifications.

B. What to measure

B.1 Concrete shall be measured by the cubic meter (m^3) in place and accepted by the Engineer based on dimensions shown on the Drawings or as otherwise directed by the Engineer in writing.

B.2 Different classes of concrete shall be measured separately.

B.3 Concrete formed by different types of form and/or falsework shall be measured separately.

B.4 Concrete of the same class requiring the same falsework but different class of surface finish shall be measured separately.

B.5 Voids, openings or gaps whose size is 0.05 cubic meters or more shall be measured and deducted from the volume of concrete in which they occur.

B.6 All service ducts irrespective of diameter shall be measured and deducted from the volume of concrete in which they are located.

C. Items not measured

C.1 Reinforcing bars shall not be measured for deduction.

C.2 Prestressing ducts, anchors, cones, couplers and grouting tubes shall not be measured for deduction.

C.3 Embedded metals, bolts, nuts, anchorages, hooks etc. shall not be measured for deduction.

C.4 Holes introduced, with the consent of the Engineer, by the contractor for the convenience of transportation, erection or construction shall not be measured for deduction irrespective of the size of the holes and whether or not the holes are made good.

C.5 Additional concrete placed, with the consent of the Engineer, by the Contractor solely for the purpose of facilitating his work shall not be measured for payment.

D. Inclusion in the Rates

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

- Cement, aggregates, water and additives, admixtures and air entraining agents including their testing, storage, handling and transportation.
- Washing of aggregates, if required, and ice added in the mix water, if required.
- Plant, machinery and equipment required for the production of concrete.
- Design of mixes, taking samples and testing specimens.
- Transportation and delivery of concrete to work areas.
- Placing, vibrating and finishing of concrete.
- All formwork irrespective of the material used and the quality of surface finish specified.
- All falsework supporting and stabilizing formwork.
- Curing of concrete.
- Tooling, if required, to achieve the specified surface finish.
- Corrective measures and the means of carrying them out required in the event of the concrete being not in accordance with the drawing and/or specification.
- Handling, transportation and erection of precast concrete members.
- Grout and/or epoxy used in precast construction including material and equipment for temporary prestress, if required.
- Material, plant and equipment associated with particular methods of construction.
- Joint fillers, joint sealants, water stops, dowel bars for water structures as shown on the drawings including material, plant handling, transportation testings storage, workmanship and associated accessories.

PAY ITEM	UNIT OF MEASUREMENT
Concrete (Specify type, class and finish)	Cubic meter (m^3)
Stumped Concrete (Specify type, class and finish)	Meter Square (m^2)
Strengthening of Existing Walls (Specify type, class and finish)	Meter Square (m^2)

SECTION 5.02 CONCRETE HANDLING, PLACING AND CURING

5.02.01 SCOPE

These operations shall consist of the placing, compacting and curing of concrete for mass concrete, reinforced concrete and prestressed concrete structures.

5.02.02 MATERIALS

All concreting materials shall comply with section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

5.02.03 PLACING

A. General

A.1 Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval. Besides specifying the characteristics of the concrete to be employed, this plan shall indicate the time at which placing is to start, the way in which it is to be performed, and the time at which it is to finish. The Engineer's approval shall be sought in writing by the Contractor at least 24 hours in advance.

A.2 The method and sequence of pour, the equipment to be used, the method of compaction and curing procedure shall be approved by the Engineer, prior to concrete pour.

A.3 In order to allow proper vibration of the concrete, it shall be placed in horizontal layers which, at no time shall be thicker than fifty centimeters (after vibration).

A.4 If the concrete is placed in successive phases, there shall be no separations, or discontinuity, or difference of appearance between two successive placings. Before each successive placing is made, the surface of the concrete already in place shall be carefully roughened, cleaned, washed free of loose particles and dampened.

A.5 Concrete shall be placed in such a way that it shall be left undisturbed once it is placed (for example, slabs shall be executed by starting to place the concrete at the side opposite the one from which the concrete is poured, so that there shall be no risk of it being disturbed by workers or equipment, or of tools falling in).

A.6 When concrete is placed for upright reinforced concrete structures, the placing must be completed (for small structures) or interrupted (for large structures) before the concrete which has already been placed has started to harden and might, therefore, be disturbed, if the operation of placing were continued. In such cases placing shall be started again only after twenty four hours have passed. This procedure is intended to avoid the risk of the concrete which has already been placed coming away from the reinforcing bars, because it is moved or disturbed during setting and the initial phase of hardening.

A.7 When the concrete is placed, its temperature shall be nearly the same as that of the reinforcing bars, in order to avoid poor adhesion due to the different coefficients of thermal expansion of the two materials. The reinforcing bars shall, therefore, be protected from the sun (or the cold in winter) or cooled by water jets prior to the

placing of the concrete, or the pouring shall start during the cooler hours of the day and be suspended when the temperature rises above thirty three degrees C.

A.8 The free-drop height of concrete shall be not greater than 1.5m and the method of placing shall be such as to suit the conditions and prevent segregation.

A.9 Placing of concrete shall be continuous between predetermined points such as construction joints, contraction joints and expansion joints.

A.10 Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point in the forms and then run or worked along the forms, thus causing segregation of the materials.

A.11 The concrete shall be deposited in the forms in horizontal layers and the work shall be carried on rapidly and continuously between predetermined planes agreed upon by the Contractor and the Engineer.

A.12 The slopes of chutes, where used, shall be not greater than 1 vertical to 2 horizontal or smaller than 1 vertical to 3 horizontal. The slope of the chute shall be constant along its length. The capacity of the chute shall be adequate to deliver the required volume of concrete at the required rate.

A.13 Aluminum pipes shall not be used for delivering concrete. The internal diameter of delivery pipes, if used, shall be not less than 8 times the maximum aggregate size. At the point of delivery, pipes shall be vertical.

A.14 Where bucket and hopper are used for delivery of concrete, the discharge opening shall be not less than 5 times the maximum aggregate size. The sides of hoppers shall be sloped al not less than 60 degrees to the horizontal.

A.15 When buggies are used to transport fresh concrete, they shall be run on level tracks which are securely fixed. The buggies shall be run smoothly without sudden jerks and the distance shall be not greater than 60 meters.

A.16 All chutes, buckets and hoppers, buggies and pipes shall be kept clean and free from coatings of hardened concrete by thorough flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

A.17 The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and to bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets, or honeycomb.

A.18 Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement content of the class of concrete being deposited in water shall be increased 10 percent without further compensation and the slump shall be approximately 15 centimeters.

A.19 When depositing in water is allowed, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, by means of a tremie, bottom-dumping bucket or other approved means that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being

deposited. No concrete shall be placed in running water, and forms which arc not reasonably watertight shall not be used for holding concrete deposited under water.

A.20 When casing is used in drilled shafts, the easing shall be smooth and properly oiled in accordance with the manufacturers' manual and shall extend sufficiently above the grade of the finish shaft to provide excess concrete to be placed for the anticipated slump due to the casing removal. When the casing is to be pulled, the concrete placed in the casing shall have such a slump and be of such workability that vibrating of the concrete will not be required.

A.21 No concrete work shall be stopped or temporarily discontinued within 45 centimeters of the top of any finished surface unless such work is finished with a coping having a thickness less than 45 centimeters in which case the joint shall be made at the under edge of the coping.

A.22 Concrete in simple slab spans shall be placed in one continuous operation for each span, unless otherwise directed on the Drawings or directed by the Engineer.

A.23 Concrete in in-situ beam and slab construction shall be placed in one continuous operation, or when so shown on the Drawings or approved by the Engineer, may be placed in two separate operations, each of which shall be continuous; first, to the top of the girder stems, and second, to completion. Where a construction joint is permitted between the girder stem and the roadway slab, shop drawings including complete details of key or other methods of bonding will be prepared by the Contractor and submitted to the Engineer for approval. When such a joint is permitted, deck concrete shall not be placed until the concrete in the girder stem has hardened sufficiently so as not to be damaged by the concreting operations of the deck pour.

A.24 Concrete in arch rings shall be placed in such a manner as to load the centering uniformly. Arch rings shall be divided into section such that each section can be cast for the full cross-section in one continuous operation. the arrangement of the section and the sequence of placing shall be as approved by the Engineer, and shall be such as to avoid the creation of initial stress in the reinforcement. The section shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings may be cast in a single continuous operation.

A.25 The method used for transporting concrete batches, materials, or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentrations of materials will be prohibited on floor slabs until the concrete has attained its design strength.

B. Pumping

B.1 The use of pumps will only be allowed after they have been carefully checked and approved by the Engineer. Only low pressure piston type pumps, which will work with a water/cement ratio of not more than sixty five hundredths (0.65), will be allowed. Using superplastizisers to facilitate pumping for low water/cement ratios is allowed subject to Engineer's review and approval.

B.2 In no case will "bell" or any other type of high pressure pump be allowed, since they require too high a water/cement ratio and because the concrete segregates as a result of the high pressure at which it is expelled, even if filled with a suitable nozzle.

B.3 The mix design shall be checked for its suitability for pumping and the concrete shall be tested regularly during pumping for its uniformity and that its properties have not been altered by pumping. If changes to slump, water-cement ratio, consistency or any other characteristics occur, corrective measures shall immediately be taken to ensure that concrete delivered by the pump complies with the requirements of the Specification. Samples shall be taken at discharge from the mixer/agitator truck, from the pump and at discharge from the pump.

B.4 The internal diameter of delivery pipe of the pump shall be not less than 3 times the maximum aggregate size. The pipes shall not rest on any part of the formwork, they shall be supported independently and securely and be readily accessible so that sections can easily be detached to remove any blockage.

B.5 Before approving the use of a pump, the Engineer shall verify that the Contractor has sufficiently reinforced the concrete placing team and the equipment for placing and vibrating the concrete.

B.6 Pumping will not be permitted from the inside of the foundation forms while concrete is being placed. If necessary to prevent flooding, a seal of concrete shall be placed through a closed chute or tremie and allowed to set.

5.02.04 COMPACTING

A. General

A.1 The vibration of the concrete can be considered completed when a thin layer of cement grout appears on the surface and when no more air bubbles, indicating the presence of voids within the concrete, appear on the surface. At the same time, there must not be too much vibration or this will produce segregation.

A.2 Vibration may be of three types:

- Internal.
- External.
- Mixed.

A.3 Vibration of the concrete and operation shall be undertaken in such a way that the proper and complete vibrations, but avoiding over vibration, is achieved. The guidelines as given in Standard Practice for Consolidation of Concrete (ACI 309) of Part 2 Concrete Practices and Inspection, Pavements, of ACI Manual of Concrete Practice 1988 issued by American Concrete Institute (ACI) shall be followed, if not otherwise directed by the Engineer.

A.4 Internal vibration shall be executed in all sections which are sufficiently large to permit the insertion and manipulation of immersion vibrators, previously approved by the Engineer, in accordance with the following recommended practices:

A.4.1 The concrete shall be placed in horizontal layers not thicker than fifty centimeters.

A.4.2 The vibrator shall be inserted vertically into the concrete to its full length such as to reach the bottom of the freshly placed layer.

A.4.3 The distance between two successive insertions shall not exceed five times the diameter of the vibrator itself.

A.4.4 The vibrator shall not rest on or against either the formwork or the main reinforcing bars.

A.5 External form vibrators shall be used for external vibration when it is impossible to use internal vibrators (heavily reinforced thin walls, pipes or other precast, small cross-section element, etc.). The water/cement ratio shall be low (0.30-0.40) in order to avoid the segregation of the concrete and, at the same time, to provide rapid hardening and, in consequence, the early removal of the formwork and the finished element.

A.6 Mixed vibration shall be used in the construction of reinforced or prestressed concrete beams. External wall vibrators shall also be used. These shall be mounted on the outside of the formwork after this has been suitably reinforced with ribs of U-bars. The mounting places of the wall vibrators shall be welded to these reinforcements. They must be symmetrically positioned on each side of the beam and produce a rotary movement within the concrete during vibration from the bottom towards the top and from the part placed first towards the part placed last.

A.7 Only the vibrators in the zone of the formwork with newly placed concrete will be used. As the casting of the beam advances the vibrators shall be dismounted and remounted as necessary.

A.8 It is absolutely essential that elastic supports be provided both under the bottom of the beam and in correspondence with the braces or tie rods of the formwork walls.

A.9 The network of reinforcing bars and tensioning cables should not move as a result of the vibration. To prevent this from happening either special ties (passing through the formwork walls) or spacers shall be used. It is better if these last are made of concrete and are of a size and shape that will ensure that the reinforcing and tensioning cables do not move.

A.10 Before starting this kind of work the Contractor shall submit to the Engineer for his approval a work plan giving the following details:

The position of the external wall vibrators their power frequency and amplitude and the number that will be utilized at the same time.

The number and type (frequency and size) of the internal vibrators to be used for the consolidation of the concrete.

The position of the spacers or the number of ties to be used to ensure that the reinforcing bar network and the tensioning cables (if any) do not move during vibration.

The way in which the concrete is to be placed and the length of time this operation is expected to take.

A.11 When required vibrating shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

B. Poker Vibrators

B.1 The type and size of poker vibrators shall suit the pour size, density of reinforcement and member dimensions. Unless otherwise authorized by the Engineer, the vibrator shall be selected from Table 5.2.1 below

Table 5.2.1: SELECTION OF POKER DIAMETER FOR SIZE OF POUR

Size of Pour (m^3/h)	Poker Diameter (mm)	Speed (Vibrations/min)
2 - 4	20 - 45	9000
5 - 10	50 - 65	9000
10 - 20	60 - 75	7000
20 - 30	80 - 115	7000
30 - 40	140 - 170	6000

B.2 Poker vibrators shall be inserted into the concrete vertically at regular intervals which shall be no greater than 0.5m. They shall be inserted quickly and withdrawn lowly. The withdrawal rate shall be not more than 75mm/sec. A cycle of insertion and withdrawal shall be between 10 and 30 seconds.

B.3 Poker vibrators shall be kept clear of formwork and concrete previously cast.

B.4 Vibrators shall be so manipulated as to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. Vibrators shall not be used as a means to cause concrete to flow or run into position in lieu of placing.

B.5 Compaction shall be sufficient to achieve maximum density without segregation in the fresh concrete.

B.6 Standby pokers of the same type shall be provided at all times. The standby shall be not less than half the number of pokers used for compacting the pour.

B.7 Vibrating shall only be carried out by professional technicians having experience in this type of work.

C. Other Vibrators

C.1 Form vibrators, vibrating tables and surface vibrators where required shall first be approved by the Engineer and they shall conform to the requirements of ACI-309.

C.2 Where form vibrators are used, the form shall be adequately designed so that the vibration will not cause joints to leak and dimensions and geometry to alter.

C.3 Unless otherwise permitted by the Engineer the use of form vibrators shall be limited to members whose thickness does not exceed 150 mm.

5.02.05 CURING

A. Materials

A.1 Hessian or Burlap: They shall be clean and free from harmful materials. Their unit weight shall be not less than 230g/m^2

A.2 Impermeable membranes: The following impermeable membranes may with the Engineer's approval be used.

- Clear polyethylene film with no holes tears scratches and contamination of any type.
- Hessian coated with white polyethylene of density not less than 300g/m^2. The coating may be on one side only but shall be not less than 0.1 mm thick and shall not peel during and after use.

A.3 Curing Compounds: These shall conform to AASHTO M148 (AASTM-C309).

A.4 Sand: It shall be natural sand free of silt and clay and contaminants which can be harmful to the concrete.

A.5 Water: It shall satisfy the requirements of Section 5.01 of these Specifications.

B. Method of Curing

B.1 General: The method of curing to be used shall be approved by the Engineer. It shall not cause any undesirable blemishes such as surface discoloration and surface roughness. Curing compounds shall not be used on construction joints and surfaces that are to receive waterproofing, paint or membranes.

B.2 Ponding: Curing by ponding may be used for horizontal surfaces such as bases, pile caps and slabs. Large horizontal surface areas shall be separated into ponds not exceeding 5 sq.m. The ponds shall first be filled between 12 to 24 hours after pour, unless otherwise authorised by the Engineer, and shall be replenished from time to time so as to maintain the ponding for the specified curing period. The concrete temperature and the temperature of the curing water shall be not greater than 10°C.

B.3 Sprinkling: Unless otherwise approved by Engineer, curing by spraying shall commence between 12 and 24 hours after the concrete pour. The concrete shall be maintained damp at all times during the curing period by periodic light sprays.

B.4 Wet Hessian/Burlap: Members to be cured by wet hessian or wet burlap shall be completely wrapped with the material which shall be kept moist at all times during the curing period by regular spraying. Unless otherwise approved by the Engineer, the overlap under normal conditions shall be not less than one-quarter the width of the hessian or burlap and not less than one-half the width in windy and/or rainy conditions. Before members are wrapped for curing, they shall first be evenly moistened. Unless approved by the Engineer, burlaps shall be supplied only in rolls and burlap bags shall not be used. Secondhand hessian and burlap, if approved for use, shall be clean without holes and contamination of any kind that can affect the concrete.

B.5 Waterproof Sheets: Waterproof sheets used for curing shall, unless directed by the Engineer, be spread immediately after the pour. The sheet shall, unless approved by the

Engineer, be clear of the concrete surface but be arranged in such a manner as to prevent the movement by air over the concrete surface. Waterproof sheets shall not be used when the air temperature is 25°C or higher.

B.6 Curing Compounds: Curing compounds shall be applied in two applications at a coverage rate of not less than 1 ltr/ 7.4 m^2 per application or as recommended by manufacturer.

The first coat shall be applied immediately after the removal of the forms and the acceptance of the concrete finish and after the disappearance of free water on unformed surfaces. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and curing compound applied just as the surface film of water disappears. The second application shall be applied after the first application has set. During curing operations, any unsprayed surfaces shall be kept wet with water. The curing membrane will not be allowed on areas against which further concrete is to be placed.

Hand operated spray equipment shall be capable of supplying a constant and uniform pressure to provide uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.

The curing membrane shall be protected against damage for the entire specified curing period. Any coating damaged or otherwise disturbed shall be given an additional coating. Should the curing membrane be continuously subjected to injury, the Engineer may require wet burlap, polyethylene sheeting, or other approved material to be applied at once.

No traffic of any kind will be permitted on the curing membrane until the curing period is completed, unless the Engineer permits the placement of concrete in adjacent sections, in which case the damaged areas shall be immediately repaired as directed.

B.7 Steam Curing

Low Pressure Steam Curing: In accordance with ACI 517 recommendations.

High Pressure Steam Curing: In accordance with ACI 516 recommendations.

C. Curing Time

C.1 The minimum curing time shall be the number of days given in Table 5.2.2 unless the average surface temperature of the concrete during the required number of days falls below 10°C, in which case the period of curing shall be extended until the maturity of the concrete reaches the value given in the Table.

C.2 The minimum curing time given in Table 5.2.2 above shall be compared with the time required for cylinders (cubes), cured under identical conditions to those which the concrete is subjected, to attain 70% of the characteristic strength. The greater shall be taken as the minimum curing time.

5.02.06 HOT WEATHER CONCRETING

A. Definitions

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

B. General

B.1 The production and delivery of concrete, the placing and curing and the testing and inspection of concrete shall, in addition to the requirements of these Specifications, accord with the recommendations of ACI 305R-77 (Revised 1982).

TABLE 5.2.2 NORMAL CURING PERIODS

Minimum periods of protection for different types of cement						
Conditions under which concrete is maturing	Number of days (where the average surface temperature of the concrete exceeds 10°C during the whole period)			Equivalent maturity (degree hours) calculated as the age of the concrete in hours multiplied by the number of degrees Celsius by which the average surface temperature of the concrete exceeds 10° C		
	Other*	**SRPC**	**OPC or RHPC**	**Other***	**SRPC**	**OPC or RHPC**
1.Hot weather or drying winds	7	4	3	3500	2000	1500
2.Conditions not covered by 1	4	3	2	2000	1500	1000

NOTE: Other*includes all permitted cements except OPC, RHPC and SRPC.
OPC = Ordinary Portland cement.
RHPC = Rapid-hardening Portland cement.
SRPC = Sulfate resisting Portland cement.

B.2 No concreting shall commence when the air temperature is 32°C and rising. The Contractor shall schedule his operations to place and finish concreting during the hours that the air temperature will be below 32°C. This should preferably be in the latter part of the day after the maximum temperature has been reached, and subject to the approval of the Engineer.

C. Control of Temperature

C.1 Stockpile of aggregates shall be protected from direct sunlight by suitable covering. If directed by the Engineer, they shall be regularly sprayed with clean water.

C.2 Water shall be stored in tanks away from sunlight and insulated by suitable means so as not to be affected by high air temperature. Water tanks liable to be exposed to sunlight shall be covered with suitable reflective paint such as white gloss paint.

C.3 If directed by the Engineer or as a condition for concreting in adverse weather conditions, sufficient ice shall be added to the mix water to ensure that the temperature of the fresh concrete shall not exceed 32°C.

C.4 The temperature of the concrete at the time of placing shall not be permitted to exceed 33 degrees C. Concrete materials shall be stored in a cool shaded position away from the direct rays of the sun. Aggregates shall be cooled if necessary prior to mixing and water shall be cooled by means of a proprietary water chilling plant. The prices in the Bill of Quantities shall be deemed to cover all such special work.

C.5 Additives as recommended in ACI 305R-77 shall be used to improve workability and/or delay initial setting.

C.6 Retarding admixtures to facilitate placing and finishing of the concrete shall conform to AASHTO M 194, Type D and used only if approved by the Engineer.

D. Mixing and Placing

D.1 The time available for handling and placing of concrete during periods of high temperature may be considerably reduced and the Contractor must take appropriate precautions. Concrete should be protected during transportation by use of damp hessian or similar means. No additional water may be added at the time of mixing without the approval of the Engineer, as this may lead to additional shrinkage of the concrete. On no account shall water be added during transportation or placing of the concrete.

D.2 Aggregates and cement shall be thoroughly pre-mixed before adding water.

D.3 Transit mixers, if used, shall be coated with a reflective paint and while waiting to be discharged, shall be kept out of direct sunlight.

E. Concrete Protection

E.1 Before the concrete can be de-shuttered, the formwork and shutters shall be cooled by spraying with water.

E.2 The concrete and the falsework shall be protected against sunlight, if directed by the Engineer.

E.3 If curing is by hessian, it shall be coated with a white polyethylene backing.

E.4 Members exposed to strong winds shall be provided with windbreakers. The windbreakers shall, if directed by the Engineer, be kept moist by regular spraying.

5.02.07 COLD WEATHER CONCRETING

A. Definitions

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

B. General

B.1 ACI 306.1-90 "Standard Specifications for Cold Weather Concreting" applies.

B.2 The production and delivery of concrete, the placing and curing and the protection requirement shall be in accordance with the recommendations of ACI 3061t-88 "Cold Weather Concreting".

B.3 No concreting shall commence when the air temperature is 6°C and falling, unless authorized by the Engineer.

C. Mixing and Placing

C.1 Aggregates and water, forms, reinforcement etc. shall be free of snow, frost or ice.

C.2 Aggregates and water may be pre-heated in which case the aggregates and water shall, if directed by the Engineer, be mixed prior to introducing cement in the mix. The aggregates shall not be pre-heated to a temperature in excess of 100°C and the water in excess of 60°C with the additional requirement that the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.3 Water may be pre-heated by boiling and added to aggregates not pre-heated provided the temperature of the water and aggregate mix, before the introduction of cement, does not exceed 38°C.

C.4 The temperature of concrete at the time of discharge shall be between 10 and 27°C and for three days after the pour not less than 5°C.

D. Protection

D.1 When directed by the Engineer, members shall be protected against cold winds by suitable windbreaks.

D.2 Adequate insulation by way of insulation boards, planks, sheets etc. shall be provided to maintain the required minimum concrete temperature during the curing period.

D.3 Protection measures shall be maintained for a period at which the concrete attains a strength of at least 65% of the characteristic strength.

5.02.08 NIGHT CONCRETING

A. Night concreting shall not be carried out unless prior approval of the Engineer, in writing, is obtained.

B. Details of the artificial lighting; system shall be submitted in advance of the proposed

concreting for the Engineer's approval. In all cases, at least one stand-by generator shall be available at all times of the concreting operation

5.02.09 MEASUREMENT

The provisions of this section are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of these Specifications.

SECTION 5.03 STEEL REINFORCEMENT AND FIXING

5.03.01 SCOPE

These works shall consist of the supply and fixing of the unstressed steel bars, wires, mesh and mats for the reinforcement of concrete in accordance with the Drawings and Specifications.

5.03.02 MATERIALS

A. Reinforcing Bars

○**A.1** High tensile steel reinforcement bars shall conform to AASHTO M31 (ASTM A615) Grade 60 (with carbon content not exceeding 0.3%) or to BS 4449.

○**A.2** Mild steel reinforcing bars shall conform to AASHTO M31 (ASTM A615) Grade 40 or BS 4461.

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

B. Welded Fabric Reinforcement

B.1 Welded steel wire fabric shall conform to AASHTO M55 (ASTM A185) or BS 4482.

B.2 Cold drawn steel wire shall conform to the requirements of AASHTO M32 or in the case of hard drawn steel wire to BS 4482.

C. Fabricated Mat Reinforcement

Fabricated mat reinforcement shall conform to AASHTO M54 (ASTM A 184).

D. Certification and Identification

D.1 Three copies of a mill test report shall be supplied to the Engineer for each lot of billet steel reinforcement supplied for use on the project. The mill test report shall be sworn to by a person having legal authority to bind the manufacturer and shall show the following information:

- The process or processes used in the manufacture of the steel from which the bars were rolled.

- Identification of each heat of open-hearth, basic oxygen, or electric furnace and/or each lot of acid bessemer steel from which the bars were rolled.

D.2 The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator before being offered for inspection. The tag shall show the manufacturer's test number and lot number or other designation that will identify the material with the certificate issued for that lot of steel.

D.3 The fabricator shall furnish 3 copies of a certificate which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

E. Inspection and Sampling

The sampling and testing of reinforcement bars may be made at the source of supply when the quantity to be shipped or other conditions warrant such procedure. Bars not inspected and sampled before shipment will be inspected and sampled after arrival at the site.

5.03.03 CONSTRUCTION

A. General

○**A.1** Reinforcing steel shall be protected at all times from damage. All reinforcement shall be free from detrimental dirt, loose mill scale, scaly rust, paint, grease, oil or other foreign substance. There shall be no evidence of pitting or visual flaw in the test specimen or on the sheared ends of the bars.

○**A.2** Rust shall be removed by wire brushing or, if directed by the Engineer, by sand blasting. Light rust without visible sign of peeling need not be removed.

B. Storage

B.1 Reinforcement shall be stored clear of the ground on platforms, skids or other supports and be protected against contamination by dirt, grease, oil etc. at all times. If directed by the Engineer, the contractor shall provide cover to the reinforcement.

B.2 Reinforcement of different grades and different diameters shall be stored separately and marked to facilitate inspection and checking.

C. Cutting and Bending

C.1 Cutting and bending of reinforcement shall be based on an approved bar bending schedule.

C.2 Reinforcement shall be cut in specialist cutting machines or cold cut by hand only. Cutting with oxyacetylene torch is strictly forbidden.

C.3 Bars shall be bent to the following bend diameters:

Bar Diameter, d.	Mild Steel	High Yield Steel
Up to 25 mm	4d	6d
25 to 35 mm	6d	8d
35 to 60 mm	10d	10d

C.4 All reinforcement shall be bent at the temperature range of 5 degrees C and 100 degrees C. Bending by heating, if approved by the Engineer, shall be carried out in such a manner as not to impair the physical and mechanical characteristics of the bar.

C.5 The straight bar length for a hook of 180° shall be not less than 4 times the bar diameter or 60mm whichever is the larger.

C.6 The straight bar length of a hook of 90° shall be not less than 12 times the bar diameter.

C.7 The straight bar length after hook in stirrups shall be 6 times the bar diameter or 60mm whichever is the larger.

C.8 Cold worked bars and hot rolled high yield bars shall not be re-bent or straightened once having been bent. Where it is necessary to bend mild steel bars projecting from the concrete, the bend diameter shall comply with the requirements of item C.3 above.

C.9 IS bending, of the bar in accordance with this specification causes the bar to crack, the bar shall be rejected, irrespective of any prior approval that may have been given, and removed from the Site.

C.10 Bars shall be cut and bent to the following tolerances:

Bar length (mm)	Tolerance (mm)
Up to 1000	5
1000 - 2000	+5, - 10
above 2000	+5, - 25

C.11 No adjustment to bar length after bending will be permitted.

D. Fixing

D.1 Reinforcement shall be placed and maintained in the position shown on the Drawings. Unless agreed otherwise by the Engineer, all bar intersections shall be securely tied together with the ends of the wire turned into the main body of the concrete. 1.2 mm diameter stainless steel wire shall be used for in situ members having exposed soffits. 1.6 mm diameter soft annealed iron wire shall be used elsewhere.

D.2 The correct cover to reinforcement on all exposed faces of concrete shall be maintained by using approved proprietary spacers. Where instructed by the Engineer the adequacy of such spacers shall be demonstrated by site trials.

D.3 Concrete cover blocks, where permitted by the Engineer, shall be of approved dimensions and designed so that they will not overturn when the concrete is placed. They shall be made with 10 mm maximum size aggregate and the mix proportion shall be such as to produce the same strength as the adjacent concrete. Tying wire shall be cast in the blocks for subsequent tying to the reinforcement.

D.4 Wherever it is necessary for the Contractor to splice reinforcement at positions other than those shown on the Drawings, the approval of the Engineer shall be sought and obtained before the reinforcement is placed. Splices shall be staggered where possible and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress.

D.5 Proprietary mechanical splicing devices shall be used only with prior approval of the Engineer in writing. They shall be able to withstand without any slippage a force of not less than 1.25 times the characteristic yield stress of the smaller bar spliced multiplied by the cross-sectional area of the smaller bar.

D.6 Mesh reinforcement shall comply with the sizes of sheets and diameter and spacing of bars as shown on the Drawings. The sheets of mesh shall be lapped as shown on the Drawings. The method of placing the mesh and securing it in position shall be approved by the Engineer.

D.7 Welding of reinforcement bars, if allowed by the Engineer, shall be carried out in accordance with the latest publications of the American Welding Society publication "Structural Welding Code for Reinforcing Steel", and shall be able to withstand a force of not less than 1.25 times the characteristic yield stress of the smaller of the welded bars multiplied by the cross-sectional area of the smaller bar.

D.8 Cold worked steel bars shall not be welded.

D.9 Where galvanizing or epoxy coating is required to be applied to the reinforcement, specific instructions will be given by the Engineer taking into account the particular design conditions which apply.

D.10 Dowel Bars: coat half of each bar with approved proprietary debonding compound or fit with approved plastics sleeve. Fix bars securely at required level, perfectly level, at right angles to and centered on the joint. Fit compressible caps to debonded ends of bars.

5.03.04 MEASUREMENT

A. Measurement of different grades of steel reinforcement will be based on the theoretical quantity of metric tons complete in place as shown on the Drawings or placed as ordered by the Engineer. No allowance will be made for clips, wire or other fastening devices for holding the reinforcement in place. Measurement will not be made of reinforcement chairs to separate slab steel or similar reinforcement to retain wall steel or similar usage elsewhere. Measurement of splices in reinforcement not shown on the Drawings will not be made, unless such splices were agreed or authorized by the Engineer.

B. Calculated weights shall be based upon Table 5.3.1

Table 5.3.1: WEIGHTS OF REINFORCING BARS

Diameter mm	Weight kg/m	Diameter mm	Weight kg/m	Diameter mm	Weight kg/m
5	0.154	18	2.000	34	7.130
6	0.222	20	2.470	36	7.990
7	0.302	22	2.980	38	8.900
8	0.395	24	3.550	40	9.870
10	0.617	26	4.170	45	12.500
12	0.888	28	4.830	50	15.400
14	1.210	30	5.550		
16	1.580	32	6.310		

C. Separate measurement for bars of different diameter but of the same grade shall not be made.

D. Fabric mesh reinforcement shall be measured separately and will be based on tile theoretical quantity of metric tons complete in place as shown on the Drawing or placed as ordered by the Engineer. No separate measurement shall be made for different mesh sizes or different wire diameters.

E. Work is deemed to include:

- Preparing schedules for bar bending.
- Fixing bars in any position and in any member.
- Fixing bars horizontally, vertically and sloping.
- Any diameter, section and length of bars.
- Forming straight bent and curved bars and links.
- Cutting, lapping and jointing (including special joints).
- Hooks, tying wire, spacers, chairs and the like.
- The weight of surface treatments and rolling margin.
- Tests and quality control procedures.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Mild steel bar reinforcement	Tonne (T)
(2) High tensile steel bar reinforcement	Tonne (T)
(3) Fabric wire mesh reinforcement	Tonne (T)
(4) Fabric bar mesh reinforcement	Tonne (T)

SECTION 5.04 FORMS, FORMWORK AND FALSEWORK

5.04.01 SCOPE

These works shall consist of the design, supply and use of forms, formwork and falsework for the construction of concrete road structures.

5.04.02 DEFINITIONS

A. Forms and Formwork

The section of the temporary works used to give the required shape and support to poured concrete. It consists primarily of sheeting material, such as wood, plywood, metal sheet or plastic sheet, in direct contact with the concrete and joists or stringers that directly support the sheeting.

B. Falsework

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

C. Scaffold

A temporarily provided structure that provides access, or on or from which persons work, or that is used to support material, plant or equipment.

D. Tower

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

E. Camber

The intentional curvature of the formwork, formed initially to compensate for subsequent deflection under load.

5.04.03 MATERIALS

A. Wood

A.1 National Wood: Soft wood free of faults such as splitting, warping, bending, knots etc.

A.2 Imported Wood: When imported softwood or hardwood is used for falsework, the minimum timber grade, determined in accordance with B.S 4978 shall be SC3.

A.3 Hardwood used as load-bearing wedges and packing shall be limited to those listed in Table 5.4.1.

Table 5.4.1: Permitted Hardwoods for Load-Bearing Wedges and Packing

Standard name	Botanical species
ash	Fraxinus excelsior
beech	Fagus sylvatica
greenheart	Ocotea rodiaei
jarrah	Eucalyptus marginata
karri	Eucalyptus diversicolor
keruing	Dipterocarpus spp
oak	Quercus spp

B. Plywood

When plastic coated plywood is used, the Phenol resin on melamine shall be not less than 20% of the total coating weight.

C. Steel

Steel shall conform to the requirements of Section 5.16 "Structural Steelwork and Metal Components".

D. Aluminum

Aluminum shall conform to the requirements of ASTM B221.

E. Other Materials

Other materials, with the approval of the Engineer, may be used for falsework. These include, but not limited to, fibre-glass reinforced plastic, polystyrene, polyethylene, PVC, rubber, concrete, brick etc.

5.04.04 DESIGN

A. General

A.1 Forms and formwork and falsework shall be designed by the Contractor and submitted to the Engineer with full design calculations, detailed drawings, material specification and test certificates for approval. Falsework shall be capable of temperature changes without causing damage to the concrete.

A.2 Falsework design shall be in accordance with B.S 5972 "Code of Practice for Falsework"..

A.3 If the Contractor intends to use ready made proprietary type of falsework, he shall submit all relevant data, including independent test certificates, which will enable the Engineer to determine whether or not the Contractor's proposed falsework are acceptable.

A.4 Notwithstanding any approval of falsework design by the Engineer, the Contractor will not be relieved of his responsibility for the adequacy and correctness of the design, manufacture and assembly of the falsework.

B. Forms and Formwork

B.1 **F**ormwork shall be sufficiently rigid so as to prevent any grout loss during concreting and shall not distort due to environmental effects and concreting operations so that member dimensions, shape, required finish and texture are within the tolerances specified.

B.2 Forms and formwork shall be designed to be readily assembled stripped and transported without distortion to panels and members of the formwork.

B.3 The method of stripping forms without damaging the concrete or special textured surface finish if incorporated shall be fully considered in the design.

B.4 If form liners are to be used to achieve the specified surface finish samples of a size as direeted by the Engineer shall be submitted for approval.

B.5 Form lining shall not bulge warp or blister nor shall it stain the concrete. Form lining shall be uscd in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same direction (all horizontal or all vertical). Thin metal form lining will not be permitted. Undressed lumber of uniform thickness may be used as backing for form lining. Wooden plyform of adequate thickness which is properly supported to meet the above requirements may be used in lieu of the lined forms specified herein.

B.6 Metal forms if used shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust grease or other foreign matter. Under such circumstances the continued use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels or panels with metal frames and wood or combination shall be so designed as to leave no lipping or ridges in the finished concrete.

B.7 The width and thickness of the lumber the size and spacing of studs and wales shall be determined with due regard to the nature of the Work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

B.8 Form bolts rods or ties and removable ties through plastic (PVC) pipes shall be made of steel. They shall be the type which permit the major part of the tie to remain permanently in the structure or removed entirely. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. Form ties will not be permitted through forms for handrail. Pipe spreaders shall not be used unless they can be removed as the eonerete is placed. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts will not be permitted except in unusual situations and then only with approval of the Engineer.

B.9 Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the terms immediately before placing the concrete.

B.10 Unless otherwise directed by the Engineer, the exterior side of forms shall be painted with an approved, good quality high gloss white oil base enamel paint prior to placing concrete. Paint shall be applied to metal forms only. When complete coverage is not obtained with one coat, the Engineer will order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

B.11 Unless provided otherwise on the Drawings or directed by the Engineer, all exposed edges shall be beveled by using dressed, millcut, triangular molding, having 20 millimeter sides.

B.12 Forms shall be maintained after erection to eliminate warping and shrinkage.

C. Falsework

C.1 Falsework and centering shall be designed to provide the necessary rigidity to support all loads placed upon it without settlement or deformation in excess of the permissible tolerance for the structure given in the Specifications. Falsework columns shall be supported on hardwood, concrete pads or metal bases to support all falsework that cannot be founded on rock, shale or thick deposits of other compact material in their natural beds. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsevvork columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to approval of the Engineer.

C.2 All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing, and the splices shall be scabbed in a manner approved by the Engineer.

C.3 The Contractor shall compute falsework settlement and deflection for bridges so that when the final settlement is complete, the structure will conform to the required camber, section and grade as shown on the Drawings.

C.4 The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete, and shall provide a competent observer to observe and correct the settlement.

C.5 Screw jacks, if used, shall be designed for use with a slenderness ratio not exceeding 60. The slenderness ratio shall be taken as the ratio of the clear distance between effective bracing in both horizontal directions to the diameter of the screw jack measured at the root of the thread. The manufacturers' certificate showing the ultimate load capacity of the screw jack shall be submitted with the design calculations for the falsework. If directed by the Engineer, the Contractor shall furnish a test certificate carried out at an approved independent laboratory.

C.6 Props and towers supporting forms or partially completed structures shall be interconnected in plan orthogonally at levels to be determined in the design. They shall also be interconnected by diagonal bracings in orthogonal vertical planes.

5.04.05 FINISHES

A. Formed Finishes

A.1 **Class F1.** This class of surface finish denotes a special finish required from aesthetic considerations. In additions to the requirements of Class F2 finish, the following additional requirements shall apply.

A.1.1 It is of major importance that the special finishes required on F1 surfaces arc uniformly and consistently maintained with no variation in the color or consistency of the concrete within the same structure. In order to achieve this, the Contractor shall make trial panels of the formed finishes specified. These panels shall be not less than 1.5 m high and 1 m wide and 250 mm thick and shall be cast in the manner and with materials as proposed for the actual Work. These panels are for the approval of the liners and are preliminary to the test samples carried out on site.

A.1.2 The Contractor shall provide at his own expense as many panels as required by the Engineer until a satisfactory trial panel has been accepted by the Engineer. In addition, the Engineer will require samples of pier, part of a deck, section of retaining wall and/or underpass wall and typical precast edge unit to be cast on site in the same manner as proposed for the prototypes. The Contractor shall submit to the Engineer and obtain his approval for all details before commencement of trials. These samples when approved, will form the standard against which the corresponding finishes on the actual work will be judged. In all cases of approvals, the decision of the Engineer alone will be final.

A.1.3 Where forms and form-liners to be used for the special finishes specified are manufactured outside the Country, the forms and form-liners shall not be permitted on Site until the Engineer has inspected the forms and form-liners and is satisfied that they are suitable for the Works. Samples and trial panels carried out at the place of manufacture to demonstrate to the Engineer that the forms and formliners and the methods of assembling and de-shuttering them are acceptable shall not be paid for and will not relieve the Contractor of the requirement for carrying out trial panels on site as described above.

A.1.4 If the required finish in the opinion of the Engineer, has not been obtained in the Works, the Contractor shall promptly carry out at his own expense all measures required by the Engineer to obtain the specified finish. These may include grit blasting followed by the application of polyester or epoxy paint. Where such remedial action is ordered by the Engineer, the entire exposed surface shall be so treated irrespective of whether or not the detective areas are localized or extensive.

A.2 **Class F2** Formwork shall be lined with a material approved by the Engineer to provide a smooth finish of uniform appearance. This material shall leave no stain on the concrete and shall be so joined and fixed to its backing so that it imparts no blemishes. It shall be of' the same type and obtained from only one source for any one structure. The Contractor shall make good any imperfections in the finish as directed by the Engineer. Internal ties and embedded metal parts will not be permitted unless otherwise approved by the Engineer.

A.3 **Class F3.** Irregularities in the finish shall be no greater than those resulting from the use of wrought thick square edged boards arranged in a uniform pattern. The finish is intended to be left as struck. Imperfections such as fins and surface discoloration shall, however, be made good as and when required by the Engineer.

A.4 **Class F4.** No special requirements.

A.5 Permanently exposed concrete surfaces to classes Fl, F2 and F3 finish shall be protected from rust marks and stains of all kinds. Internal ties and embedded metal parts will not be permitted.

A.6 The Contractor shall submit to the Engineer all details of' formwork liners joints and materials including fabrication drawings and stating procedures involved in the use of formwork for approval before commencement of any work on fabrication. No formwork shall be brought to site without the prior approval of the Engineer. Adequate time shall be allowed by the Contractor in his program for these approvals after consultation with the Engineer.

B. **Unformed Finishes**

B.1 **Class U1.** The concrete shall be uniformly leveled and screeded to produce a plain or ridged surface as described in the Contract. No further work shall be applied to the surface unless is used as the first stage for Class U2 or Class U3 finish.

B.2 **Class U2.** After the concrete has hardened sufficiently the concrete Class U1 surface shall be floated by hand or machine sufficiently to produce a uniform surface free from screed marks.

B.3 **Class U3.** When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface a Class U I surface shall be steel-trowelled under firm pressure to produce a dense smooth uniform surface free from trowel marks.

5.04.06 TOLERANCES

A. The tolerances in the forms and formwork shall be such that members formed shall be within the tolerances for the size and type of the member specified elsewhere in these Specifications.

B. Falsework shall be fixed such that the completed structure shall be within the required tolerances in plan elevation and slope for the size and type of structure specified elsewhere in these Specifications.

C. Surfaces which are to receive deck waterproofing shall be finished to an accuracy such that when tested with a three meter long straight edge the maximum depression shall not exceed five mm.

5.04.07 CONSTRUCTION REQUIREMENTS

A. The forms and falsework shall be inspected by the Engineer after assembly on the work area and immediately before concreting. No pour shall commence until the forms and falsework have been approved by the Engineer.

B. The inside surfaces of all forms shall, except for pavement formwork, or unless otherwise agreed by the Engineer, be coated with a release agent approved by the Engineer. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with the reinforcement or prestressing tendons and anchorages. Different release agents shall not be used in formwork which will be visible in the finished work.

C. Immediately before concrete is placed, all forms shall be thoroughly cleaned out.

D. Forms that are to be re-used shall be thoroughly cleaned and re-oiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber will be condemned by the Engineer, and shall be removed from the Site.

E. Formwork shall be constructed so that the side forms of members can be removed without disturbing the soffit forms. If props are to be left in place when the soffit forms are removed, these props shall not be disturbed during the striking.

F. Runways used to move plant, equipment or materials shall be clear of the reinforcement and shall be robust enough not to deflect excessively or cause movement to the forms due to dynamic effects.

G. During concreting, the forms and their supports shall be constantly monitored for signs of imminent failure. There shall be skilled operatives in constant attendance during concreting who are qualified to make immediate adjustments to the forms and falsework so that concreting can satisfactorily be completed.

H. The engineer may suspend concreting operations it; in his opinion, the forms and falsework are in danger of failure and that the actions taken by the Contractor are insufficient or inadequate to guarantee the sate and satisfactory completion of concreting. In such an event, the Engineer may instruct the Contractor to remove, at his expense, the concrete already poured.

I. If at any period of work during or after placing of concrete the forms show signs of sagging or bulging the Contractor at his own expense shall remove the concrete to the extent directed by the Engineer bring the forms to the proper position and place concrete.

J. Immediately after the removal of the forms all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of 1 part by volume of Portland cement and 2 parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar so that when dry the color will match the surrounding concrete. Patches shall be moistened prior to mortaring to obtain a good bond with the concrete. When directed by the Engineer the Contractor shall al his own expense substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgment of the Engineer pockets are of such extent or character as to materially affect the strength of' the structure or to endanger the life of the steel reinforcement he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.

5.04.08 REMOVAL OF FORMWORK AND FALSEWORK

A. To facilitate finishing forms on handrails ornamental work, and other vertical surfaces that require a rubbed finish shall be removed as soon as the concrete has hardened sufficiently that it will not be injured as determined by the Engineer. In determining the time for the removal of forms consideration shall be given to the location and character of the structure weather and other conditions influencing the setting of the concrete.

B. Formwork shall be removed in a manner not to damage the concrete and at times to suit the requirements for its curing and to prevent restraint that may arise from elastic shortening shrinkage or creep.

C. Any remedial treatment to surfaces shall be agreed with the Engineer following inspection immediately after removing the formwork and shall be carried out without delay. Any concrete surface which has been treated before being inspected by the Engineer shall be liable to rejection.

D. Where the concrete compressive strength is confirmed by tests on concrete cylinders (cubes) stored under conditions approved by the Engineer that simulate the field conditions formwork supporting concrete in bending may be struck when the strength is 10 N/sq.mm or three times the stress to which it will be subjected which ever is the greater.

E. For ordinary structural concrete made with ordinary Portland cement only, in the absence or control cylinders (cubes) the period before striking shall be in accordance with the minimum periods given in Table 5.4.2 unless otherwise directed by the Engineer.

Table 5.4.2: Minimum Period Before Striking for Ordinary Structural Concrete Made With Ordinary Portland Cement

Type of Formwork	Minimum period before striking Surface Temperature of Concrete		
	16°C	**7°C**	**t°C**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	300 hours t + 10
Soffit formwork to slabs	4 days	6 days	100 days t + 10
Props to slabs	10 days	5 days	250 days t + 10
Soffit to formwork to beams	9 days	14 days	230 days t + 10
Props to beams	14 days	21 days	360 days t + 10

5.04.09 MEASUREMENTS

A. The provisions of this section of these Specifications are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

B. Test panels carried out by the Contractor to demonstrate to the Engineer's satisfaction that the specified F1 finish can be achieved shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.0l "Concrete and Concrete Mixes and Testing" of the Specification. Test panels not accepted by the Engineer shall not be measured for payment.

C. Test samples, such as a section of retaining wall or a complete pier, carried out by the Contractor and approved by the Engineer for use as reference bench marks for the quality to be attained in the Works shall be measured for payment for the appropriate class of concrete measured for payment under the provision of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification. Test samples not accepted by the Engineer shall not be measured for payment.

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SECTION 5.05 PLAIN AND REINFORCED CONCRETE STRUCTURES

5.05.01 SCOPE

This Section of these Specifications describes tile 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 and Concrete Mixes and Testing".

B. Reinforcement

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

C. Formwork and Falseworks

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

D. Plant and Equipment

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

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

B. Concreting

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

C. Slump

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

D. Construction and Expansion Joints

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

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

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

E. Cold Joints

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

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

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

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

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

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

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

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

F. Finishing

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

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

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

F.1.3 Backs of retaining walls and solid abutments, outer faces of box culverts, faces of abutment columns and bottom of bank seats for spill-through abutments, plinths for columns, piers, lighting masts and sign gantries etc., which are generally in permanent contact with earth Class F3

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

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

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

F.2.1 Top of bases, footings, pile caps, box culvert roof etc, which are to be backfilled Class U1

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

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

F.3 Finish to bridge decks that are to receive an approved waterproof system shall first be finished to Class U1. Then, when the concrete has sufficiently hardened to prevent laitance being worked to the surface it shall be floated to produce a uniform surface

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

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

G. Concrete Cover to Reinforcement

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

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

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

H. Tolerances

H.1 In-Situ Construction

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

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

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

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

H.2 Pre-cast Construction

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

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

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

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

H.3 Squareness

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

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

H.4 Straightness

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

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

H.5 Alignment

The alignment of members shall be within the following tolerances:

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

H.6 Flatness

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

H.7 Twist

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

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

5.05.04 MEASUREMENT

The provisions of this Section of the Specifications are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specifications.

SECTION 5.06 NOT APPLICABLE

SECTION 5.07 NOT APPLICABLE

SECTION 5.08 NOT APPLICABLE

SECTION 5.09 DRAINAGE AND UTILITY STRUCTURES

5.09.01 SCOPE

This work shall consist of the construction of catch pits manholes curb ditch inlets and outlets and similar structures in connection with the drainage of groundwater from the surface and below the surface of land and paved surfaces

5.09.02 MATERIALS

A. Concrete shall conform to the requirements as specified in Section 5.01 "Concrete and Concrete Mixes and Testing".

B. Reinforcement shall conform to the requirements as specified in Section 5.03 "Steel Reinforcement and Fixing".

C. Structural steel shall conform to the requirements as specified in Section 5.16 Structural Steelwork and Metal Components".

D. Concrete pipes and tiles shall conform to the requirements of:

- AASHTO M86 Concrete sewer storm drain and culvert pipe
- AASHTO M 175 Perforated concrete pipe
- AASHTO M 1 76 Porous concrete pipe
- AASHTO M178 Concrete drain tile

E. Precast concrete manhole sections shall conform to the requirements as specified in

- AASHTO M 199 Precast reinforced concrete manhole sections

F. Precast concrete culverts shall conform to the requirements as specified in

- AASHTO M206 Reinforced concrete arch culvert storm drain and sewer pipe
- AASHTO M207 Reinforced elliptical culvert storm drain and sewer pipe
- AASHTO M259 Precast reinforced concrete box sections for culverts storm and
- M173 drains and sewers

G. Bricks for masonry manholes shall be from local manufacturers and shall conform with BS 3921.

H. Precast concrete blocks for Masonry walls shall conform to BS 6073.

I. Vitrified clay pipes and tiles shall conform to the requirements as specified in

- AASHTO M65 Vitrified clay pipe, extra strength, standard
- (ASTM C700) strength and perforated clay drain tile
- AASHTO M179 Clay Drain Tile

J. PVC pipe shall conform to the requirements as specified in

- AASHTO M278 Class P5 50 PVC pipe

K. Corrugated aluminum alloy culverts and underdraws shall conform to the requirements as specified in

- AASHTO M196 Corrugated Aluminum Alloy Culverts and Underdrains

L. Asbestos-Cement pipes, couplings and fittings shall conform to the requirements of ASTM C663.

M. Grey cast iron castings shall conform to AASI-ITO M105 (ASTM A48) Class 25 or higher. Castings shall be manufactured to the sizes and dimensions shown on the Drawings.

N. Test bars shall be prepared and tested as specified in AASHTO M105.

O. Steel castings: mild to medium strength castings shall conform to AASHTO M103 (ASTM A27). Unless otherwise shown on the Drawings or instructed by the Engineer, castings shall be grade 65-35 fully annealed. Steel castings shall conform to the dimensions shown on the Drawings. Test bars shall be prepared and tested as specified in AASHTO M 103.

P. Wrought iron plates and shapes shall conform to the dimensions shown on the Drawings. Rolled wrought iron bars and shapes shall conform to the requirements of ASTM A207 Wrought iron plates shall conform to ASTM A42.

Q. Safety steps and hand bars shall be manufactured of 20mm diameter mild steel deformed reinforcing bars and hot dip galvanized in accordance with ASTM A153.

R. Testing and Certification: the Contractor shall submit to the Engineer all specified test coupons and Manufacturers' Certificates of Guarantee for all structural steel cast iron cast steel and wrought iron parts stating that the materials supplied meet the appropriate AASHTO or ASTM specification. The submission of such test certificates shall not relieve the Contractor of his obligations to carry out independent tests at an approved laboratory as directed by the Engineer at his own expense.

5.09.03 CONSTRUCTION

A. Excavation

The method of excavation shall conform to the requirements of Section 2.09 “Structural Excavation and Backfill”.

B. Pipe Installation

B.1 No pipes shall be installed until the excavations foundations and bedding have been approved.

B.2 Each pipe shall be inspected before laying and damaged pipes shall be rejected.

B.3 Pipes shall be laid true to line and grade commencing at the downstream end unless otherwise approved.

B.4 Bedding haunching and surrounding operations shall be carried out strictly in accordance to dimensions shown on the Drawings. The plant equipment and methods used for such operations shall be approved.

C. Concrete

C.1 The composition, consistency, proportioning, batching, mixing and transportation of the concrete shall conform to Section 5.01 “Concrete and Concrete Mixes and Testing”.

C.2 The formwork for, and the placing, curing, and protection of the concrete shall conform to the requirements of Section 5.06 "Plain and Reinforced Concrete Structures".

C.3 Class 210/25 concrete shall be used unless otherwise shown on the Drawings or ordered by the Engineer

D. Ready-Mix Concrete

When concrete is manufactured by a commercial ready-mix plant, the handling of cement and aggregates, composition, consistency, proportioning, batching and mixing shall conform to the requirements specified in Section 5.01 "Concrete and Concrete Mixes and Testing" and in this Section, "Drainage and Utility Structures".

E. Masonry

E.1 When so indicated on the Drawings or approved by the Engineer, brick or concrete block masonry may be used in lieu of concrete for the walls of catch basins, manholes or curb inlets. Masonry manholes may be constructed circular, with an inside diameter equal to the greater of the inside dimensions indicated on the Drawings for the concrete manhole.

E.2 When masonry is used in lieu of concrete for square or rectangular structures, the inside dimensions of the structure shall be of the dimensions shown on the Drawings unless ordered otherwise by the Engineer. The mortar for masonry shall be as specified in Section 5.01 "Concrete and Concrete Mixes and Testing ". The brick or concrete block shall be laid with full mortared joints and with sufficient header courses to tie the masonry together properly as approved by the Engineer.

F. Reinforcement

The method of reinforcing shall conform to the requirements of Section 5.03 "Steel Reinforcement and Fixing.

G. Placing Castings

Castings shall be set in full mortar beds or otherwise secured as shown on the Drawings and approved by the Engineer. Mortar for setting and casting shall be mixed as specified in Section 5.01 "Concrete and Concrete Mixes and Testing". Castings shall be set accurately to correct elevation so that no subsequent adjustment is necessary.

H. Backfilling

Backfilling shall conform to the requirements of Section 2.09 “Structural Excavation and Backfill”.

I. Cleaning

All catch basins, catch pits, drop inlets, manholes, inlets and outlets shall be thoroughly cleaned of any accumulations of silt, debris or foreign matter of any kind, and shall be free from such accumulations at the time of final inspection.

J. Painting

Structural steel cover plates shall be painted with one shop coat of Paint Number 2, one field coat of paint Number 6, and one field coat of Paint Number 7. Painting, shall be in accordance with the requirements of Section 6.09 "Painting of Structures". Painting of castings will not be required.

K. Testing of Manholes

Plug the manhole inlets and outlets, fill it with water and allow for at least 24 hours or such longer period to allow for complete absorption. Refill with water. Allowable leakage is not to exceed 1 % over 24 hours, otherwise make good and retest.

5.09.04 MEASUREMENT

A. Manholes, drop inlets, catchbasins, catchpits, curb inlets, ditch inlets and ditch outlets shall be measured by the number of each type constructed, completed as shown on Drawings and accepted including protective painting, furnishing and installation of all materials, frames, grates, covers and steps.

B. Channel grating basins shall be measured by the linear meter of each clear opening width, constructed, completed and accepted including furnishing and installation of all materials, frames and grates.

C. No separate measurement or payment shall be made for any excavation, shoring, sheeting or backfilling, or for breaking into existing pipes, channels or culverts in order to install new manholes, catchbasins, catchpits, Drop inlets, curb inlets, ditch inlets, ditch outlets and channel grating basins, all such work being considered subsidiary to the relevant Pay Items.

D. No separate payment shall be made for blinding, protective and bituminous painting, equipment, forms, tools, furnishing and placing materials, labor, or any other item necessary for the proper completion of the work.

PAY ITEM	UNIT OF MEASUREMENT
(1) Manhole (specify dimension and depth)	Number (Nr)
(2) Catch basin	Number (Nr)
(3) Catchpit	Number (Nr)
(4) Curb Inlet,	Number (Nr)
(5) Ditch inlet	Number (Nr)
(6) Ditch outlet	Number (Nr)
(7) Channel grating basin	Linear Meter (m)
(8) Drop Inlet (specify dimension and depth)	Number (Nr)

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SECTION 5.10 WATERPROOFING FOR STRUCTURES

5.10.01SCOPE

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

5.10.02MATERIALS

A. Asphalt

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

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

B. Bitumen

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

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

C. Fabric

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

C.1 Self-Adhesive Polyethylene Sheet

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

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

D. Tar for Absorptive Treatment

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

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

E. Tar Seal Coat

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

F. Joint Fillers

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

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

G. Waterstops

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

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

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

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

degree)C both at 21kg per cm^2, the tensile strength and elongation shall not be less than 65 percent of the original when tested in accordance with ASTM D572.

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

H. Proprietary Waterproofing Systems

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

I. Epoxy Coating System

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

5.10.03SURFACE PREPARATION

A. Waterproofing

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

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

B. Dampproofing

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

5.10.04INSTRUCTION DELIVERY AND STORAGE

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

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

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

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

5.10.05CONSTRUCTION

A. Asphalt and Bitumen Waterproofing Membranes

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

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

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

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

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

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

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

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

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

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

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

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

B. Proprietary Waterproofing Membranes

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

C. Damage Patching of waterproofing Membranes

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

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

D. Dampproofing

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

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

E. Protection of Waterproofing and Dampproofing

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

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

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

F. Water Stops

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

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

G. Testing

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

5.10.06PROTECTIVE PAINTING TO CONCRETE

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

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

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

5.10.06.1 Rubber Bitumen Emulsion

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

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

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

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

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

5.10.06.2 Epoxy Resin Coating System

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

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

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

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

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

C. Tests

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

5.10.06.3 External Quality Emulsion Paint

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

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

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

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

C. **Testing and acceptance Criteria**

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

5.10.07MEASUREMENT

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

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

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

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

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

F. Unless otherwise indicated, measurement of protective painting or coating of concrete

shall be by the meter square of developed surface areas covered by the protective painting.

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

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

I. Work is deemed to include:

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

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

SECTION 5.11 NOT APPLICABLE

SECTION 5.12 NOT APPLICABLE

SECTION 5.13 JOINT SEALING AND JOINT FILLER

5.13.01SCOPE

This work covers joint sealing materials and performed expansion joint filler for use where shown on the Drawings or as directed by the Engineer.

5.13.02MATERIALS: JOINT SEALING COMPOUNDS

A. Hot Type

A.1 Composition

This type shall be a mixture of virgin synthetic rubber or reclaimed rubber, or a combination of the two, with asphalt plasticisers and tactified. Ground cured rubber scrap shall not be used.

A.2 Physical requirements

A.2.1 The joint sealing compound, after heating and application, shall form a resilient and adhesive compound capable of effectively sealing joints in concrete against the infiltration of moisture and foreign material through repeated cycles of expansion and contraction. It shall be capable of being brought, by heating, to a uniform, smooth pouring consistency, free from lumps, and suitable for completely filling the joints and without damage to the material. It shall not flow from the joints or be picked-up and tracked by vehicle tyres at summer temperatures.

A.2.2 **Pour point:** The pour point shall be at least 11 degrees C lower than the safe heating temperature. The safe heating temperature is defined as the highest temperature to which the material can be heated and still meet all requirements of this specification. No sample of the material will be tested until the manufacturer furnishes his recommended safe-heating and pouring temperatures.

A.2.3 **Prolonged heating:** After 6 hours of continuous heating, with constant mixing in the laboratory matter at the manufacturer's recommended pour temperature, the joint sealer shall meet all requirements of this specification. (For initial qualifying tests and subsequently as directed by the Engineer).

A.2.4 **Penetration:** The penetration at 25 degrees C, 150 gm, 5 sec, shall not be less than 50 nor more than 90 mm.

A.2.5 **Flow:** The flow at 60 degrees C and at a 75 degree angle shall not exceed 1cm in 5 hours.

A.2.6 **Ductility:** Ductility at 25 degrees C shall be not less than 35 cm.

A.2.7 **Bond:** The material when tested at minus 17.8 degrees C to 100 percent extension (1.27 cm extended to 2.54 cm) shall, after 5 cycles, show no surface checking, cracking, separation or other opening in the material or between the material and the block. At least 2 test specimens in a set of 3 specimens representing a given sample shall meet this requirement.

A.2.8 **Resilience:** Recovery shall be not less than 25 percent.

A.2.9 Compression recovery: Compression recovery of bond specimens shall be not less than 1 cm within 15 min.

A.2.10 Impact: No failure in cohesion or adhesion shall occur.

A.3 Methods of Sampling and Testing

A.3.1 Sampling: Samples for testing shall consist of not less than a 4.5 kilogram sample from each batch of the joint sealer. A batch shall be considered as all finished material that was manufactured simultaneously or continuously as a unit between the time of compounding and the time of packaging or placing in shipping containers. Each package or container shall be marked properly to indicate clearly the batch of which it forms a part. The material shall be sampled in accordance with the requirements of the "Standard Methods of Sampling Bituminous Materials" (ASTM Designation: D 140) for solid materials in cakes**.**

A.3.2 Testing: Testing shall be in accordance with AASHTO T187 except that the tolerances on dimensions of test specimens Article 6.3 shall be ± 0.13 cm and the temperature tolerances Article 6.4 shall be ± 2.2 degrees C.

B. Cold Type

B.1 Composition

This type shall be homogeneous material of such consistency that it can be applied by means of high-pressure pump through suitable nozzles to completely fill the joints. The compound may be blended with a suitable solvent or solvents by the manufacturer to provide better workability during installation in the joints. The volatility of these solvents must be such that they will evaporate within a short time after installation leaving a material that is adhesive and resilient.

B.2 Physical Requirements

B.2.1 Flow: The flow during a 5 hour period at 60 degrees C shall not exceed 0.5 cm.

B.2.2 Penetration: After evaporation of the solvent the penetration at 25 degrees C 150 gm 5 sec shall not exceed 220 mm.

B.2.3 Bond: When the compound is tested at minus 17.8 degrees C the development at any time during the test procedure of a crack separation or other opening which is at any point over 64 mm deep in the material or between the material and the concrete block shall constitute failure of the test specimen. The failure of more than 1 test specimen in a group of 3 specimens representing a given sample of joint sealing compound shall be cause for rejection of the sample on the basis of this requirement.

B.3 Methods of sampling and testing

Cold-type joint compound shall be tested in accordance with ASTM D 1851 except that the material for test specimens Article 7(c) will be stirred manually rather than mechanically.

B.4 Preformed

Preformed Polychloroprene Elastomeric Joint Seals shall comply with the requirements of AASHT0 M220(ASTM D2628).

C. **Joint Sealant** for movement joints in water retaining structures is to be polysulphide based compound to BS 4254 or as manufactured by:
Man: Expandite Ltd.
Ref.: Thioflex 600

Man: Servicised Ltd.
Ref.: Paraseal

or other equal and approved.

D. **Exposed Joint Sealant** for movement joints is to be approved polysulphide rubber based compound unless otherwise specified.
Man: Dunlop Ltd.
Ref.: High butyl mastic 421.8

Man: Expandite Ltd.
Ref.: Thioflex 600

or other equal and approved.

E. **Backing Strip**: type recommended by joint sealant manufacturer.

5.13.03PREFORMED EXPANSION JOINT FILLER

A. **Description**

This type of filler shall be a non-extruding and resilient bituminous type and shall have relatively little extrusion and a moderate to high amount of recovery after release from compression.

B. **Requirement**

Nonextruding and resilient type of expansion joint filler shall conform to all the requirements of the Standard Specification for "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous types)", AASHTO Designation M 213 (ASTM D1751)

C. **Movement Joint Sheet Material Filler**

For expansion joints in water retaining structures is to be bonded granular cork to ASTM D 1752 or ASTM D 1751 or as manufactured by:
Man: Expandite Ltd.
Ref.: Cork filler

Man: Servicised Ltd.
Ref.: Kork-Pak

or other equal and approved

5.13.04CERTIFICATE OF GUARANTEE

The Contractor shall furnish the Engineer with a Manufacturer's Certificate of Guarantee for each type of joint material delivered to the Site. The certificate shall note compliance to the appropriate specifications and shall state the results of the tests performed on the material as required by the specifications. The Contractor shall when so directed by the Engineer have the joint material tested for conformance to the applicable specifications at an approved testing laboratory. All costs connected with Certificate of Guarantee and any subsequent quality testing shall be at the Contractor's expense.

5.13.05CONSTRUCTION

A. Generally: joints are to be:
- Straight, vertical, horizontal or as detailed or approved
- Formed to accommodate projecting reinforcement

B. Movement Joints are defined as:
- Formed expansion joints
- Formed contraction joints
- Induced contraction joints.

C. Formed Movement Joints: construct rigid stop ends and formwork at formed movement joints to permit separate construction of structurally separate parts of the work.

D. Construction Joints: where not coincident with movement joints submit proposals for positions of construction joints and obtain approval.

E. Construction Joints: lightly roughen face to expose coarse aggregate unless otherwise instructed. Wet and cover with 1:1 cement and sand grout immediately prior to placing fresh concrete. Stop roughening 25 mm from arises to surfaces exposed to view in finished work. Remove small mortar lips from exposed arises with carborundum stone. Face is to be clean and damp before fresh concrete is placed against it.

F. Concrete Floors side and end forms are to be square edged with steel top surface.

G. Waterbars: nail to forms prior to concreting and butt joint in accordance with the manufacturer's instructions.

H. Sealing of Movement Joints: preparation and application is to be strictly as manufacturer's recommendations. Joints are to be thoroughly clean and dry, free from oil and loose material. Vigorously wire brush or grit blast the joint faces and clean out with compressed air. Prime faces of joint and allow to dry. Where exposed to view mask edges of joint with tape before priming and remove immediately after sealing. Apply sealant ensuring maximum adhesion to sides of joint and a neat, smooth and clean finish.

5.13.06MEASUREMENT

A. No part of this Section is a Bid Item and no measurement shall be made.

B. The materials provided for this Section will not be paid for directly, but will be considered subsidiary to other items of work appearing in the Bill of Quantities.

SECTION 5.14 DRAINAGE OF STRUCTURES

5.14.01SCOPE

This work shall consist of furnishing and installing gully and channel grates and frames on bridge decks, subways and underpasses, for collecting surface water from structures. It shall also consist of furnishing and installing hoppers, draining pipes and downpipes which arc connected to the gully and channel grates by hoppers.

The gully and channel grates and frames may be of cast iron or cast steel with or without integral cast hoppers. In the absence of integral cast hoppers, fabricated PVC or GRP hoppers will be necessary. The Contractor shall submit, as early as possible, details of all drainage material and components he proposes to use for the approval of the Engineer. No material or component shall be incorporated in the Works without written approval of the Engineer.

5.14.02MATERIALS

A. Gully and Channel Grates and Frames

Frames and grating shall comply with the following

- AASHTO M105 (ASTM A48) or BS497: Part 1 for cast iron
- AASHTO M192 (ASTM 486M) or BS497: Part 1 for cast steel.

B. Iron and Steel Pipes

Cast iron pipes shall conform to the requirements of BS78 Parts 1 and 2 and spun iron pipes to BS1211. Steel pipes shall conform to the requirements of ASTM A 135, ASTM A139 or BS534.

C. PVC and UPVC Pipes

Pipes of synthetic materials for general drainage use shall be approved pipes of polythene, polypropylene, or polyvinylchloride. Unplasticised polyvinylchloride pipes shall conform to the requirements of Class 2 and Class 3 ASTM D3033.

5.14.03CONSTRUCTION

A. Drainage pipes and gullies shall be laid to the lines and levels and bedded laid, jointed and protected, all as shown on the Drawings, or as established by the Engineer.

B. When drainage pipes are cast into concrete structures, the Contractor shall take adequate precautions to prevent any displacement of the pipes during the concreting operation.

C. Drainage pipes shall be tested for water tightness and the test procedure shall be agreed with the Engineer. Where drainage pipes are located within the cellular parts of a bridge deck where access after completion of the deck is limited, then the installation and testing of the pipes shall be completed and accepted by the Engineer before the deck

construction is allowed to proceed to the stage where free access to the pipes will not be possible.

5.14.04MEASUREMENT

A. Gully grates and frames of different types shall be measured by the number installed, completed, and accepted. Hoppers connecting the gully frames to drainage pipes shall not be measured separately but shall be considered subsidiary to gully grates and frames.

B. Different types of channel grates and frames shall be measured by the linear meter installed, completed, and accepted. Hoppers connecting channel frames to drainage pipes shall not be measured separately but shall be considered subsidiary to channel grates and frames.

C. Different types of drainage pipes shall be measured by the linear meter of each diameter and each type of pipe installed, completed and accepted. No separate measurement will be made for pipes cast into concrete or for pipes connecting gully and channel frames to drainage pipes (only if the connection length is greater than 10m) or for pipe supports and joints or for discharge hoppers from drainage pipes to down-stand pipes, but shall be considered subsidiary to drainage pipes.

D. No separate measurement will be made for testing of gully grates and frames gully hoppers, or drainage pipes and their support system but shall be considered subsidiary to the items tested.

E. Compensation for completed and accepted work shall be considered included in the lump sum price of the Contract, which price shall be full compensation for furnishing all materials, labor, equipment, tools, tests, records and all other- items necessary for the proper completion of the works as specified.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Gully Grates and Frames (state type)	Number (Nr)
(2) Channel Grates and Frames (State type)	Linear meter (m)
(3) Iron pipes (state dia)	Linear meter (m)
(4) Steel pipes (state dia)	Linear meter (m)
(5) UPVC pipes (state dia)	Linear meter (m)
(6) PVC pipes (state dia)	Linear meter (m)

SECTION -10-

ENVIRONMENTAL WORKS

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SECTION 10.00 GENERAL REQUIREMENTS

A. Environmental works shall comprise:

- Water distribution and related works
- Wastewater collection
- Storm water drainage
- Landscape irrigation works

B. Works shall consist of finishing all materials and the construction installation and completion in all respects of works as described in this Specification and as shown on the Drawings.

C. Special Requirements

C.1 Manufacturer's certificate: Materials shall be supplied with a certificate, in respect of each delivery, stating that products comply with and have been factory tested in accordance with specified Standards.

C.2 Marking: Unless otherwise specified in the relevant Standard, products shall have legibly cast, stamped or indelibly painted on, the following marks, as appropriate:

- Manufacturer's name, initials and identification mark.
- Nominal diameter.
- Class designation.
- Initials and number of relevant Standard.
- Length of pipe if shorter than standard length.
- Angle of bends in degrees.
- Date of manufacture.

C.3 Special tests: Whenever required by the Engineer, the Contractor must supply and transport to an approval testing laboratory samples of materials selected by the Engineer. Number of samples shall not be less than 0.5% of total supplied, with at least one from each class, diameter and manufacturer. Failure of any sample shall be followed by a second and if necessary a third test from the same batch. A third test failure will result in all material from that manufacturer being rejected and replaced by material from a different manufacturer, subject to approval and satisfactory tests. Laboratory test reports in an approved form must be provided.

D. Workmanship: Operations

D.1 Manufacturer's recommendations on handling, repairing, laying, jointing, anchoring, testing and other works for pipes and fittings shall be strictly followed.

D.2 Loading and unloading: The Contractor shall use cranes, hoists or skidways as directed by the Engineer. The Contractor shall use hooks, spreader beams, ropes, band or wire slings etc. as recommended by manufacturer for each type of pipe and as approved by the Engineer.

D.3 The Contractor shall stack pipes on level surface. The Contractor shall not rest pipes on sockets or jointing fairlings and shall securely chock end pipes in bottom row. Height of stacks shall be to manufacturer's instructions.

D.4 The Contractor shall handle material with care to avoid damage whether moved by hand, skidways or hoists.

D.5 Storing: The Contractor shall provide safe storage for material. Interior of pipes, fittings etc. shall be kept free from dirt and foreign matter. The Contractor shall provide shade for materials as required by manufacturer's instructions and to the Engineer's approval.

D.6 Cutting: The Contractor shall use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. If, in the opinion of the Engineer, special precautions shall be taken to eliminate airborne particles, the Contractor shall use methods and equipment as directed by the Engineer. The Contractor shall prepare ends according to type of joint used and follow manufacturer's recommendations. The Contractor shall take care not to damage lining, if any. The Contractor shall repair on site, minor damage, if permitted.

D.7 The Contractor shall repair damaged coating, sheathing or lining in accordance with the Specification and manufacturer's instructions. The Contractor shall use material compatible with that originally used. Repair shall be approved by the Engineer before incorporating materials into the work.

SECTION 10.01 PIPING AND APPURTENANCES

10.01.01 GENERAL

A. Special requirements

A.1 Manufacturer's certificate: materials are to be supplied with a certificate, in respect of each delivery, stating that products comply with and have been factory tested in accordance with specified Standards.

A.2 Marking: unless otherwise specified in the relevant Standard products are to have legibly cast, stamped or indelibly painted on, the following marks, as appropriate:

- Manufacturer's name, initials and identification mark,
- Nominal diameter,
- Class designation,
- Initials and number of relevant standard,
- Length of pipe if shorter than standard length,
- Angle of bends in degrees,
- Date of manufacture,

A.3 Special tests: whenever required by the Engineer, supply and transport to a testing laboratory samples of materials selected by the Engineer. Number of samples is not to be more than 0.5% of total supplied, with at least one from each class, diameter and manufacturer. Failure of any sample is to be followed by a second and if necessary a third test from the same batch. A third test failure will result in all material from that manufacturer being rejected and replaced by material from a different manufacturer, subject to approval and satisfactory tests. Provide laboratory test report in an approved form.

B. Workmanship: Operations

B.1 Manufacturer's recommendations on handling, repairing, laying, jointing, anchoring, testing and other works for pipes and fittings are to be strictly followed.

B.2 Loading and unloading: use cranes, hoists or skidways as directed by the Engineer. Use hooks, spreader beams, ropes, band or wire slings etc. as recommended by manufacturer for each type of pipe and as approved by the Engineer.

B.3 Stack pipes on level surface. Do not rest pipes on sockets or jointing fairlings. Securely chock end pipes in bottom row. Height of stack is to be to manufacturer's instructions.

B.4 Handle material with care to avoid damage whether moved by hand, skidways or hoists.

B.5 Storing: provide safe storage for material. Interior of pipes, fittings etc. are to be kept free from dirt and foreign matter. Provide shade for materials as required by manufacturer's instructions and to the Engineer's approval.

B.6 Cutting: use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. If, in the opinion of the Engineer, special precautions are to be taken to eliminate airborne particles, use methods and equipment as directed by the

Engineer. Prepare ends according to type of joint used and follow manufacturer's recommendations. Take care not to damage lining, if any. Repair on site, minor damage, if permitted.

B.7 Repair damaged coating, sheathing or lining in accordance with the Specification and manufacturer's instructions. Use material compatible with that originally used. Repair is to be approved by the Engineer before incorporating materials into the work.

10.01.02 PIPES, FITTINGS AND ACCESSORIES

10.01.02.1 MATERIALS

A. Concrete pipes (for Sewage and Drainage)

A.1 Pipe to BS 5911 Part 100 1988 Class H or ASTM C76-95A Class IV or DIN 4032 Class KW. Cement used in manufacture is to be ordinary Portland cement to BS 12.

A.2 Joints: to be of gasket type with flexible spigots and sockets. The shape of the joint must be designed to prevent any movement of the gasket during assembly and as such produce full water tightness. Rubber gasket shall be to BS 2494.

A.3 Factory protection for pipes

For drainage networks internal and external lining not required.

For sewage networks:

- Internally: pipes smaller than 900 mm diameter, use coal tar epoxy coat 70% minimum epoxy content. Coat minimum thickness 40 mils. For pipes 900 mm and larger use Polyethylene liner.
- Externally: unless otherwise specified external coating not required.

B. Ductile iron pipes (for Water Supply)

B.1 Pipe to EN 545 or equivalent. Unless otherwise indicated in the Bill of Quantities. Class K9 for diameters up to 500 mm, Class K8 for diameters from 500 to 800 mm and Class K7 for diameter greater than 800 mm.

B.2 Joints: spigot and socket ended pipes shall be used for straight runs and adjacent to elbows or fittings. These joints shall be provided with rubber gaskets, and an external thrust block is required at elbows or fittings. Anchored or self-restrained joints shall be used for sections on the 1000 mm pipe adjacent to elbows. Anchored joints are to be push-in, self anchored type able to take up the axial forces thus allowing concrete thrust blocks to be dispensed with. The Contractor shall submit calculations verifying the number of restrained joints required noting that pipe pressure testing will be made when pipes are partially backfilled.

B.3 Joints: flanged pipes wherever specified are to have screwed-on or cast-on flanges to sustain working pressure of NP 16 minimum.

B.4 Flanges to BS 4504.

B.5 Factory protection for pipes:

- Internally: cement lined to EN 545 or BS 4772 Appendix C with ordinary Portland cement to BS 12 to specified thicknesses,
- Externally: metallic zinc to EN 545 or BS 4772 and either hot applied material to BS 4164 or bitumen to BS 3416, minimum thickness 6 mils.

B.6 Factory protection for fittings:

Coated internally and externally by dipping, or other method, using hot applied coal tar based material to BS 4164 or hot applied bitumen to BS 3416, Type 1, grade d, minimum thickness 10 mil.

C. UPVC pipes

C.1 Pipes to DIN 8061/8062, Series 4 and 5 or ISO R161 Class 10 and & 16. Use concrete encasement if cover is less than 1 meter.

C.2 Fittings to DIN 8063 part 1 fabricated from pipe.

C.3 Joints to DIN 8063 Part 1, socket spigot with rubber sealing rings to BS 2494.

D. Polyethylene (PE) pressure pipes for water supply

D.1 Pipe and fittings to DIN 8074/8075 or AWWA C906-90. Straight with straight ends suitable for heat fusion. Class 10 and 16 kg/cm2.

D.2 Materials used shall have a standard PE code designation 3408 and a minimum hydrostatic design basis of 1600 psi according to AWWA C906 Table 1.

D.3 Manufacturers to provide certification that stress regression testing has been performed on the pipe products. Materials shall also meet elevated temperature requirements as given in Table 2 AWWA C906.

D.4 Fittings shall be to AWWA C906, extruded or injection molded suitable for class of pipe required.

D.5 Joints for pipes and fittings shall be by heat fusion and in strict accordance with pipe manufactures recommendations. Joints shall have a tensile strength equal to that of the pipe. Fusion temperature, interface pressure, alignment and cooling time, shall be according to manufactures recommendations.

D.6 Tests on PE compounds: where PE is used for potable water, PE compounds in pipes and fittings are to contain no ingredients in an amount that has been demonstrated to migrate into water in quantities considered to be toxic. PE compounds are to be tested and certified suitable for potable water by the National Sanitation Foundation (NSF) Testing Laboratory - USA or the Canadian Standard Association (CSA) Testing Laboratory or other accredited testing agency. Tests are to be made in accordance with requirements no less restrictive than those in NSF Standard No. 14 (1976) Sections 3 and 4. The seal and mark of the testing laboratory are to be included on pipes and fittings.

E. Steel pipes

E.1 Steel pipe size 150 mm (6") and smaller shall be black steel, seamless or welded, and shall conform to BS 1387 medium class, ISO R65 or DIN 2440.

E.2 Steel pipe size 200mm (8") and larger shall be welded black steel, and shall conform to BS 3602, AWWA C200, grade A, or equivalent. Wall thickness to AWWA C200-91 Section 3-4. Minimum wall thickness to BS 3600 or as given in the Bill of Quantities.

E.3 Steel pipe shall be reasonably round and straight and shall be free from injurious defects. Defects shall be considered injurious when the depth of defect is greater than 12.5% of the tabulated wall thickness. Pipe shall be substantially free from rust.

E.4 Steel pipe shall be joined by double submerged arc welding. All welding shall be performed in conformance with the rules and regulations of the American Welding Society, including surface preparation methods, welding procedures and qualification of welders and welding operators.

E.5 Surface preparation: Prior to coating, surface is to be prepared by acid pickling until all scale has been removed.

E.6 Internal lining: all steel pipes and specials shall be lined internally to the thickness specified with concrete made from ordinary Portland cement to BS 12 and fine aggregate The materials used for lining, the method of lining and curing of the finished lining and the manufacture and testing of test cubes shall comply with BS 534 and shall be carried out to the approval of the Engineer.

E.7 External coating: steel pipes fittings and specials shall be protected externally with bituminous laminate tape 1.6mm thick and with 55% overlap or as recommended by manufacturer. Approved manufacturer's Denso, Serviurap… or equivalent.

F. GRP pipes

F.1 **General:** GRP (Glass Reinforced Plastic) pipes shall meet the requirements of the most recent edition of ASTM D 3262 together with the requirements specified herein, GRP pipes and fittings shall be purchased locally provided they conform to these Specifications.
The contractor shall supply to the Engineer, manufacturer's signed certificates stating that the pipes comply in all respects with the provisions of these Specifications and giving the results of all specified tests.
Other methods for manufacturing of GRP pipes may be proposed but such methods will be subject to the approval of the Engineer. Acceptable alternatives to the filament-wound type of pipe described above include the centrifugally cast type complying with BS 5480 subject to independent evidence of a long record of satisfactory use and subject to the Engineer’s approval of the detailed specification.

F.2 **Appearance:** The internal surface of all pipes and fittings shall be smooth, hard, durable and free from all tack, protruding fibers, voids, pits, bubbles, cracks, blisters and foreign matter. The external surface of all pipes and fittings shall be a fiberglass surface mat impregnated with polyester resin and shall be commercially free of resin runs, dry areas, dirt and black marks.

The resin reinforcement and aggregates, when combined as a composite structure, shall produce pipes and fittings that satisfy the performance requirements of these Specifications.

F.3 Design Requirements: All pipes and joints shall be designed for a minimum working life of 50 years. Pipelines may run beneath roads and be subjected to maximum loading conditions, therefore, design shall be for the worst surcharge conditions and loading applicable in Lebanon.

The pipe shall be designed to withstand the internal environmental conditions specified below:

pH value	1 to 13
BOD	up to 1000 mg/1
Suspended solids	up to 1000 mg./1
Chloride	500 mg/1
Free NH_3	150 mg/1
Sulphate	1000 mg/1
Temperature	5 to 50 °C
Prevailing temperature throughout sewage medium is:	30 °C
Sewage dissolved H_2S	Up to 20 mg/1
H_2S gas concentrations	Up to 2000 mg/1

The ground and groundwater in which the pipes shall be laid are high in salts and are aggressive.

F.4 Resins:
All pipes Resins shall comply with the relevant requirements of BS 5480. Details of all resins to be used in the manufacture shall be provided and shall include all the properties listed in the table herein. The resin system adopted shall be that most suitable to the internal and external environmental conditions and resin properties shall be tested in accordance with the following table.

RESIN PROPERTIES

Property	Test Method	Units
Liquid Resin		
- Acid Value	BS 2782, BS 3532	mg KOH/g
- Viscosity at 25 deg C	BS 188 &BS 3532	m Pas
- Specific Gravity	BS 3532	
- Volatiles content	BS 3532 &	BS 2782
- Refractive Index	ASTM	D 1045
Cured Resin		
- Heat distortion temperature	BS 3532 Appendix A	deg C

- Glass transition temperature	Differential thermal analysis	deg C
- Tensile strength	BS 2782	MN/m²
- Flexural strength	BS 2782 & BS 3532	MN/m²
- Ultimate elongation	BS 2782	
a.Basic resin		%
b.If flexibilised		%
- Barcol hardness	BS 4549 Appendix A	
- Water absorption	BS 2782 & BS 3532	mg
Information supplied on cured resin shall include details of the cure system employed, which shall be the same as that proposed for manufacture of pipes and fittings.		

F.5 Fiber Reinforcement:

With the exception of a veil on the inside face of the pipe, all fiber reinforcements used shall be of ECR/ADVANTEX type glass and shall comply with the appropriate standard listed below and shall have a surface treatment compatible with the resin.

BS 3691 Glass fiber roving for the reinforcement of polyester and of epoxy resin system.

BS 3496E Glass fiber chopped strand mat for the polyester resin systems

BS 3396 Woven glass fiber fabrics for plastic reinforcement

BS 3749 Woven roving fabrics of glass fiber for the reinforcement of polyester resin systems. If a veil is used on the inside face of the pipe, this shall be "C" glass fiber.

F.6 Aggregates and Fillers:

Aggregates and fillers shall comply with the relevant requirements of BS 5480. Silica sand, if used in the manufacture, shall be a minimum of 95% pure silica. The maximum percentage by weight of all aggregates and fillers in the laminate(s) shall not exceed 30%.

No pigment shall be added to any resin used

F.7 Liner:

All pipes and fittings shall have a suitably reinforced resin rich liner to give high corrosion, impact and abrasion resistance. The thickness of this liner shall be determined by the pipe manufacturer, but shall not be less than 1½ mm. No aggregate or fillers shall be included in the liner.

The liner shall consist of two layers, a surface layer and a barrier layer. The surface layer shall be a minimum of 1 mm thick with a minimum of 90% Venylester resin. Any reinforcement in this layer shall be of C type glass or approved suitable synthetic material. The barrier layer shall have 70% to 80% Vinylester resin with ECR/Advantex glass reinforcement

F.8 Structural Design:

Details of loading and pressures shall be as shown on the drawings. Pipes and fittings shall be designed to these standards for the ground conditions to be encountered. All pipes and fittings shall have a minimum stiffness of 5000 N/m² to accommodate handling and transportation stresses unless specified otherwise.

For buried pipes stiffness shall depend upon depth of cover above the crown of the buried pipe in accordance with the following:
For depths of cover over the pipe more than 6.0 meters or less than 1.5 meters, pipe stiffness shall be minimum 10000 N/m². For depth of cover more than 1.5 m and less than 6.0 meters, pipe stiffness shall be minimum 5000 N/m².

Note: Stiffness factor 'F' shall be calculated as follows:

$$F = \frac{EI}{d^3}$$

where, E = Flexural modulus of elasticity of pipe material in circumferential direction.

$$I = \frac{S^3}{12}$$

S = Wall thickness (m)

d = Mean pipe diameter (m)

Pipe shall have an initial ultimate resistance to longitudinal tensile force per unit of circumference of not less than the following :

DIAMETERS	**RESISTANCE**
Up to and including DN 600	150 N/mm²
Greater than DN 600 up to and including DN 1200	200 N/mm²
Greater than DN 1200 up to and including DN 2400	250 N/mm²

F.9 Sizes, Diameter:

The diameter of the pipe shall be designated by the nominal internal diameter. The manufacturing tolerance of the internal diameter shall be in accordance with BS 5480.
All deviations from roundness, with the exception of pipe deformation due to its own weight, shall be contained within the tolerances. Deviations in diameter of spigot and sockets shall be kept to the absolute minimum and shall be such that the seal at the joints is not affected.

F.10 Sizes, Length:

Effective length of pipes and tolerance on effective length shall be as specified in BS 5480.
Where it is found necessary to cut or turn down a pipe in order to form a joint, the exposed surfaces shall be fully sealed with a continuous coating of fully cured resin.

F.11 Wall Thickness:

Wall thickness shall be as recommended by the pipe manufacturer and to the approval of the Engineer.

G. Flanged Adaptors: Ferrous

G.1 Material: cast iron body to BS 1452 grade 14 or mild steel plate to BS 4360 - 4SA and malleable cast iron flange to BS 310 grade 20/10 or rolled steel to BS 970 - 060A12 with bolts to BS 970 - EN3A and rubber rings to BS 2494.

G.2 Length of adaptor is to be 200mm for diameters up to 150mm, 250mm for diameters between 200 and 300 mm and as approved for diameters larger than 300 mm.

G.3 Factory protection: coated with bitumen or coal tar to BS 3416 or 4164 respectively.

H. Tapping saddles: Cast iron

H.1 Type: suitable for tapping ductile iron pipe and for working pressure of 16kg/cm2.

H.2 Material: malleable cast iron, ductile cast iron or gunmetal to BS 310 - B310/10, BS 2789 - 420/2 or BS 1400 LG2- C respectively, with rubber '0' ring to BS 2494 suitable for water supplies and manganese bronze high tensile non-corrosive bolts, nuts and washers.

H.3 Dimensions: width not less than 38 mm and diameter of disc not less than 75 mm.

H.4 Threads for tapping to BS 21.

H.5 Factory protection: hot bitumen dipped to BS 4164 or cold bitumen coated to BS 3416.

10.01.03 WORKMANSHIP

Earthwork for pipelines to be according to Section 2.10 of Division 2.

A. Pipe laying and jointing - Generally

A.1 Lowering: do not lower pipe into trench until pipe bed is brought to grade and approved.

A.2 Lowering: use ropes, wire slings, band slings, spreader beams etc. as recommended by manufacturer for each type of pipe and as approved.

A.3 Examine Material carefully for damage: Tests in accordance with manufacturer's instructions before laying to the satisfaction of Engineer.

A.4 Examine material: ensure internal coating or lining and outer coating or sheathing are undamaged. If damaged, make good or dispose of as directed.

A.5 Pipe cleanliness: remove dirt and other materials before lowering.

A.6 Pipe cleanliness: clear construction debris from inside of before making joint.

A.7 Pipe placement: lay pipe-on an even formation true to grade and line, with sockets (if any) facing up the gradient.

A.8 Pipe on solid ground: cut holes in bottom of trench to allow proper jointing and for barrel of pipe to bear evenly on solid ground for its full length.

A.9 Pipe on granular bedding: scoop out locally at sockets/couplings to enable pipe to rest uniformly on barrel and adjust to exact line and level. After testing lay and compact further granular material in 150mm layers or as approved to levels shown on the Drawings.

A.10 Pipe on concrete bed or surround: provide rectangular blocks of concrete Class B, made in approved moulds at least 14 days before use, and approved hardwood folding wedges. Provide two concrete blocks for each pipe, set and bone into correct level on formation bottom and lay pipe properly centered and socketed. Insert two hardwood folding wedges, of width equal to width of concrete block, between body of pipe and block and drive together until pipe is brought to exact level required. Leave blocks and wedges undisturbed while pipes are being jointed and concrete bed and haunch or surround are being placed. Ensure blocks and wedges are of sufficient size and strength to prevent settlement of pipes. Leave sufficient space to enable joints to be made, tested and inspected.

A.11 Pipe plugs: when pipe laying is not in progress, close open ends of pipes with properly fitted temporary wooden plugs or standard caps as directed.

B. Jointing

B.1 Manufacturer's instructions are to be followed regarding placement of bedding and backfilling, cleanliness of joint surfaces, lubricant used, correct location of components, provision of correct gaps between end of spigot and back of socket for flexible joints etc.

B.2 Deflection of joint: do not deflect flexible joints beyond maximum permissible angles given by manufacturer and/or relevant Standard.

B.3 Patent detachable and flexible joints: strictly comply with special instructions issued by manufacturer's of proprietary joints when laying and jointing.

B.4 Differing pipe and fitting material: joint with adaptors as recommended by pipe manufacturer.

C. Line and gradient

C.1 In open excavation: provide and maintain sight rails and boning rods properly painted to ensure correct alignment of pipe runs. Sight rails are to be positioned either vertically above the lines of pipes or immediately adjacent thereto. At no time are there to be less than three sight rails in position on each length of pipeline under construction to any one gradient.

C.2 In heading: provide and maintain marks to establish line and level of pipeline. Marks are to be fixed in each working shaft and two further marks established in each length of heading.

D. Tolerances

D.1 Gravity sewers: tolerances are to be 6 mm in level and 25 mm in line between manholes or access points unless otherwise specified. Where pipe is to be constructed in straight lines between manholes or lampholes the length will not be accepted if a light at each manhole or lamphole cannot be seen from adjacent manholes.

E. Floatation

E.1 Prevention: whenever-water is excluded from interior of pipe, place sufficient backfill above pipe to prevent floatation.

E.2 Removal of pipe: any pipe that has floated, correct bedding and relay.

F. Pipe built into structures

F.1 Treatment of external surface: thoroughly clean outside surface of pipes to be built-in immediately before installation. Remove protective coating to metal pipes, where ordered. Roughen clay and concrete pipes as directed. Paint plastic pipes with appropriate solvent cement and sprinkle with dry coarse sand whilst wet. Cut away sheathing from sections to be built-in and after installation restore protection up to external face of structure with approved bituminous material.

F.2 Flexible joints: provide two flexible joints or flexible patented joints adjacent to structures. Place first joint not more than one pipe diameter from face of structure and second not more than the following distances away from first:

- Pipelines not exceeding 450 mm: 2 pipe diameters
- Pipelines over 450 mm and not exceeding 1000 mm: 1.2 m
- Pipelines over 1000 mm: 1.8 m.

G. Field testing: Generally

G.1 Provision of test equipment: All items for test have to be provided on site before the test i.e. pressure gauges, instruments, water etc...

G.2 Carry out tests in the presence of the Engineer's Representative.

G.3 Fittings and joints: permanently anchor fittings before testing and leave all joints exposed for checking.

G.4 Test sections: limit test sections to not more than 500 m.

G.5 Test sections: test pressure lines between valve chambers whenever possible.

G.6 Test sections: test gravity sewers in sections between manholes.

G.7 Test sections: no testing shall be carried out against or through the pressure reducing valves. The setting of the pressure reducing valves shall not be changed for testing purposes.

G.8 Test plug: secure end of main and test plug by struts.

G.9 Closed valve: do not test against a closed valve unless there is no acceptable alternative.

G.10 Apply pressure by manually operated test pump or, in the case of large diameter mains, by power driven test pump, if approved.

G.11 Examine exposed joints and repair visible leaks.

G.12 Failure: should a test fail locate leak and replace or make good defective pipe or replace and make good faulty joint. Retest main.

G.13 Records: keep test records in an approved form. Hand original copy to the Engineer immediately after completion of test.

G.14 Pressure lines: carry out hydrostatic test while pipeline is partially backfilled.

G.15 Non-pressure lines not exceeding 1000mm diameter are to be air tested before backfilling and hydrostatic tested after backfilling.

G.16 Non-pressure lines over 1000 mm diameter are to be visually inspection tested from the inside as well as hydraulic individual joint tested.

G.17 Non-pressure lines: carry out infiltration tests where crown of pipe at high part of length under test is more than 1.2 m below water table.

H. Hydrostatic testing of pressure pipelines

Pressure test shall be made when pipeline section is partially backfilled, having all its joints exposed.

H.1 Fill pipe slowly with water from lowest point. Do not use power-driven pump unless approved.

H.2 Fill absorbent pipes with water and allow to stand for at least 24 hours to allow complete absorption.

H.3 Entrapped air is to be bled before pressurizing.

H.4 Pressurizing is to continue until specified test pressure is reached in lowest part of section under test. Bleed further quantities of entrapped air while raising pressure.

H.5 Maintain test pressure for specified test duration with pumping stopped.

H.6 Repressurize to original test pressure and record respective volumes of water pumped.

H.7 Failure: pipeline will be deemed to have failed test if:

- Visible leaks are detected, regardless of leakage being within specified limits.
- Volume of water lost during period when pumping was stopped, exceeds the allowable leakage volume.

H.8 Test pressure: Generally 1.5 times the maximum sustained pressure, minimum 13.5kg/cm^2.

H.9 Test period: 2 hours.

H.10 Allowable leakage 0.1 liter/mm diameter/km length/day/30 m of applied pressure.

I. Hydrostatic Testing of Non-pressure Pipelines

I.1 Procedure is to be as described for pressure pipelines.

I.2 Test pressure: 1.0 m head of water above pipe soffit at highest point and not greater than 6 m head of water at lowest point of section under test. If maximum head is exceeded, test section in stages.

I.3 Test period 30 minutes.

I.4 Allowable leakage: 0.02 liters/linear meter/meter diameter/30 minutes.

J. Air Testing of Pipelines

J.1 Carry out test to BS 8005. Plug effectively length under test.

J.2 Apply pressure by approved method (i.e. hand pump) until a pressure 3 psi head of water is indicated on a U-tube connected to the system.

J.3 Pressure drop: without further pumping, pressure is not to fall to less than 1 psi after period of 10 minutes.

J.4 Failure to pass the air test is not conclusive and if no leakage can be traced by external application of soapy water to all sealing areas then an hydrostatic test is to be carried out before final rejection.

K. Infiltration Test for Gravity Pipes

K.1 Timing: carry out test after total backfilling of length under test.

K.2 Plug effectively all inlets to system as directed.

K.3 Measure residual flow by approved method i.e. weir or other.

K.4 Infiltration limits: the following limits are not to be exceeded:

- Pipelines not exceeding 700 mm: 0.02 litres/hour/100 linear meters/mm diameter.
- Pipelines over 700 mm: 0.03 litres/hour/100 linear meters/mm diameter.

K.5 Failure: test will be deemed to have failed if allowable infiltration water is exceeded. Locate source of excessive infiltration by approved means i.e. traversing light and mirrors or inflated rubber plug etc. and make good. Repeat test until successful.

L. Visual Inspection Test

L.1 Timing: carry out test after total backfilling of length under test.

L.2 Limit of length to be tested at one time is three full- length pipes unless otherwise approved.

L.3 Apparatus: use rubber tyred bogies which do not damage lining of pipe and an adequate supply of electric lamps.

L.4 Check joints by means of feelers to ensure rubber rings are correctly located.

L.5 Check pipe barrel for visible cracks.

M. Hydraulic Individual Joint Test for Pipes Exceeding 1000 mm

M.1 Procedures: carry out to BS 5886, Type 2 testing after backfilling, or equivalent. Pressurize joint to 2 bars. Wait for 2 minutes at the end of which repressure to 2 bars. Wait for 5 minutes. No pressure drop shall be observed at the end of the latter period.

M.2 Test pressure: 2 bar.

M.3 Test period: 5 minutes.

M.4 Allowable leakage or pressure drop: None.

N. Flushing and Disinfection of Water Mains

N.1 Procedure: to AWWA C651.

N.2 Provide equipment, gauges, temporary connections, chlorine and water needed for flushing and disinfection

N.3 Arrange with the Employer to draw water from existing sources.

N.4 Sections: flush and disinfect mains in sections as directed by the Engineer.

N.5 Draining use washout valves and fire hydrants to drain flushing and disinfecting water.

N.6 First flushing: before commencing disinfection, flush main until effluent is clean and then clean as directed. 1 to 2 times volume of pipe is usually required for such flushing.

N.7 Type of chlorine: disinfect with chlorine gas or solutions of calcium hypochlorite or sodium hypochlorite and agree with the Engineer on method of application.

N.8 Initial dosing is to be 40-50 ppm.

N.9 Contact period is to be 24 hours.

N.10 Residual chlorine: after the contact period has been achieved, measure residual chlorine by orthotolidin test. Residual chlorine is not to be less than 5 ppm or test is to be repeated as directed.

N.11 Final flushing: after disinfection, reflush network until chlorine concentration in water leaving main is less than 1 ppm.

N.12 Tests: perform bacteriological tests to AWWA C651, Section 9. Number of samples is to be one per 1 km of main feeders and one per 0.25 km of distribution lines.

N.13 Procedure after cutting into existing main: generally to AWWA C651, Section 11.

O. Field Protection and Coating

O.1 Iron pipes: polyethylene encasement is to be to ANSI/AWWA C105, Section 4.1 minimum thickness 8 mils and or in accordance with the manufacturer's instructions.

O.2 Patented detachable and flexible joints and flanged connections: protect metal joints with mastic compound and protective tape in accordance with the manufacturer's instructions. Minimum overlap 55%. Press out firmly all folds and irregularities.

P. Water Supply House Connections

P.1 Location: agree location of tapping with the Engineer before starting construction.

P.2 Program connections to follow closely construction of main network.

P.3 Tapping: drill, thread and tap ferrule cocks to manufacturer's instructions.

P.4 Excavate, install, bed and backfill in same manner as main network.

P.5 Test with main network but excluding water meter.

P.6 Records: maintain accurate records of location of house connections to main network. Record details of the following:

- Diameter
- Length
- Location
- Stop valves.

P.7 Survey Logbook: keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. Transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

Q. Sewer house connections

Q.1 Location: agree location and invert level of connections with the Engineer before starting construction.

Q.2 Program connections to follow closely construction of sewer.

Q.3 Execution: connection to sewer is to be at manhole, where possible, or by T or Y junction.

Q.4 Minimum Grade: lay connections at minimum grade of 20 per 1000 unless otherwise approved.

Q.5 Install, Bed and Test connections in same manner as main sewers.

Q.6 Records: maintain accurate records of location of connection to main sewer. Record details of the following:

- Connection number
- Type of connection
- Diameter
- Downstream manhole number
- Distance from manhole
- Position (left or right) when facing upstream of street sewer
- Distance from center line of sewer to end lateral
- Invert of street sewer
- Lateral invert at end point
- Number of inspection chambers
- Cover type
- Location, description and elevation of obstructions and method of protection.

Q.7 Survey Logbook: keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. Transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

R. Cleaning and inspection of sewers

R.1 Cleaning: clean pipeline of silt and debris after backfilling pipe trenches and completing manholes, hatch boxes etc. but before surfaces are permanently reinstated and make ready for inspection by the Engineer.

R.2 Inspection: pipelines of 700 mm diameter and over are, where practicable, to be inspected from the inside and when necessary a suitable trolley is to be provided for this purpose.

R.3 Inspection: pipelines less than 700 mm diameter and larger pipelines which cannot be inspected from the inside, are to be inspected by passing a cylinder of diameter 25 mm less than the internal diameter of the pipe and length not less than the internal diameter of the pipe through each pipeline.

10.01.04 MEASUREMENT

A. Earthwork

Measurement and payment for trench excavation and backfilling shall be made in accordance with the provisions of Section 2.10.3 of Division 2.

B. Pipelines

B.1 Pressure pipes installation or relocation shall be paid for per linear meter measured as a straight line between the centers of consecutive coupling section. The distance between the two centers of the couplings on both sides of any fitting or valve shall be included as pipe length. No allowance will be made for cut ends and waste. No separate payment for any in-line fitting shall be made. The cost shall be included in the rate for pipelines.

For gravity networks, pipes installation or relocation shall be paid for per linear meter measured as straight line between inside edges of manholes plus 20 cm inside the manhole from each side. No allowance shall be made for cut ends and waste.

B.2 Rates for pipes installation shall include for the following:

1) Staking out, field surveying and preparation of shop Drawings.
2) Pipes, couplings and fittings.
3) Appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes.
4) Additional self-restrained coupling sections adjacent to bends.
5) Bolts, nuts, gaskets and others for flanged fittings.
6) Transportation and hauling about the Site, loading, unloading and lowering materials in the trench.
7) Lubricating agent used for assembling the pipe sections.
8) Cutting, machining, chamfering, etc. of standard length pipes.
9) Assembling the pipes and couplings and connecting to fittings and valves, or chambers, manholes and or structures as applicable.
10) Concrete thrust blocks including associated over excavation and anchors or additional self restrained coupling sections at bends. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
11) Testing as per specification.
12) Ancillary works and materials.
13) Flushing Cleaning painting, lining and coating.
14) Disinfections of water supply pipes.

B.3 Rates for pipes relocation shall include for the following:

1) Staking out, field surveying and preparation of shop Drawings.
2) Appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes.
3) Additional self-restrained coupling sections adjacent to bends.
4) Bolts, nuts, gaskets and others for flanged fittings.
5) Transportation and hauling about the Site, loading, unloading and lowering materials in the trench.
6) Lubricating agent used for assembling the pipe sections.
7) Cutting, machining, chamfering, etc. of standard length pipes.
8) Assembling the pipes and couplings and connecting to fittings and valves, or chambers, manholes and or structures as applicable.
9) Concrete thrust blocks including associated over excavation and anchors or additional self restrained coupling sections at bends. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
10) Testing as per specification.
11) Ancillary works and materials.
12) Flushing Cleaning painting, lining and coating.
13) Disinfections of water supply pipes.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Concrete Pipes (specify size)	Linear meter (m)
(2) Ductile Iron Pipes (specify size)	Linear meter (m)
(3) UPVC Pipes (specify size)	Linear meter (m)
(4) Polyethylene (PE) pipes (specify size)	Linear meter (m)
(5) Steel Pipes (specify size)	Linear meter (m)
(6) GRP Pipes (specify size)	Linear meter (m)

SECTION 10.02 VALVES AND ACCESSORIES

10.02.01 SCOPE

A. These works shall consist of furnishing all materials, constructing, installing and completing all works described in this Section of the Specification and as shown on the Drawings.

10.02.02 MATERIALS

10.02.02.1 Valves

A. Gate Valves Cast Iron

A.1 Type: Size 50 mm and smaller to BS 5154 inside screw, solid wedge, rising stem and screwed bonnet.

A.2 Type: Size 65mm and larger to BS 5163, inside screw, solid wedge, resilient seated, for valves 350 mm and smaller and metal seated for valves 400 mm and larger, bolted bonnet, non-rising stem type, suitable for NP 16 for water supply networks.

A.3 Material of component parts from basic or alternative materials listed in BS 5163 and BS 5164.

A.4 End connections: Size 50 mm and smaller screwed end to BS 21.

A.5 End connections: Size 65 mm and larger flanged end connection to BS 4504.

A.6 End connections: These shall be as shown on the Drawings and/or as described in the Bill of Quantities. Plain end connections shall be machined to suit joints specified for adjoining pipes.

A.7 Operation: Valves larger than 400 mm diameter shall have spur gear drive operated by removable key. Valves smaller than 400 mm shall be operated by handwheel.

A.8 Factory protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat shall be 250 microns.

B. Butterfly Valves: Cast Iron

B.1 Type shall be to BS EN 593, double flange with resilient seating, for horizontal use and suitable for NP 16.

B.2 Size: Shall be used for 350 mm and larger.

B.3 Material of component parts: Shall be made from basic materials listed in BS EN 593 Table 3.

B.4 End connections: Flanged to BS 4505: PT3.

B.5 Operation: Shall be by hand wheel. Maximum shut off pressure against which valve is operated shall be 15 kg/cm2.

B.6 Factory protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat shall be 250 microns.

C. Ball Valves

C.1 Ball Valves 50 mm and under shall be full port of 2-piece construction, lever operated with bronze body and stem, chrome-plated brass ball, replaceable PTFE seats and packing, plastic coated steel handle, threaded end connection for steel piping, and copper compression or solder end connections for copper piping.

D. Globe Valves

D.1 Type: Shall be to ASTM A48 grade 30B with valve disc to ASTM A276 type 430, valve seat to ASTM A276 type 420 and stem to ASTM A276 type 403. Valve shall be suitable for a working pressure of 16 bars.

D.2 Construction: Non-rising stem, straight pattern with flanged connections.

D.3 Material of component parts: Valves Class PN 10 and 16 shall be cast iron with stainless steel trim.

D.4 Operation: Manual operated valves shall have hammer type handwheel and electric operated valves shall have motor actuator.

E. Check Valves

E.1 Type: Shall be to BS 5153, swing, straight, for horizontal use and suitable for working pressure of 16 bars.

E.2 Material of component parts: Ductile iron from basic materials listed in BS 5153 Table 5, under “copper alloy faced” column.

E.3 Special Requirements: Seating or facing rings shall be renewable. An arrow showing direction of flow shall be visible from outside and cast integral with the valve housing.

E.4 End Connections: Either flanged to BS 4504 or screw ended to BS 21 to suit joints specified for adjoining pipes.

E.5 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Minimum thickness of coating to be 250 microns.

F. Float Valves

F.1 Type: Globe pattern, with two operating chambers, sealed through piston disc.

F.2 Operation: To operate with a mechanical compensating float valve controlling flow to tank by modulating in direct ratio to minimum fall in water level. Control of valve shall be through mechanically operated, three-position, four- way valve. Moving four-way valve control in one direction shall open valve and moving lever in other direction shall close-out valve. When lever is moved to center, valve will throttle in an intermediate position.

F.3 Valve positioning control consists of float operated linkage mechanism for remote mounting which feeds water level changes back to main valve through low friction, flexible push-pull cable supplied by same manufacturer.

F.4 Valve operating control consists of secondary linkage, mechanism functioning off common lever connected to both main valve position indicator rod and control valve position indicator rod and control valve operating lever. Minute changes in water level are transmitted through push-pull cable to three-position, four-way control valve.

F.5 Construction: Cast iron body to ASTM A 126, bronze valve trim and valve operating mechanism to ASTM B62 and all stainless steel valve float and pilots.

F.6 Factory Protection: Internal coating of epoxy to a thickness of 120 microns and external coating of epoxy and nickel plating to a thickness of 120 microns.

G. Air Valves for Water Mains

G.1 Generally: Valves shall have cast iron body and bolted cover to BS EN 1561 grade 14 minimum, rubber outlet seat, plastic or ebonite ball, forged bronze screws and guide for ball acting under pressure. Valves shall be dynamic type where there is no possibility of ball being drawn into orifice due to high air velocities. Valves shall be factory tested to 1.5 times working pressure and factory coated with coal tar or bituminous coating to BS 4164 or BS 3416 respectively. Thickness of coat to be 250 microns.

G.2 Double air valves (or combination air valves): These are required for relieving air under pressure and in bulk. Large orifice releases or admits air during charging or emptying of mains while small orifice releases air accumulated at summits of mains under pressure. Large orifice area shall be equal to or greater than inlet of valve. Valves shall be fitted with nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Valves shall be flanged to BS 4504 and suitable for working pressures up to NP16.

G.3 Single air valves: Type 1 (or air vacuum valve) for releasing or admitting air during filling or emptying of pipes. Type II (or air release valve) for automatically releasing, under pressure, accumulated air at summits of mains. Air valves larger than 50 mm shall be flanged to BS 4504 and shall have nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Air valves 50 mm and smaller shall have B.S.P. thread with brass or gun metal male screwed stop valves. Valves shall be suitable for working pressures up to NP16.

H. Air Valves for Pressurized Sewage Mains

H.1 Generally: Valves shall have cast iron body, cover and baffle to BS EN 1561, Grade 14, stainless steel float and float guide, Buna-N seat or needle and Dirlin internal linkages. Air valves shall have long float stem and body to keep valve operating

mechanism free from contact with sewage by maintaining an air gap between mechanism and waste media. Float shall hang freely in center of valve body with 12 mm clearance all around to prevent large solids getting above the float. Valves shall be fitted with blow off valves, quick disconnect couplings and minimum 2.0 m of hose to permit backflushing without dismantling valve. Valves shall be factory tested to 1.5 times working pressure and factory coated with bituminous coating to BS 4164 or BS 3416 respectively. Thickness of coat to be 250 microns.

H.2 Single air valves: Type I (or air vacuum valve) for releasing or admitting air during filling or emptying of pipes. Type II (or air release valve) for automatically releasing, under pressure, accumulated air at summits of mains. Air valves 50 mm and smaller shall have screwed inlet to B.S.P. thread with gunmetal male screwed stop valve. Air valves larger than 50 mm shall be flanged to BS 4504 and have nitrite rubber lined butterfly valve with nylon coated disc on stainless steel shaft operated by lever handle with indicator and locking thumb screw. Valves shall be suitable for working pressures up to NP10.

H.3 Double air valves (or combination air valves): These are required for relieving air under pressure and in bulk, shall be an assembly of an air vacuum and an air release valve. Valves shall be suitable for working pressures up to NP16.

I. Sluice Gates

I.1 Type: Shall be to AWWA C501, rising stem, having a flat back for bolting to wall, suitable for 6 meters seating pressure and 4 meters off-seating pressure, with standard conventional closure and rectangular or circular aperture.

I.2 Material of component parts: unless otherwise specified on the Drawings, any materials listed in Section 2 of the Standard may be used in manufacture except that materials identified as being subject to de-zincification or de-aluminumization shall not be used.

I.3 Operation shall be by floor pillar with gear box. The maximum operating head from surface of water to center line of gate shall be 6 meters.

I.4 Factory Testing: A leakage test to meet the requirements of Section 6.3 of the Standard shall be carried out on all sluice gates.

I.5 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat to be at least 250 microns.

J. Flap Valves

J.1 Type shall be flange mounted, designed for use on end closures to prevent entrance of backwater. Seating plane shall have 10 deg. inclination.

J.2 Materials: Cast iron body and cover, bronze seat faces, bronze hinge pins and spring pins, cast iron follow ring and plated steel ring draw bolts. Materials subject to de-zincification or de-aluminumization are not be used.

J.3 End Connections: If flange mounted, flanges shall be to BS 4504.

J.4 Factory Protection: Casting surfaces shall be given an initial coat of protective paint immediately after shot blasting and a second coat on assembly. Protective coating shall be hot applied coal tar or bitumen to BS 4164 or BS 3416 respectively. Thickness of coat to be at least 250 microns.

10.02.02.2 Irrigation Specialties

A.1 Type: Normally closed 24 VAC 50/60 cycle solenoid actuated globe pattern with a balanced pressure diaphragm design. The valve operating pressure range shall be between 1.5 and 14 bars.

A.2 Material: The valve body and bonnet shall be constructed of heavy-duty glass-filled UV-resistant nylon and have stainless steel studs and flange nuts; diaphragm shall be of nylon reinforced rubber.

A.3 Operation: The valve shall have manual open/close control (internal bleed) for manual opening and closing of valve without electrically energizing the solenoid.

A.4 Operation: The valve shall have a brass flow control stem for accurate manual regulation and/or shut off of outlet flow.

A.5 Construction: The valve construction shall be such as to provide for all internal parts to be removable from the top of the valve without disturbing the valve installation.

B. Electric Remote Control Valves with Pressure Regulation

B.1 Type: Electric remote control valve as specified above shall have a pressure regulating module capable of regulating outlet pressure between 1 and 7 bars (15 and 100 psi).

B.2 Operation: module shall have an adjusting screw for setting pressure and Schrader valve connection for monitoring pressure. The pressure shall be adjustable from the pressure regulating module when the valve is manually bled.

C. Pop-Up Spray Sprinkler

C.1 Type: Fixed, non-rotating spray or stream spray adaptable for full circle, part circle, or strip wetting pattern, suitable for installation on a pop-up mechanism. Spray head to have built in check valve and pressure regulated stem.

C.2 Material: The sprinkler body, stem, nozzle, and screen shall be constructed of heavy duty, ultra-violet resistant plastic, with a heavy-duty stainless steel retract spring.

C.3 Construction: Spray head to retract flush with the finished ground level when not in operation. When spraying, net pop-up height to be 150 mm from finished ground level.

C.4 Performance shall meet requirements of discharge and spray radius as specified on the Drawings for the given nozzle pressure. The sprinkler shall have a matched precipitation rate nozzle with an adjusting screw capable of regulating the radius of flow.

C.5 Tests: The Contractor shall provide test results carried out at factory substantiating required performance (discharge and radius of throw at prescribed operating pressure and height above ground) and giving actual precipitation rate and its uniformity as obtained for uniformity test carried out using catch cans.

D. Pop-Up Rotor Sprinkler

D.1 Type: Full or part circle pop-up rotor sprinkler, single nozzle. The part circle sprinkler shall have adjustable arc coverage from 25° to 360°. The sprinkler shall have a built in check valve and pressure regulated stem.

D.2 Material: The sprinkler body, stem, nozzle, and screen shall be constructed of heavy duty, ultra-violet resistant plastic, with a heavy duty stainless steel retract spring.

D.3 Construction: Sprinkler head shall retract flush with the finished ground level when not in operation. When operating, net pop-up height to be 100 mm from finished ground level.

D.4 Performance shall meet requirements of discharge, radius and rotation angle as specified on the Drawings for the given nozzle pressure. The sprinkler shall have a matched precipitation rate nozzle, with an adjusting screw; capable of regulating the radius and the flow.

D.5 Tests: The Contractor shall provide test results carried out at factory substantiating required performance (discharge and radius of throw at prescribed operating pressure and height above ground) and giving actual precipitation rate and its uniformity as obtained for uniformity test carried out using catch cans.

E. Bubblers

E.1 Type shall be pressure compensating, of the full circle umbrella or trickily discharge, with inlet screen.

E.2 Construction: Bubbler shall be of a permanently assembled design constructed of durable ultra-violet resistant plastic.

E.3 Performance: Bubbler shall operate at constant flow discharge over a pressure range specified on the Drawings.

F. Emitters

F.1 Type shall be pressure compensating, single outlet.

F.2 Construction: Emitter shall have self piercing inlet barb constructed of durable ultra-violet resistant plastic.

F.3 Performance: The emitter shall have a self flushing action to minimize clogging, and shall operate at a constant flow discharge over a pressure range specified on the Drawings.

G. Quick Couplings Valve

G.1 Type: The quick coupling valve shall be a two piece type.

G.2 Construction: The valve body shall be constructed of heavy cast brass.

G.3 Cover: The cover shall be a durable, protective self-closing, locking rubber cover.

G.4 Valve operating key: The valve shall be opened and closed by a brass key supplied by valve manufacturer having a 25 mm male top pipe threads and 19 mm female top pipe threads outlet. The valve throat shall have a keyway with detent positions for regulating water flow. Operating keys shall be supplied at the rate of 1 per five valves installed or fraction thereof.

H. Backflow Preventers

H.1 Backflow preventers shall be installed in the locations shown on the Drawings. Normally for each control head in the system a backflow preventer shall be installed upstream of all other components in the control head. Backflow preventers shall only be installed in locations where they are readily accessible for maintenance and testing and shall not be located where any part of the device can become submerged at any time.

H.2 Backflow preventers shall be of the reduced pressure type.

H.3 Backflow preventers shall be evaluated and tested by an approved authority and certified by the American Society of Sanitary Engineering Standards 1013 (latest edition) for reduced pressure principle backflow preventers. Such valves shall also meet the performance requirements of AWWA C 511 and the performance requirements of the University of Southern California Foundation for Cross Connection Control Research or approved equivalents.

H.4 Backflow preventers up to 75 mm in size shall be of machined cast bronze body construction and up to 150 mm in size shall be of cast iron body construction and 11 with internal waterways epoxy coated, stainless steel and/or brass internal parts and stainless steel flange bolts, durable, tight-seating rubber check valve assemblies.

H.5 Backflow preventers shall be suitable for supply pressure up to 1.2 MN/sq.m (12 kg/sq.cm) and for water temperature up to 44 degrees C. The operating range for flow and pressure loss shall be as shown on the Drawings.

H.6 The backflow preventer assembly shall consist of a pressure differential relief valve located in a zone between two positive seating check valves. The relief valve shall contain a separate means whereby free air will enter the zone, and contained water will be discharged to the atmosphere, when the valve is fully open.

H.7 The backflow assembly shall include 2 gate valves for isolating unit, and 3 test cocks for testing the device to ensure proper operation.

H.8 Backflow preventers shall be designed for inline servicing.

10.02.02.3 Fire Hydrants

A. Post Type

A.1 Type: To AWWA C502, dry barrel, post type suitable for maximum working pressure of 16 bars. Hydrant size shall be 100 mm for 2 outlets and 150 mm for 3 outlets. Stand post shall be supplied with 2 nozzle hoses 65 mm for 100 mm hydrants; and 2 nozzle hoses 65 mm, and 100 mm pumpers for 150 mm hydrants. Hydrant shall be complete with duckfoot and isolating gate valve. Hydrants shall be of the tilt off version, and shall be provided with intermediate seal bush to guarantee leak tightness in case of breakage due to traffic accidents.

A.2 Material: Any materials stipulated in the Standard except that materials identified as being subject to de-zincification or de-aluminumization shall not be used.

A.3 End Connection: To be as shown on the Drawings. Flanged connections, if used, shall be to BS 4504.

A.4 Special Requirements: Finishing color of hydrant and threads of screwed outlet nozzles shall suit local fire Authority requirements.

A.5 Operation: Direction of rotation of operating nut to open hydrant shall be counter-clockwise. Operating keys shall be provided at the rate of 1 per 5 hydrants installed or fraction thereof.

B. Underground Type

B.1 Type: To BS 750 screw down type.

B.2 Flanges: To BS 4504.

B.3 Special Requirements: Threads of screwed outlet or mouth piece shall suit local fire Authority requirements.

B.4 Covers and Frames: Cast iron to BS EN 124, medium type.

B.5 Operation by Keys: Direction of opening shall be counter-clockwise. Operating keys shall be provided at the rate of 1 per 5 hydrants installed or fraction thereof.

10.02.02.4 Service Connections

A. Water Service Connection

A.1 Ferrule Cocks and Stop Valves:

A.1.1 Type: Plug, quarter-turn closing type.

A.1.2 Material: Cast gunmetal to BS 1400 - LG2-C or cast iron body to BS EN 1561 and copper alloy plug.

A.1.3 End Connection: One end screwed male fitted directly to pipe saddle and the other end to fit push fit joints to polyethylene pipe as shown on the Drawings.

A.1.4 Pressure Class: Suitable for main network pressure.

A.1.5 Accessories: Surface boxes, valve caps, extension spindles and protection tube and protective cover shall be same material as specified for gate valves with dimensions and constructional details as shown on the Drawings and/or to manufacturer's standards.

A.2 Underground Stop Valves:

A.2.1 Type: To BS 5433 with crutch or square head.

A.2.2 Materials: Unless otherwise specified, body, lead, gland, spindle and washer plate square head shall be gunmetal to BS 1400-LG2, seating-washer shall be vulcanized synthetic rubber to BS 3457 Clause 6 and head sealing '0' ring shall be to BS 2494 Class D or E.

A.2.3 End Connections: Inlets and outlets of valves shall be internally threaded to BS 2779, Class B, Table 4M to fit threaded specials to polyethylene pipe.

B. Taps for Hose Connection

B.1 Type: Globe valve to BS 5154 suitable for NP16, comprising ductile iron or brass hose outlet to match hose connection tip, enclosed in block work box, for buried installation, with ductile iron hinged lockable cover.

B.2 Factory protection of external surface of box shall be hot applied coal tar or bitumen to BS 4164 or 3164 respectively. Thickness of coat to be 250 microns.

B.3 Box locking key: Ductile iron, supplied at the rate of 1 in every 3 boxes.

C. Water Meters

C.1 Water flow meters shall be installed in the locations shown on the Drawings.

C.2 Unless stated otherwise on the Drawings, the meter shall be of the helical rotary type and suitable for a normal flow stated on the Drawings. It shall be accurate to within 5% over the specified how range.

C.3 The meters shall measure the instantaneous rate of flow as well as total flow.

C.4 No negative reading shall be imposed by air passage or suction due to the emptying of the pipe system upstream from the meter.

C.5 The meter shall be made of corrosion and wear resistant materials. It shall have dial glass wipers. The meter shall be scalable against unauthorized tampering

D. Tapping Saddles: Cast Iron

D.1 Type: Suitable for tapping ductile iron pipe and for working pressure of 16kg/cm^2.

D.2 Material: Malleable cast iron, ductile cast iron or gunmetal to BS EN 1561, BS EN 1563 and BS EN 1564 respectively, with rubber '0' ring to BS 2494 suitable for water supplies and manganese bronze high tensile non- corrosive bolts, nuts and washers.

D.3 Dimensions: Width not less than 38 mm and diameter of disc not less than 75 mm.

D.4 Threads for tapping to BS 21.

D.5 Factory protection; Hot bitumen dipped to BS 4164 or cold bitumen coated to BS 3416.

10.02.02.5 Jointing Materials and Adaptors

A. Generally

A.1 Gaskets: Elastomeric full face 3 mm thick joint rings to BS 2494 with dimensions to BS 3063.

A.2 Rings: Elastomeric to BS 2494 with dimensions to manufacturer's recommendations to suit type of joint required.

A.3 Bolts and Nuts: ISO metric black hexagon to BS 4190, minimum tensile strength 433MN/m^2, maximum elongation 17%. After fixing, bolt projection shall be maximum 6 mm, minimum 3 mm.

A.4 Washers: Black steel to BS 4320.

A.5 Dielectric Joints shall have insulating gasket between flanges and teflon sleeves and washers between bolts and nuts and flanges. Joints shall be suitable for operating pressure of system.

B. Flexible Couplings

B.1 Type shall be gasketed sleeve type, to allow angular deflection and axial movement of two joined pipe ends and to maintain permanent, leak-tight joint.

B.2 Components comprise one center sleeve, two end followers or flanges, two rubber-compounded wedge-section gaskets and sufficient draw bolts and nuts to properly compress gaskets. Tightening of bolts to draw end followers together shall compress gaskets in recess between center sleeve and followers onto pipe ends to effect positive seal.

B.3 Size: Couplings shall have diameter specifically supplied for and to properly fit type of joined pipe ends. Center sleeve shall be of adequate thickness and whole coupling suitable for minimum working pressures shown on the Drawings.

B.4 Center sleeve and followers shall be true circular sections, free from irregularities, flat spots or surface defects and formed from steel mill sections with space between sleeve and follower designed to provide confinement of gasket.

B.5 Bolts shall be special steel having minimum yield strength of 2800 kg/cm2 (40,000 psi) and ultimate strength of 4200 kg/cm2 (60,000 psi). Bolts shall be track-head design to prevent turning when nut is drawn up and threads shall be rolled with a nominal diameter larger than diameter of shank. Manufacturer shall supply information regarding recommended torque to which bolts shall be tightened.

B.6 Gaskets shall be synthetic rubber-base compound with other products to produce material which will not deteriorate from age, heat or exposure to air and which is resilient and able to resist cold flow of material so that joint will remain sealed and tight indefinitely when subjected to shock, vibration, pulsation, temperature and adjustment of connected pipes.

B.7 Factory Protection: Coupling shall be factory painted internally with 250 microns coating of epoxy and externally with red primer to AWWA 203 Type B chlorinated rubber solution compatible with bitumen, coal tar and general paints.

B.8 Installation: Couplings shall be assembled on site in accordance with manufacturer's instructions to ensure permanently tight joints under all conditions of expansion, contraction, shifting and settlement.

C. Dismantling Couplings

C.1 Type shall ensure extensible connection between sections of pipework, to be mounted next to valves to enable easy dismantling from pipework or to permit joining pipework when butterfly valve is removed for maintenance.

C.2 Components: Dismantling piece shall be flanged type composed of two parts, one sliding into the other, and a free flange to compress a trapezoidal section seal to ensure water tightness. Coupling shall have locking devices to provide elements of complete rigidity.

C.3 Construction: All steel with flanges class PN 10, PN 16 or PN 25 depending upon coupling location on pipework.

C.4 Size: Couplings shall have diameter specifically supplied for and to properly fit type of joined ends of pipes and valves. Coupling shall permit tightening of end flanges without risk of misalignment. Seal shall be locked after end joints are tightened.

D. Flanged Adaptor: Ferrous

D.1 Material: Cast iron to BS EN 545.

D.2 Length of adaptor shall be 200mm for diameters up to 150mm, 250mm for diameters between 200 and 300 mm and as approved for diameters larger than 300 mm.

D.3 Factory protection: Coated with bitumen or coal tar to BS 3416 or 4164 respectively.

10.02.02.6 Valve Accessories

A. Accessories

A.1 Handwheels shall be BS 5163, of cast iron to BS EN 1561. Handwheels shall be marked “CLOSE” with an arrow to indicate clockwise direction of closure. Diameters and other constructional details shall be to manufacturer's standards. Handwheels shall be supplied at a rate of 1 in 5 valves.

A.2 Valve caps shall be to BS 5163, of cast iron or malleable iron to BS EN 1561 and BS EN 1562 respectively. Set screw of valve cap shall be mild steel Ml 2.

A.3 Operation Keys: Combination prizing bar and lifting key type, with 1.5 m vertical bar and 0.5 m horizontal bar. Keys shall be supplied at a rate of 1 in 5 valves.

A.4 Extension Spindles for Gate Valves: Steel to BS 2470 - Ml 2, hot dip galvanized to BS 1387, size 18x18 mm for valves up to 200 mm diameter and 24 x 24 mm for valves 250mm to 400 mm diameter. Length for each valve size shall suit excavation requirements. Spindles shall have cast iron or malleable iron cap and coupling, to BS EN 1561 and BS EN 1562 respectively, on both sides of extension spindle (cap for operating spindle and coupling for connecting to valve). Set screws of caps and couplings shall be mild steel Ml 2.

A.5 Protection Tubes: Either UPVC or cast iron. Shape, sizes and other constructional details shall be to manufacturer's standards and/or as shown on the Drawings. Tubes shall have caps circling extension spindles.

A.6 Surface boxes shall be to BS 5834: Part 2. Frames and lids shall be cast iron to BS EN 1561. Studs, bolts, nuts and hinge pins shall be mild steel Ml 2, chains shall be mild steel or wrought iron and lid shall have the letter 'W cast on. Boxes shall be of the following types:

- For carriageways (wheel loads up to 11.5 Tons)	Heavy grade type A
- For use where heavy commercial vehicles are exceptional	Medium grade type M
- For use in places inaccessible to wheeled vehicles	Light grade type L

A.7 Lifting Key Sets: Malleable iron, supplied at the rate of 1 per 5 covers installed or fraction thereof.

A.8 Guards for Underground Stop Valves: PVC, shape and size and other constructional details to manufacturer's standards and/or as shown on the Drawings.

B. Valve Chambers and Markers

B.1 Unless shown otherwise on the Drawings all backflow preventers, gate valves, pressure regulators, electric solenoid valves, manual control valves, pressure gauges and water meters shall be installed in precast concrete access boxes of proper size for easy access. Access boxes shall be complete with precast concrete cover.

B.2 Unless shown otherwise on the Drawings all access boxes shall be installed on a suitable base of gravel for proper foundation of box and easy leveling of box to proper grade and also to provide drainage of the access box.

B.3 Valve markers showing the reference numbers of the valves shall be of materials and to the dimensions, shapes and details as shown on the Drawings.

10.02.02.7 Valve Operators

A. General

A.1 Gate, butterfly and ball valves shall be manually or electrically operated depending upon size, torque applied on valve stem or as shown on the Drawings.

A.2 Valves 350 mm and smaller shall be operated manually with a maximum applied torque on hand wheel of 100 Nm.

A.3 Valves 400 - 500 mm shall be operated manually with a maximum applied torque of l50Nm.

A.4 Valves of higher torque shall have appropriate thrust bearings, slides and gearboxes to fulfill these requirements.

A.5 Gate valves 600 mm and larger and ball valves, are always electrically operated using thrust bearings, gearboxes and motor actuators.

A.6 Butterfly valves 600 mm and larger shall be either manually or electrically operated as shown on the Drawings.

B. Manual Gearboxes

B.1 Type: Totally enclosed, sealed construction to protect moving parts from damage and corrosion. Gearbox shall be either spur or level type depending upon mounting position of valve.

B.2 Components shall include corrosion resistant bearings, gear of rugged cast iron construction, cast housing cover complete with seals and gaskets and handwheel actuator. Housing cover shall have indicator window to show position of valve. Gearbox shall also have stainless steel bolts.

C. Electric Valve Operators

C.1 Type shall consist of motorized unit including gear train mounted in cast iron housing, flange mounted electric motor, control cabinet and handwheel for manual operation.

C.2 Installation shall be suitable for flange mounting directly on valve body, for gate valves with non-rising stem and for manual operation locally.

C.3 Rating shall be of adequate horsepower and thrust ratings to open and close operated valve smoothly at all conditions of load and pressure.

C.4 Components shall include adjustable mechanical stop- limiting devices to prevent over-travel of valve in either direction. Operator housings, supports and connections to valve shall have a minimum safety factor of 5 based on ultimate strength of materials used.

C.5 Construction shall be weatherproof, with rugged cast iron housing and with handwheel having appropriate gearing for emergency manual operation such that maximum applied torque is 150 Nm. Declutch lever shall disengage drive motor during handwheel operation and prevent handwheel rotating during power operation for safety of personnel. Handwheels shall close valve in clockwise direction and shall have arrows and the word “CLOSE” cast on.

C.6 Controls shall comprise integral electric controls enclosed within weatherproof compartment and including magnetic starter and reversing controller for motor, open-stop-close push-button for local operation, limit switches to give remote indications when valve is fully opened or closed, torque switch to shut down drive on excessive thrust loads, indicating lights, control voltage transformer etc.

C.7 Electric motor shall be totally enclosed, squirrel cage, induction type conforming to NEMA Publication No. MGI including characteristics, tests and ratings. Motor shall carry maximum possible load encountered in valve operation under all normal and abnormal operating conditions without exceeding nameplate rating and without benefit of service factor.

10.02.02.8 Irrigation Valve Accessories and Operators

A. Plastic Valve Boxes

A.1 Generally: Valve boxes may be glass reinforced plastic (GRP) or plastic conforming to the following specifications.

A.2 GRP valve boxes shall be designed to suit site conditions and loadings. GRP shall be manufactured from E-glass type fibers and thermosetting resin and shall incorporate a corrosion resistant liner. Glass fibers shall be compatible with the resins used. Liner shall comprise an inner face being a smooth hard suitably reinforced resin rich layer. Exterior surface of valve box shall be resin rich.

A.2.1 Inside surface of valve box shall be hard, durable, free of tackiness and free of bulges, dents, ridges or other defects that result in a variation of inside dimensions of more than 3 mm from that obtained in adjacent unaffected portions of the surface.

A.2.2 No glass fiber reinforcement shall penetrate interior surface of valve box wall, and any glass fiber reinforcement on exterior surface must be thoroughly impregnated with resin.

A.2.3 Glass content will be determined by ignition loss analysis in accordance with ASTMD2584orIS01172.

A.3 Plastic valve boxes shall be manufactured from high impact, acid and heat resistant, self-extinguishing, hard, durable, low coefficient of expansion PVC compound.

B. Program Controllers

B.1 Type: Solid state or hybrid (combining electro-mechanical and micro-electronic circuiting), capable of fully automatic or manual operation of the remote solenoid valves, with dual program, independent station timing, 14-day calendar dial for every day or every other day or any sequence starts, time-setting control up to 60 minutes per station in 2 minutes increments 23 starts per day. Number of stations shall be as indicated on the Drawings or in the Bill of Quantities. Maximum number of 24 VAC solenoid valves that can be controlled by a station is 4. Controller shall allow for valve power output to be interrupted without affecting the controller timers.

B.2 Operation: The controller shall have a remote pump start circuit to activate a remote pump start relay to run the pump during the irrigation cycle.

B.3 Operation: The controller shall allow for opening the first remote control valve before operating the pump and also for closing the last remote control valve within 15 seconds after stopping the pump.

B.4 Installation: The controller shall be installed in pedestal weatherproof, heavy-duty, locking, steel cabinet adequately protected. Pedestal mount shall include terminal strips for the quick connection of cables.

B.5 Electrical Features: To accept 220 V 50/60 cycle current; to command 24 VAC solenoid valves; to include output surge protection to protect controller from power surges; to include one arrester for each valve wire and one for the common or ground wire; to include a master on-off switch.

B.6 The Controller without exception shall be of the same manufacturer as the remote control valve.

C. Cabling for Irrigation Control

C.1 Low Voltage Wiring: From automatic controllers to remote control valves shall be direct burial type, 600 volt solid copper single conductor wire with heat resistant insulation minimum of 0.4 mm thickness. The Contractor shall submit proposed low voltage wire routing shop drawing for the Engineer's approval prior to installation. The low voltage wire shall be encased in 5 mm diameter conduit.

C.2 Medium Voltage Cables: Shall conform to the requirements of BS 5467, IEC 502, or other approved comparable international standards as applicable. Cables shall be 600/1000 volt grade, multicore, stranded copper conductor, cross-linked polyethylene (XLPE) insulated, UPVC over heather type. The service cable for irrigation controllers shall be 3 core 10 mm2 minimum.

C.3 Conductors: Shall be annealed stranded copper in accordance with BS 6360. Conductor insulation shall be moisture and heat resistant, 90 degrees C, grade conforming to BS 6899. The cable cores unless otherwise approved shall be colored as follows:

- Single phase system: Red (phase), black (neutral), green or green/ yellow (ground).

10.02.03 CONSTRUCTION AND INSTALLATION

10.02.03.1 Generally

A. Prior to installation, the Contractor shall inspect for cleanliness of bores, seating surfaces etc. and for handling damage, cracks, missing parts and tightness of pressure-containing bolting.

B. The Contractor shall ensure gates and hydrants are in closed position before installation.

C. The Contractor shall operate hydrants through one complete opening and closing cycle in the position in which they shall be installed to ensure proper functioning.

10.02.03.2 Installation

A. Valves

A.1 The Contractor shall set and joint valves to pipe in manner specified for laying and jointing pipe and/or to manufacturer's instructions.

A.2 Concrete Pads: The Contractor shall provide valves with Class B concrete pads as shown on the Drawings so that pipe does not support weight of valve.

A.3 Valves Without Concrete Pads: The Contractor 'shall place on firm footing to prevent settling and excessive strain on connection to pipe.

A.4 The Contractor shall not use valve to bring misaligned pipe into alignment during installation.

A.5 The Contractor shall inspect all pressure-containing bolting (bonnet, seal plate and end connections) for adequate tightness after installation but prior to field testing.

B. Hydrants

B.1 The Contractor shall join hydrants to pipe in manner specified for laying and jointing pipe and/or to manufacturer's instructions.

B.2 The Contractor shall set hydrants to established grades as directed by the Engineer.

B.3 The Contractor shall set hydrants plumb with nozzles parallel with or at right angles to the curb. Where hydrants have a pumper nozzle, the Contractor shall set the latter facing the curb. Where hydrants have two hose nozzles 90 deg. apart, the Contractor shall set with each nozzle facing the curb at 45 deg. angle.

C. Sluice Gates

C.1 The Contractor shall install gate, wall thimble, operating mechanism, stem and stem guides in accordance with manufacturer's drawings and recommendations, avoid warping the frame and maintain tolerance between seating faces.

C.2 The Contractor shall protect tapped holes in thimbles during concrete paving and setting.

C.3 The Contractor shall protect surface of thimble and gate from concrete spillage, paint, oil and debris.

C.4 The Contractor shall support thimbles to prevent shifting during pouring and brace horizontally and vertically to prevent distortion.

C.5 The Contractor shall tighten nuts in sequence after setting.

C.6 The Contractor shall adjust and lubricate entire assembly after installation.

C.7 The Contractor shall operate through one complete cycle to ensure proper functioning.

D. Field Protection

D.1 Valves: The Contractor shall protect valves against action of external agents by a coat of approved bituminous compound applied cold by brush after pressure tests on pipelines have been completed.

D.2 Hydrants: The Contractor shall apply one coat of paint, of color specified by the Engineer, after backfilling and surface restoration is completed.

D.3 Gates: The Contractor shall protect against action of external agents with one coat of approved bituminous compound applied cold by brush after installation.

D.4 Bolts: The Contractor shall protect buried bolts against corrosion with approved paint or by polyethylene wrapping.

E. Water Supply House Connections

E.1 Location: The Contractor shall agree location of tapping with the Engineer before starting construction.

E.2 The Contractor shall program connections to follow closely construction of main network.

E.3 Tapping: The Contractor shall drill, thread and tap ferrule cocks to manufacturer's instructions.

E.4 The Contractor shall excavate, install, bed and backfill in same manner as main network.

E.5 The Contractor shall test with main network but excluding water meter.

E.6 Records: The Contractor shall maintain accurate records of location of house connections to main network. Record details of the following:

- Diameter.
- Length.
- Location.
- Stop valves.

E.7 Survey Logbook: The Contractor shall keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. The Contractor shall transfer information to sketches and tables as agreed with the Engineer, provide three bound copies and hand to the Employer.

F. Sewer House Connections

F.1 Location: The Contractor shall agree location and invert level of connections with the Engineer before starting construction.

F.2 The Contractor shall program connections to follow closely construction of sewer.

F.3 Execution: Connection to sewer shall be at manhole, where possible, or by T or Y junction.

F.4 Minimum Grade: The Contractor shall lay connections at minimum grade of 20 per 1000 unless otherwise approved.

F.5 The Contractor shall install bed and test connections in same manner as main sewers.

F.6 Records: The Contractor shall maintain accurate records of location of connection to main sewer. Record details of the following:

- Connection number.
- Type of connection.
- Diameter.
- Downstream manhole number.
- Distance from manhole.
- Position (left or right) when facing upstream of street sewer.
- Distance from centerline of sewer to end lateral.
- Invert of street sewer.
- Lateral invert at end point.
- Number of inspection chambers.
- Cover type.
- Location, description and elevation of obstructions and method of protection.

F.7 Survey Logbook: The Contractor shall keep records in an approved survey logbook, made available for inspection and handed to the Employer on completion. The Contractor shall transfer information to sketches and tables as agreed with the Engineer provide three bound copies and hand to the Employer.

10.02.03.3 Installation of Irrigation System Components

A. Installation of Valves

A.1 Prior to installation, valves shall be inspected for cleanliness of bore, seating surfaces etc. and for handling damage, cracks, missing parts and tightness of bolting. Valves shall be in close position before installation.

A.2 Valves shall be operated through one complete opening and closing cycle in the position in which they shall be installed to ensure proper functioning.

A.3 Valves shall be set and jointed to the pipe in the manner specified for laying and jointing pipe and in accordance with the manufacturer's recommendations. Each valve shall be provided with a concrete pad as shown on the Drawings so that the pipe does not support the weight of the valve. Valves shall not be used to spring misaligned pipe into alignment during installation.

A.4 All stressed bolts (bonnet, seal plate and end connections) shall be inspected for adequate tightness after installation and prior to field-testing.

A.5 Valves shall be protected against action of external agents by a coat of approved bituminous compound, applied cold by hand brushing after pressure tests on pipelines have been completed. Buried bolts etc., shall be protected against corrosion, with approved paint or polyethylene wrapping.

B. Installation of Penstocks

General

All penstocks shall be designed and installed so that the maximum working pressure acts in a seating direction on the gate.

Both gate and frames shall be sufficiently rigid to withstand twice the maximum working pressure and any eccentric pressures created by the tightening of the anchor bolts during installation. All penstock frames shall have a spigot back.

The frame shall be designed to ensure that the gate is supported over not less than two thirds of its depth when the gate is fully raised.

Penstocks shall be of the rising spindle type unless otherwise specified, and the spindles shall be of adequate size to avoid buckling under load.

All spindle nuts shall be self aligning and their length shall be not less than twice the spindle diameter.

The top part of the penstock frames shall be sufficiently robust and substantial to prevent the frames bowing and if necessary, additional holding down bolts shall be fitted. The penstocks shall be fitted with matching wedges on doors and guides, the wedges shall be fitted with renewable seatings of zinc free bronze. Under no circumstances shall wedges be fitted to the bottom or lower sections of the penstock doors. The wedges shall be adjustable with stainless steel adjusting screws and shall be readily removable.

On rectangular penstocks the inverts shall be flush with renewable synthetic rubber seals on the bottom of the doors. The rubber shall be suitable for the application and of an approved type.

The doors shall have lifting eyes cast in, or eye bolts of sufficient size to permit the lifting of the door against seating pressure.

Where extended spindles installations require to be operated at elevated floor level, spindle guides or guide brackets shall be provided close to the floor level.

Where penstocks are required to be operated by the tee keys, spindles caps shall be fitted. The caps shall be drilled and each provided with nut and bolt for securing to the spindle which shall also be drilled. Where caps are fitted they shall each be supplied complete with operating tee key.

All penstock shall be provided with headstocks (except where the Handwheels can be mounted on the penstock frames). For penstocks of 300mm ND (square or circular) and above and for all motorized and actuator operated penstocks, unless otherwise stated, thrust tubes shall be provided between the penstocks frame and the headstock, in order to absorb the operating thrust in both directions. Thrust tubes shall incorporate all necessary fixing brackets and spindle quid plates.

Headstocks and foot brackets shall be provided for non-rising spindle penstocks where the latter are specifically called for. Guide brackets shall be provided where necessary. Non-rising spindles shall be fitted with thrust collars and arranged so as to transmit the thrust arising from operation of the penstock directly to the Penstocks frame. Where headstocks are required on non-rings spindles installations they shall incorporate a penstock position indicator.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specifications and/or the contract drawings.

Penstock shall be water-tight under the conditions of head and direction of flow as stated in the appropriate clause or schedule of the specification and/or the contract drawings.

All bolt holes shall be drilled and spot faced.

Simple templates shall be supplied as soon as possible after approval of drawings to enable the Civil contractor to position the holes for holding down bolts for all penstocks over 1.0 m square.

Penstock Materials

Penstock doors, wedge support beams, frames, guides, frame extensions, headstocks and bridge pieces shall be cast iron, of minimum grade 220 to BS 1452. Doors and frames shall be fitted with renewable seatings of zinc free bronze.
Spindles shall be manufactured from stainless steel 431S29 (EN 57) or similar approved material.

Extension Spindles

Extension spindles shall be adequately sized to prevent buckling and shall be attached to the valve/penstock stem by a suitable adaptor incorporating two muff couplings, scarf lap jointed and pinned with at least two coupling joints included. Universal joints and waterproof sleeves shall be provided where specified. Extension spindles shall be manufactured from 080M40 (EN 8) steel.

Intermediate bearing support or guide brackets of cast iron, with slotted holes for site adjustment, shall be fitted to long shafts where necessary. Bearings shall be of PTFE or similar approved type.

Pedestals and Spindle Covers

Penstock and valve pedestals shall be of cast iron or heavy duty, welded, mild steel construction with a substantial base and fixing provision. The base and top of the pedestals shall be machined normal to the axis of the drive shaft.

Where necessary, support guide bushes shall be fitted as the base of the pedestal.

The pedestal height shall be such that the handwheel is approximately 1 metre above the operator's floor level.

Clear polycarbonate covers of an approved type shall be provided for all rising spindles to totally enclose them when in the fully raised position.

Penstocks

Each tube shall be clearly and permanently engraved to indicate the position of the penstock.

B.1 For each penstock, the wall thimble, operating mechanism, stem and stem guides shall be installed in accordance with the manufacturer's recommendations. Tolerances between seating faces shall be maintained and any warping avoided.

B.2 Tapped holes in thimbles shall be protected during concreting and setting. Surfaces of thimbles and gates shall be protected from concrete spillage, paint, oil and debris. Thimbles shall be supported to prevent shifting during pouring and braced horizontally and vertically to prevent distortion.

B.3 Nuts shall be tightened in sequence after setting and the entire assembly shall be cleaned, adjusted and lubricated after installation.

B.4 Penstocks shall be operated through one complete cycle on installation to ensure proper functioning.

B.5 Penstocks shall be protected against action of external agents with one coat of approved bituminous compound applied cold by brush after installation. Buried bolts, etc. shall be protected against corrosion, with approved paint or polyethylene wrapping.

C. Installation of Other System Components

C.1 Irrigation components forming a control head shall be located in downstream order as follows: backflow preventer, control valve, fertilizer applicator and gate valve, pressure gauge, filter, pressure gauge, electric solenoid valve, water flow meter and pressure regulator.

C.2 Filter and fertilizer applicator equipment shall be mounted on a concrete pad forming an integral installation. The filter shall be located downstream of the fertilizer applicator to prevent contamination from the injection process. The concrete pad shall be Class 210/20 with dimensions as recommended by the equipment manufacturer.

C.3 Installation of miscellaneous components of the system shall be in accordance with the manufacturer's instructions.

10.02.04 MEASUREMENT

10.02.04.1 Valves and Accessories

A. Valves shall be paid for per unit installed according to size indicated in the Bill of Quantity.

B. Air valves shall be paid for per unit installed according to size indicated in the Bill of Quantity.

C. Drain or pipe flush valves shall be paid for per unit installed as per type and size indicated in the Bill of Quantity.

D. Rates for Gate valves shall include for:

- Supply of valves as specified.
- Lowering into the trench and installing.
- Over excavation for concrete supports and boxes.
- Concrete supports and thrust blocks. Concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES.
- Appropriate fittings and/or couplings and dismantling joint for connecting to adjacent pipe or fitting.
- Flanged and socket necessary adaptors for connecting to adjacent spigot ends.

- Valve chamber complete with cover lock, required couplings and rungs as shown on Drawings for valves placed in chambers.
- Valve surface box complete with cover, lock and key and concrete surround for directly buried valves.
- BOLTS, nuts, gaskets operating key, or hand wheel and others.
- Ancillary works and material required.
- Painting, lining and coating.
- Extension spindles plus square nuts to fit spindles.

E. Rates for air valves, shall include for:

- Supply of valve as specified.
- Items, tee and/or saddle for connecting to main line.
- Isolating gate valve.
- Drilling and fixing the flanged spool outlets for air valve connections. Ancillary works and material required.
- Installing, painting, coating and testing.
- Concrete valve chamber complete with cover and lock as shown on Drawings.

F. Rates for drain valves, end flush and low point flush shall include for:

- Supply of material, items forming the complete unit, as shown on the Drawings, pipes, flexible coupling, valve, flanged pipe, duckfoot elbow, housing, polyethylene pipe, etc...
- Bolts, nuts and gaskets.
- Thrust and support blocks.
- Valve chamber complete with cover, lock, surface box, rungs, etc..., all as shown on Drawings.
- Painting, lining and coating.
- Ancillary works and materials.
- Polyethylene pipe diameter 150 or 200 mm, 50 m long with protection and anchorage at outlet to allow free discharge into the wadi or drain.
- Ductile iron pipe and flexible couplings between invert level tee and valve chamber.
- Installing, painting, coating and testing.

10.02.04.2 Sluice Gates and Penstocks

A. Sluice gates and/or penstocks shall be measured and paid for per unit installed according to size and type indicated in the Bill of Quantity.

B. Rates for sluice gates and penstocks shall include for:

- Gate.
- Frame, rubber bottom seal, anchor bolts, stem and stem guide.
- Lift with wall brackets, anchor bolts and handwheel.
- Cleaning and painting.
- Assembly, installation, testing and adjustment.
- Stop planks.

10.02.04.3 Fire Hydrants

A. Rates for fire hydrants shall include for all the requirements in item (F) above (pipe drain or flush valves) with the exception of:

- Ductile iron pipe and flexible couplings between invert tee and valve chamber.

B. Fire hydrants are paid for per unit installed according to type indicated in the Bill of Quantity.

10.02.04.4 Service Connections

A. Potable water house connection shall be paid per connection installed.

B. Sewer connections are measured per connection installed.

C. Rates for taps for hose connections shall be paid per connection installed.

D. Rates for house connections for water supply shall include:

- Supply and installation of all materials including pipes, accessories and fitting specials,extension spindle, water service unit box and cover.
- Supply of stopcocks and saddles on mainline (tapping collar, elbows, tees, caps, valves).
- Excavation, bedding and backfilling, concrete works, thrust block, reistatement, and only if mentioned in the Bill of Quantities, “water meter installation and house chamber construction”.
- Installation and connection to new network and to the service box, or to the existing service connection, and testing.
- Coordination with the Enginner in collaboraion with water authority offices and bearing of all cost associated with their requirements and procedures for maintaining uninterrupted service.

E. Rates for sewer connections shall include:

- Supply and installation of all materials including pipes, fittings or specials.
- Excavation, bedding, backfilling concrete works and reinstatement, and only if mentioned in the Bill of Quantities, “new inspection chamber construction.”.
- Connection to adjacent inspection chamber or to existing building discharge line and to the collection network using all necessary fittings and machining required to facilitate connection.
- Installation, testing and commissioning.

F. Rates for taps for hose connections shall include:

- Supply of all materials including pipes, fitting specials, and service box and cover.
- Supply of stopcocks and saddles on mainline. Excavation bedding and backfilling, concrete works and reinstatement.
- Installation and connection to new network and to the service box, or to the existing service connection, and testing.

10.02.04.5 Irrigation Specials

A. Irrigators (excluding drip emitter distribution tubing) shall be measured by the number of each type and size installed, completed and accepted.

B. Drip emitter distribution tubing shall be measured by the lin.m of each size installed, completed and accepted.

C. Spares for the irrigation system shall be a Prime Cost Item and shall be measured by the numbers of each type and class of spare part authorized by the Engineer, purchased by the Contractor, handed over, and accepted.

PAY ITEMS		UNIT OF MEASUREMENT
(1)	Valves (Stating type and size)	Number (Nr)
(2)	Air valves (Stating type and size)	Number (Nr)
(3)	Drain valves or pipe flush valves (Stating type and size)	Number (Nr)
(4)	Sluice gates and/or Penstocks (Stating size and type)	Number (Nr)
(5)	Fire hydrants (Stating size and type)	Number (Nr)
(6)	Water service connection per connection installed	Number (Nr)
(7)	Sewer service connection per connection installed	Number (Nr)
(8)	Taps for Hose Connection (Stating type and size)	Number (Nr)
(9)	Irrigation Program Controller	Item
(10)	Irrigators (Each type and size)	Number (Nr)
(11)	Drip Emitter Distribution Tubing (each size)	Linear meter
(12)	Spares for Irrigation System	Prime Cost (P.C.)

SECTION 10.03 NOT APPLICABLE

SECTION 10.04 MANHOLES, CHAMBERS AND GULLIES

10.04.01 GENERALLY

A. Excavation and Backfilling generally are to comply with the appropriate requirements of Division 2 of the Specification.

B. Concrete Work generally is to comply with the appropriate requirements of Division 5 of the Specification.

10.04.02 PRODUCTS

A. Coatings

A.1 Coal tar epoxy coating for internal surfaces of precast concrete manholes and chambers.

A.2 Asphaltic Composition Coating for external surfaces of precast concrete manholes and chambers.

B. Components

B.1 Precast Units: to BS 5911, Section C & D, reinforced concrete Class 250/20 respectively. Cement is to be ordinary Portland cement.

B.2 Cast In Situ Units: plain and reinforced concrete 210/25 and 250/20 respectively. Cement is to be ordinary Portland cement to BS 12.

B.3 Bricks: to BS 3921.

B.4 Covers and Frames: Ductile iron to BS EN 124, or equivalent coated, non-rock, locking, solid top. Frame to be bolted to manhole / gully bricks to ensure proper fixity. Wording on cover to be related to service. Grades to be as follows:

- For roadways: Grade A.. Heavy duty test load 40 tons.
- For sidewalks, carriage drive and cycle tracks: Grade B medium duty test load 25 tons.
- For footpaths and fields: Grade C light duty, test load 7 tons.

B.5 Manhole covers are of circular pattern unless otherwise indicated on Drawings.

Covers and frames shall be coated to BS 3416. Minimum thickness 200 microns.

B.6 Road Gully Gratings: Ductile iron to BS EN 124, non-rock; coated to BS 3416. Minimum thickness 200 microns; Types to be as follows:

- For carriageways: Grade A, minimum test load 40 tons.
- For footpath cycle tracks and fields, tight duty, test load 7 tons.

B.7 Step Irons: to BS 1247.

B.8 Steel Ladders: to BS 4211, mild steel, galvanized to BS 729 with 240 grams of zinc per square meter.

B.9 Safety Chains: 12mm diameter wrought iron short link chain, galvanized to BS 729 with 200 grams of zinc per square meter.

B.10 Guardrailing: to be: one of the following as shown on the Drawings:

a) Tubular steel: mild steel, medium grade to BS 1387 with screwed joints, galvanized to BS 729.

b) Solid steel: round bars to BS 4229, Part 2 with welded joints, galvanized to BS 729.

c) Aluminum: tubular rails fixed to double ball pattern solid forged standards. Rails of alloy to BS 1471, type HT 30 WP or to BS 1474, type HV 30 WP. Standards of alloy to BS 1472, type HF 30 WP.

B.11 Fixing Bolts: to BS 1494, Part 2. When used to fix galvanized material, washers are to be galvanized and fixing bolts and nuts cut to pre-plating limits and electroplated with zinc to BS 1706.

10.04.03 WORKMANSHIP

A. Manholes and Inspection Chambers

A.1 Construction: In situ concrete or precast concrete as shown on Drawings or as proposed by Contractor. In-situ units shall be to Division 5 concrete works.

A.2 Precast Units: cast in steel watertight forms at least 3 weeks before sections are used. Bed lowest unit on in situ concrete base and bed and haunch in cement mortar. Liberally coat joints of units with approved bituminous material of trowelling grade prior to fixing. Ensure joints are filled solid and neatly strike off surplus compound. Do not disturb work for 7 days thereafter. Alternatively seal joints with approved preformed jointing strip in accordance with manufacturer's instructions. Bed precast concrete cover slab on top unit in cement mortar.

A.3 Manholes are to be precast or cast in situ as shown on the Drawings. Channels in bottom of manhole are to be smooth, semi-circular and size equal to diameter of adjacent sewers. For straight through manholes, construct channels of half pipe sections. Make changes in direction of flow with smooth curves as large as manholes permit. Changes in size and grade of channels are to be gradual and even.

A.4 Benching: form in sulphate resisting concrete Class 110/25 to rise vertically from top of channels to a height not less than soffit of outlet pipe, then slope upwards 1 in 10 to walls. Within 3 hours, float with coat of sulphate resisting cement-sand mortar 1:2 and finish smooth with steel trowel.

A.5 External Coating: cover faces of manholes and chambers with three coats asphaltic composition applied by brush in accordance with manufacturer's instructions. Minimum thickness 600 microns.

A.6 Internal Coating: cover faces of manholes and chambers with four coats of coal tar epoxy paint, 70% epoxy and 30% coal tar. Applied by brush in accordance with manufacturer's instructions. Minimum thickness 1000 microns.

A.7 Step Irons: cast into precast units or grout into preformed mortises. Do not use step irons as lifting eyes. Devices for lifting and handling are to be provided on exterior faces.

A.8 Adjustment for Level: build top courses of brickwork or concrete rings after completion of surrounding levels. Adjust as necessary to give accurate and even final levels.

A.9 Covers and Gratings: bed frame solidly in mortar and fix firmly using fixing bolts. Set cover in position to prevent twisting. Position centrally over opening and level and square with surrounding finishes.

A.10 Testing of Manholes: plug manhole inlets and outlets, fill manhole with water and allow to stand for at least 24 hours or such longer period to allow for complete absorption. Re-top with water. Allowable leakage over 24 hours is not to exceed 1 % of total volume of manhole, otherwise make good and retest.

B. Valve Chambers

B.1 Construction: to be in situ concrete, precast concrete or blockwork as shown on the Drawings.

B.2 External Coating: cover faces of chambers with two coats asphaltic composition applied by brush in accordance with manufacturer's instructions. Minimum thickness 400 microns.

B.3 Covers: bed frame solidly in mortar and fix firmly using fixing bolts. Set cover in position to prevent twisting. Position centrally over opening and level and square with surrounding finishes.

C. Road Gullies / Curb Inlets

C.1 Construction: to be in situ concrete or precast to size and shapes indicated on the drawings and conforming to the construction requirements of manholes.

10.04.04 MEASUREMENT

A. Manholes, Gullies, Inlets and Chambers

A.1 Manholes shall be paid for per unit and according to the depth categories shown in the Bill of Quantities.

A.2 Gullies and catch basins/curb inlets shall be paid for per unit including the outlet pipe and the connection to the main network. An average length of 10 meters shall be included with the rate for every gully. Additional length required will be paid for separately.

A.3 Interceptors shall be paid for per linear meter. Payment includes excavation, backfilling, concrete works, grates, frames, connection to the main network and all other ancillary works to make a complete unit.

A.4 Drop inlet shall be paid per unit complete, including all necessary material and ancillary works to make a complete unit.

A.5 Valve chambers, if priced separately, should be paid per unit complete including all necessary connections to the adjacent pipes.

A.6 Access shafts shall be paid per unit complete including all materials and necessary connections to existing culverts.

A.7 Inspection chambers shall be paid per unit complete, including all necessary connections to adjacent networks or houses. An average length of 10 meters shall be included with the rate for every chamber. Additional length required will be paid for separately.

A.8 Rates for manholes, drop inlet, gullies, curb inlets, inspection chambers, interceptors, access shafts and valve chambers shall include for as applicable:

1) Excavating in any natural material including rock in accordance with the preambles for "Excavation and Earthwork", including soil support, as required dewatering, if any, backfilling and carting away.

2) Concrete, reinforcing steel, blinding, beds, surrounds, benching and suspended slab in accordance with the preambles for "Concrete Work".

3) Supplying and application of protective and epoxy coatings to internal surface of concrete.

4) Two flexible couplings from each side as given in the specification.

5) Granolithic rendering to benching.

6) Protective coating to exposed faces of concrete.

7) Concrete rings or brick "blockwork" corbelling as required to make up levels.

8) Supply and fixing of labeled covers as specified, grates and frames with all ancillary works and protective coating.

9) Testing structures for water tightness and any subsequent re-testing.

10) Ladders, rungs and puddle flanges built properly into walls.

11) All other ancillary items necessary for the proper completion of works.

B. Protective Coatings

B.1 No separate payment will be made for protective coating. The cost shall be included with the rate of the respective item requiring such work.

B.2 The item for protective coatings shall include for applying the necessary coatings to surfaces of metalwork as detailed in the Specification and shall include for:

1) Preparation of surface.

2) Supplying all necessary tools and equipment, adhesives, bonding agents, etc.

3) Work in any location.

4) Any area or width.

5) Rubbing down between coats.

6) Cutting in edges.

7) Making good to damaged areas.

8) Protection.

9) Testing when required by the engineer.

PAY ITEMS	UNIT OF MEASUREMENT
(1) Storm water or Sewer Manholes (Specify size and depth)	Number (Nr)
(2) Road Gully (Specify size and depth)	Number (Nr)
(3) Interceptors (Specify size and depth)	Linear meter (m)
(4) Access Shaft (Specify size and depth)	Number (Nr)

SECTION 10.05 MEASUREMENT

10.05.01 EARTHWORK

A. Rates for excavation for pipe trenches manholes, chambers and inlets shall include for:

i Excavating in any material encountered,

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

iii Excavation at any level and to any depth,

iv Excavating curved on plan,

v Allowance for working space,

vi Increase in bulk for excavating,

vii Excavating below water table and dewatering as necessary,

viii Keeping excavations free from water,

ix Levelling, ramming, trimming and grading bottoms and trimming sides and bottoms of excavation,

x Planking and strutting,

xi returning, filling and ramming selected excavated material around foundations, multiple handling of excavated material and excavation from borrows and transporting about the Site,

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

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

B. Rates for trench excavation for pipelines and associated structure shall include for:

i requirements (i) to (xiii) of item A, hereof, where applicable,

ii pipe bedding and initial backfilling,

iii Filling over-excavation,

iv consolidation of primary backfill (initial backfill) material using water or hand tamping,

v compaction of secondary backfill (main backfill) material,

vi Reinstatement of surfaces at wherever applicable.

C. Trench excavation for pressure pipes shall be paid for per meter cube. Trench width and depth as shown on Drawings.

D. Trench excavation for gravity networks shall be paid for per meter cube. Trench length shall be measured between outer surfaces of manholes. Trench width and depth shall be as shown on Drawings.

10.05.02 PIPELINES

A. Rates for pipes shall include for the following as applicable for pressure and/or gravity pipes.

i supply of pipes and couplings,

ii transportation and hauling about the Site, loading, unloading and lowering materials in the trench,

iii lubricating agent used for assembling the pipe sections,

iv cutting, machining, chamfering, etc. of standard depth pipes,

v assembling the pipes and couplings and connecting to fittings and valves, or manholes and culverts,

vi supply of fittings as specified,

vii appropriate fittings and/or couplings for connecting to adjacent pipe or fitting like flanged fittings connecting to socket ended pipes,

viii bolts, nuts, gaskets and others for flanged fittings,

ix concrete thrust blocks,concrete supports, including associated over excavation and anchors. The concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES,

x testing as per specification,

xi ancillary works and materials,

xii Flushing, cleaning, painting, lining and coating for gravity pipes,

xiii Flushing and disinfection as specified of water supply pipes.

B. Pipes shall be paid for per linear meter measured as a straight line between the centers of consecutive coupling section. The distance between the two centers of the couplings on both sides of any fitting or valve shall be included as pipe length. Pipes within manholes shall be included as pipe length. No allowances will be made for cut ends and waste.

10.05.03 VALVES AND ACCESSORIES

A. Rates for valves shall include for:

i supply of valves as specified,

ii lowering into the trench and installing,

iii over excavation for concrete supports and boxes,

iv concrete supports and thrust blocks. Concrete work shall include all items required for CONCRETE WORK and CONCRETE STRUCTURES,

v appropriate fittings and/or couplings dismantling joint for connecting to adjacent pipe or fitting,

vi flanged and socket adaptors (2 Nr) for connecting to adjacent spigot ends,

vii valve box complete with cover, lock and key, and concrete surround, for directly burried valve.

viii valve chamber complete with cover lock and rungs as showm on Drawings for valves placed in chambers.

ix Bolts, nuts, gaskets operating key, or hand wheel and others.

x ancillary works and material required,

xi painting, lining and coating,

xii extension spindles plus square nuts to fit spindles.

B. Valves shall be paid for per unit installed.

10.05.04 CONNECTION OF PRESSURE PIPES TO EXISTING PIPELINE

A. Rates for connecting to the existing pipelines shall include but not limited to:

i Hand excavation to expose and locate existing pipe and diposal of unsuitable backfill material.

ii Shutdown and drainage of the existing pipeline.

iii All cutting, machining, equipement and tools, required to facilitate connection,

iv Pumping out the water from the excavation.

v All co-ordination required with utility owners and all cost associated with their requirements and procedures for maintaining uninterrupted service,

vi Supply and installation of tee sections, valves, bends, all adaptors, accessories fittings, and connecting pieces on the main line,

vii Field testing,

viii Pipe protection and supports, including concrete thrust block if required,

ix Construction of reinforced concrete service chamber including frame, cover, steps, bituminous coating.

x Backfilling and reinstatement of surface wherever required.

xi Any other required necessary items for the proper completion of works.

B. The rate shall be a lump sum value based on the number of all required connections, completed and accepted.

10.05.05 CONNECTION OF GRAVITY PIPE OR CULVERT TO EXISTING CONCRETE WALL OF MANHOLE OR CULVERT

This item shall consist of supplying, transporting, storing & installing all materials and equipment necessary for a waterproof connection between a pipe or culvert (whatever its diameter is) and an existing or proposed reinforced manhole or culvert (or other structures) concrete walls.

A. Rate for such connection shall include for :

a- Submission of materials & acessories original thecnical data sheets.
b- Compliance with tender drawings.
c- Application of relevant specification division & standards.
d- Compliance with the method of measurement indicated here below.
e- Submission of application details & revision thereto if any subject to Engineer's consent.
f- Preparation of all submittals, design details, execution drawings subject to Engineer's consent.
g- Resources (Equipement, Materials, tools, Manpower,etc…)
h- Reinforced concrete demolition.
i- Supply, transportation, storing, pouring of a non shrink expanding mortar with all necessary admixtures and its application around the pipe.
j- Supply, transportation storing and installing of sealing ring around the pipe.
k- Supply, transportation, storing and installing of a sealing mastic around the pipe.
l- Supply, transportation storing and installing a short piece of pipe or a coupling inside the concrete wall.
m- Supply, transportation storing and installing of a waterproof membrane when requested by the Engineer around the external side of the short piece of the pipe.
n- Sampling & testing of materials as required in specification or requested by Engineer.

B. The rate shall be a lump sum value based on the number of all required connections, completed and accepted.