REPUBLIC OF GHANA

Ministry of Transportation

STANDARD SPECIFICATION

FOR

ROAD AND BRIDGE WORKS

JULY 2007

FOREWORD

The main purpose of this review was to take into account various comments made by users of the 1991 Standard Specification for Road and Bridge Works of the Ministry.

Comments were made by Agencies of the Ministry, Consultants, Contractors and the Ghana Institution of Engineers who are the primary users of the document. In this revised version, all the ambiguities and conflicting clauses have been streamlined.

Major inclusions worthy of note are the specifications on safety and Environment, Streetlighting and Traffic Lights. Furthermore, specification on the use of modern technologies viz Superpave Asphalt Mix design criteria and stabilization of cement, lime and bitumen have been included.

It should be noted that this document is not meant to be used as a design manual but as a specification to be complied with.

I certify that this Standard Specifications for Road and Bridge Works 2006 for the Ministry of Transportation are prepared under my direct supervision and is approved for application on highway and related construction contracts as referenced in the Contract Documents or specification and shall apply as noted and amended by those documents.

J. OSEI-ASAMOAH
CHIEF DIRECTOR

ACKNOWLEDGEMENTS

This Specification has been prepared at the request of the Ghana MRT (now MOT) under the World Bank component of the Road Sector Development Programme (RSDP).

The production has been a joint effort between a Steering Committee composed of officials from the Ministry of Transportation, Ghana and a joint venture of CSIR Transportek and Stewart Scott International, who acted as the Consultant. The CSIR/SSI team were:

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1. SYMBOLS

Symbols for units of measurement conform to the SI system as set out in BS ISO 31.). Examples are given below:

cP	centipoise
cSt	centistoke
g	gram = kg x 10^{-3}
g/m^2	grams per square metre
g/mℓ	grams per millilitre
GPa	giga-pascal
h	hour
ha	hectare
Hz	Hertz
kA	kilo amp
kg	kilogram
kg/m^2	kilogram per square metre
kg/m^3	kilogram per cubic metre
km	kilometre
km^2	square kilometre
km/h	kilometres per hour
kN	kilo-Newton (N x 10^3)
kV	kilo volts
kW	kilowatt
m	metre
m^2	square metre
m^3	cubic metre
min	minute
mg	milligram = kg x 10^{-6}
mg/ℓ	milligrams per litre
mℓ	millilitre
mm	millimetre = m x 10^{-3}
mm^2	square millimetre
MPa	mega-pascal (equivalent to N/mm^2)
MΩ	mega Ohm
N	newton
N/m^2	newton per square metre
N/mm^2	newton per square millimetre
rad	radian
s	second
t	tonne = kg x 10^3
V	volts
VAC	volts (alternating current)
W	watt
°C	degrees Celsius
ℓ	litre
$ℓ/m^2$	litres per square metre
$ℓ/m^3$	litres per cubic metre
Ω	Ohm

μm	micron = m x 10^{-6}
μs	microsecond

2. ABBREVIATIONS

The following abbreviations are used:

AASHTO	American Association of State Highway and Transportation Officials
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ALD	Average Least Dimension
ASTM	ASTM International (formerly American Society for Testing and Materials)
BA	Bitumen Affinity
BS	British Standard
CAA	Coarse aggregate angularity
CBR	California Bearing Ratio
CDROM	Compact disc read only memory
dia	diameter
D_{90}	90 th percentile layer thickness construction tolerance (See 2.21.4(b))
D_{max}	Maximum layer thickness construction tolerance (See 2.21.4(b))
$D_{average}$	Mean layer thickness construction tolerance (See 2.21.4(b))
DVDROM	Digital video disc read only memory
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EN	European Standard
EPA	Environmental Protection Agency
FAA	Fine aggregate angularity
FI	Flakiness Index
FIDIC	Fédération Internationale des Ingénieurs-Conseils
FM	Fineness modulus
GGBS	Ground granulated blastfurnace slag
GHA	Ghana Highway Authority
GS	Ghana Standard
H_{90}	90 th percentile surface level construction tolerance (See 2.21.4(a))
H_{max}	Maximum surface level construction tolerance (See 2.21.4(a))
HIV/AIDS	Hunan immunodeficiency virus/ acquired immune deficiency syndrome
ICL	Initial Consumption of Lime
ISO	International Standards Organization
LAA	Los Angeles Abrasion Value
LL	Liquid Limit
LS	Linear Shrinkage
MC	Moisture Content
MDD	Maximum Dry Density
n	number
OMC	Optimum Moisture Content
PFA	Pulverised fuel ash
PI	Plasticity Index
PL	Plastic Limit
PM	Plasticity Modulus (PI x % passing 0.425 mm sieve)

PTFE	Polytetraflouroethelene
SE	Sand Equivalent
SG	Specific Gravity
SI	International Standard Units of Measurements
SSS	Sodium Sulfate Soundness Test, (loss on 5 cycles)
STD	Sexually Transmitted Disease
STV	Standard Tar Viscosity
TS	Tensile Strength
UC	Uniformity Coefficient
UCS	Unconfined Compressive Strength
VIM	Voids in Mix
VFB	Voids Filled with Binder
VMA	Voids in Mineral Aggregates
w/c	Water cement (ratio)

SECTION 1

GENERAL

CONTENTS

1. GENERAL

1.1. Scope

This Specification defines the standard and quality of materials and workmanship to be used in the construction of roads and bridges in the Republic of Ghana. It is applicable for trunk, urban and feeder roads administered by the Ministry of Transportation and its Agencies, namely:

Ghana Highway Authority
Department of Urban Roads, and
Department of Feeder Roads.

It should be read in conjunction with the Special Specification, which may amplify or modify this Standard Specification, as well as the Conditions of Contract, the Drawings and any other documents forming the Contract.

1.2. National Specifications

All standards, codes of practice and specifications referred to in the Specification or in the Special Specification or in any Drawings or Instructions forming part of the Contract or issued under the provision of the Contract shall refer to the current editions including all amendments published 30 days prior to the bid opening date.

The Contractor may propose that the materials and workmanship be defined in accordance with the requirements of other equivalent National Specifications and the Contractor may execute the Works in accordance with such other National Specifications as may be approved by the Engineer. A copy of the National Specification, together with its translation into the English language, if the National Specification is in another language, shall be submitted to the Engineer with a request that it is to be adopted.

In referring to National Specifications, the following abbreviations are used:-

GS	Ghana Standard
GHA	Ghana Highway Authority (Test methods)
BS	British Standard
EN	European Committee for Standardization
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Materials
ISO	International Organisation for Standardisation
SABS	South African Bureau of Standards
SIS	Swedish Standard
NCHRP	National Cooperative Highway Research Program (USA)
	US Federal Specification
IEC	International Electrotechnical Commission

The Contractor shall supply and maintain one complete set of all National Specifications referred to in this Specification and all other approved Specifications for use by the Engineer.

Where alternative specifications are provided in this document and conflicts arise, the Ghana Standard (GS) shall take precedence, followed by the BS (and/or EN when the BS has been replaced) and then ASTM and AASHTO. Soil and aggregate test methods shall conform to the Ghana Highways Authority (GHA) methods where such methods are defined or to the above precedence where no applicable GHA method exists.

1.3. Definition of Terms

Principal terms relating to the cross-section, pavement and bridge designs are shown in Figures 1-1 to 1-3 and defined below. Terms not included below shall have the meanings assigned to them as defined in the Glossary of Highway Engineering Terms, BS 6100, Part 2: 1990 or the FIDIC General Conditions of Contract.

Abutment
The end support of a bridge or an arch

Approach Road
The road leading up to the bridge

Approach Slab
A slab constructed on the approach road embankment, below road level, with one end on a bridge abutment, designed to eliminate a localised settlement in the roadway at the abutment.

Apron
A hard surface to the bed or banks of a stream or canal to prevent scour.

Asphalt concrete
A mixture to predetermined proportions of aggregate, filler and bituminous binder material prepared off the road and usually placed by means of a paving machine.

Asphalt surfacing
The layer or layers of asphalt constructed on top of the base course, and, in some cases, the shoulders.

Ballast Wall
The part of the abutment, which holds back the approach embankment above the bearing shelf

Base
A layer of material constructed on top of the subbase, or in the absence thereof, the selected layer. A base may extend to outside the travelled way.

Beam (girder)
A structural member designed to resist loads by bending

Bearings
The supports of bridge superstrucures, which rest on the abutments and piers

Bearing Shelf
A ledge formed in the abutment, on which the bearings supporting the deck are accommodated

Borrow area
An area within designated boundaries, approved for the purpose of obtaining borrow material. A borrow pit is the excavated pit in a borrow area.

Borrow material
Any gravel, sand, soil, rock or ash obtained from borrow areas, dumps or sources other than cut within the road prism and which is used in the construction of the Works. It shall not include crushed stone or sand obtained from commercial sources.

Caisson
A foundation built partly or wholly above the ground and sunk below ground, usually by digging out the soil inside it

Carriageway
The surface normally traversed by vehicles and which consists of one or a number of contiguous traffic lanes, including auxiliary lanes and shoulders.

Catchwater drain or bank
A longitudinal drain or bank outside the road prism for diverting water that would otherwise flow into the road prism.

Conditions of Contract
The appropriate edition of the Conditions of Contract issued by the Authority for which the Contract is being executed, together with any Special Conditions of Contract forming part of the Contract.

Cut
Cut shall mean all excavations from the road prism, including side drains, excavations for cross-roads, interchanges, and, where classified as cut, excavations for open drains.

Deck
That part of the bridge superstructure, which carries the road. The slab carrying the road on a beam and slab deck is commonly referred to as a Deck slab

Drainage system
The method by which excess rain or other water will be removed from the roadway or bridge deck.

Embankment
A ridge of earth constructed to carry a road, railway or canal at a higher level than the surrounding ground

Employer
The person named as Employer in the Contract and the legal successors in title to this person

Environment
The environment includes all natural and social systems and their constituent parts, including people, communities and atmospheric, physical, ecological, aesthetic, cultural, economic, historic, institutional and social factors

Environment Impact Assessment (EIA)
A process for orderly and systematic evaluation of a proposal, its alternatives and objectives and its effects on the environment, including the mitigation and management of those effects. The process extends from the initial concept of the proposal through implementation to completion and, where appropriate, decommissioning.

Environmental Management Plan (EMP)
An action plan or system which addresses the how, when, who, where and what of integrating environmental mitigation and monitoring measures throughout an existing or proposed operation or activity. It encompasses all the elements that are sometimes addressed separately in mitigation, monitoring and action plans.

Excess overburden
Overburden within a borrow area which is not required or is unsuitable for use in construction.

Expansion Joint
A joint formed between the abutment ballast wall and the end of a bridge deck, or between successive lengths of bridge deck, to allow both expansion and contraction. Expansion joints are usually sealed to prevent the passage of water through the joint. Assembled elements designed to bridge and/or seal wide gaps in large movement joints, are also often referred to as Expansion Joints

Fill
That portion of the road prism consisting of approved imported material that lies above the roadbed and is bounded by the side slopes, shown on the typical cross-sections on the Drawings running downwards and outwards from the outer shoulder breakpoint and on which the selected layer, subbase, base, shoulders and, in the case of dual carriageways, the median, are to be constructed. Material imported to replace unsuitable material in the roadbed shall also be classified as fill.

Formation level
The formation level is the top of the subgrade.

Foundation
That part of the substructure, which is in direct contact with, and transmits load to the ground

Grade line
The grade line is a reference line in the Drawings of the longitudinal sections of the road indicating at regular intervals the elevations according to which the road is to be constructed. The grade line may refer to the level of the completed road, base or any other layer and may indicate the elevations either along the carriageway centre line or along any designated position on the road cross-section.

Influenced Area
Geographical area within which the project will cause impacts. This may extend beyond the planning area.

Inlet and outlet drains
Channels leading into or discharging from culverts, stormwater conduits and bridges.

Invert
The lowest visible surface, the floor, of a culvert, drain, sewer, channel or tunnel.

Lane
Part of a travelled way intended for a single stream of traffic in one direction, which has normally been demarcated as such by road markings.

Lot
A sizable portion of work or quantity of material which is assessed as a unit for the purpose of quality control and selected to represent material or work produced by essentially the same process and materials.

Median
The area between the two carriageways of a dual carriageway road.

Mitigating Measure
Practical measures to reduce the adverse impacts or enhance the beneficial impacts of an action

Mitre drain and bank
A drain constructed at an angle to the centre line of the road to divert water from a side drain. Mitre drains include mitre banks placed across the side drains.

Monitoring
Continuous periodic surveillance of the physical implementation of a project to ensure that inputs, activities, outputs and external factors are proceeding according to plan.

Parapet
A low wall built along the edge of a bridge

Pavement layers
The upper layers of the road comprising the selected layers, subbase, base, wearing course and the shoulder layers.

Pier
A wide column or short wall forming a support to a bridge

Pilecap
A slab or beam resting on and connecting the tops of a group of piles, and distributing loads down to them from the structure above

Piles
Columns or sheeting, which are sunk into the ground to support vertical loading or to resist lateral pressures

Pollution
The introduction of unwanted substances into the environment, which has the capacity to affect human health and the environment in general (Ghana EPA).

Proof rolling
Proof rolling is the action of applying loaded vehicles to a compacted layer to check whether the surface deforms under these loads. It is essentially a quick check that a satisfactory compaction has been achieved.

Reseal
The application of a seal on an existing bituminous sealed carriageway.

Roadbed
The natural in situ material on which the fill, or in the absence of fill, any pavement layers, are to be constructed.

Road prism
That portion of the road construction included between the original ground level and the outer boundaries of the slopes of cuttings, fills and side drains. It shall not include the selected layer, subbase, base, surfacing, shoulders or roadbed (see Figure 1 .1).

Road reserve
The entire area included by the boundaries of a road as proclaimed.

Road surface
The top surface of the road

Roller passes
Unless otherwise specified in the Special Specification, an area will be taken to have received one roller pass when a roller has passed over such area once. Additional passes made only as a result of nominal overlapping so as to ensure full coverage shall not be taken into account.

Seal
The application of one or more layers of bituminous binder with or without layers of crushed stone or sand in successive layers on the carriageway, shoulders or on any other compacted layer on which movement of traffic takes place.

Selected layer
The lower layer or layers of the pavement which is constructed directly onto the fill, or in some cases the roadbed. It may include roadbed material compacted in situ.

Services
Cables, pipes or other structures to provide, inter alia, conduits for electricity, telephone and telegraph connections, water, sewage, etc.

Service duct
A conduit or pipe used to convey services such as electricity or communication cables, watermains, etc.

Shoulder

(a) When referring to this as a surface: The area between the outside edge of the travelled way and the shoulder breakpoint.
(b) When referring to this as a pavement layer: The upper pavement layer lying between the outside edge of the base and the shoulder breakpoint.

Shoulder breakpoint
The line along which the extended flat planes of the surface of the shoulder and the outside slope of the fill and pavement intersect. This edge is normally rounded to a predetermined radius.

Side drain
A longitudinal drain situated adjacent to the road.

Site
The places where the Permanent Works are to be executed and to which Plant and Materials are to be delivered, and any other places as may be specified in the Contract as forming the Site.

Slope
Unless otherwise stated, slope is given in terms of the ratio of the vertical difference in elevation between any two points and the horizontal distance between them. This ratio may also be expressed as a percentage.

Special Specification
The specifications relating to a specific project, which contain supplementary and/or amending specifications to the Standard Specification.

Spoil
Material originating from construction operations that is unsuitable or cannot be used as fill or is surplus to that required for fill for that project.

Stabilization
An operation which significantly changes (generally in the medium to long term) the characteristics of the soil in a way that renders it stable, particularly with respect to the action of water: it gives a permanent strength that can be measured by methods typical of solid materials.

Subbase
The layer of material on top of the selected layers or fill and below the base and shoulders.

Subgrade
The structure beneath the pavement layers comprising in situ material and/or imported fill.

Substructure
In a bridge, the piers, abutments, including the wingwalls, and towers that support the superstructure

Subsurface drainage system
A system of subsurface drainage pipes (including any permeable material) constructed to intercept and remove subsurface water.

Superstructure
In a bridge, that part of the structure which is supported by the piers and abutments

Sustainable development
Development that satisfies the needs of the present generation without in any way jeopardising the needs of future generations

Transverse beams
Beams positioned across the main beams of a bridge deck, for the distribution of concentrated loads over a number of main beams.

Travelled way
That portion of the carriageway which includes the various traffic lanes and auxiliary lanes but excludes the shoulders and laybys.

Verge
The area between the outer edge of the road prism and the boundary of the road reserve.

Waterproofing
The process of rendering surfaces of materials impervious to water.

Weepholes
Holes that allow water to escape from behind a retaining wall, and thus reduce the pressure behind it

Wingwalls
Walls at the abutment of a bridge, which extend beyond the bridge to retain the approach embankment

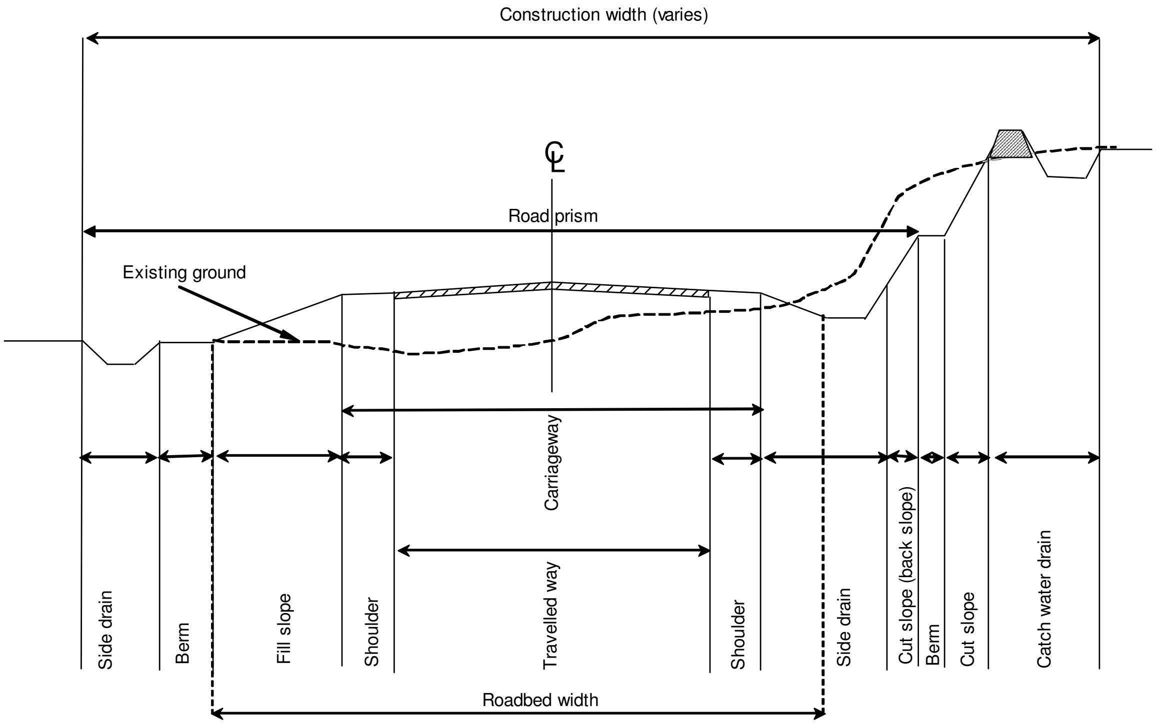

Figure 1.1: Definitions of road components

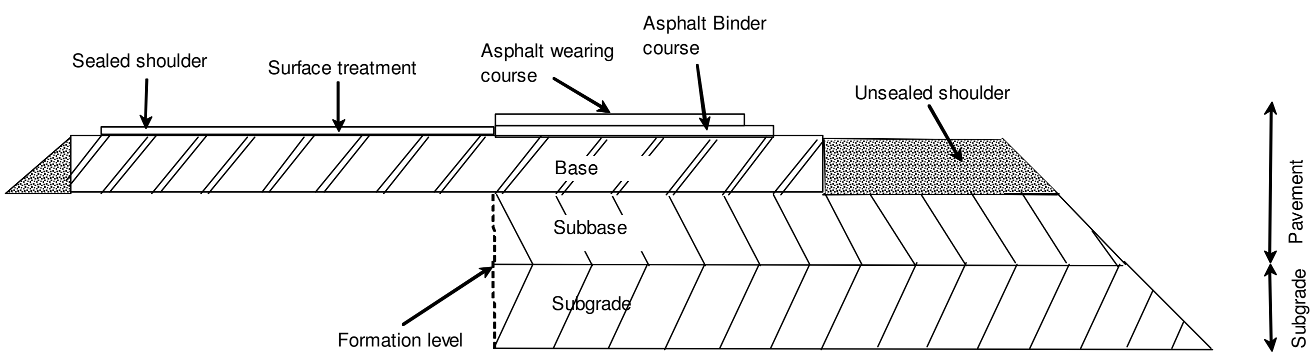

Figure 1.2: Definitions of pavement components

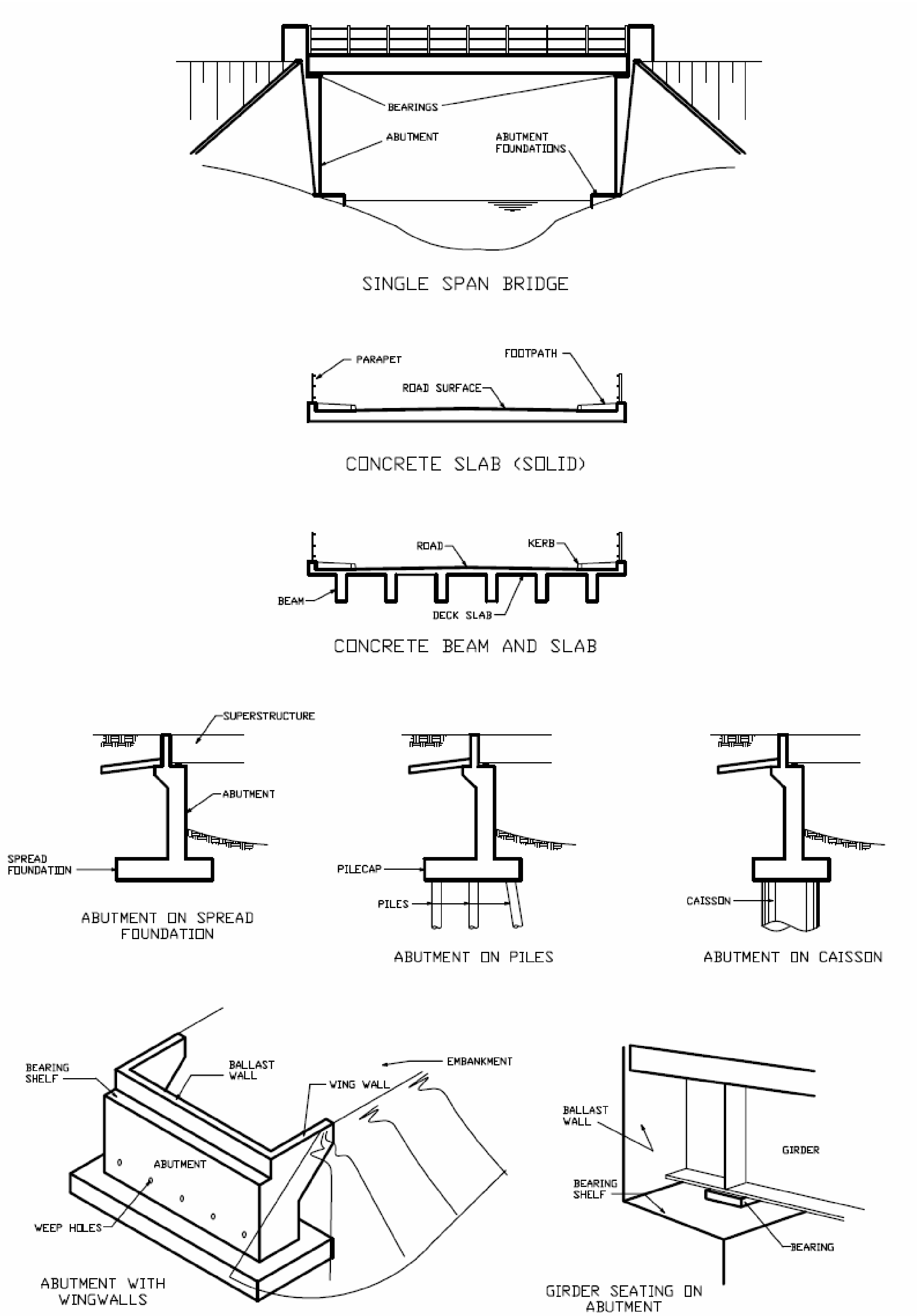

Figure 1.3: Bridge definitions

1.4. Units and Abbreviations

Calculations, technical information and measurement shall be expressed in units conforming to the Systeme International d'Unites (SI). A list of common symbols and abbreviations used in this document precedes Section 1.

1.5. Submissions to the Engineer

Whenever the Contractor is required to submit to the Engineer proposals, details, drawings, calculations, information, literature, materials, test reports or certificates, the Engineer will consider each submission and reply in accordance with the requirements of the Contract. Unless a defined period of time is stated in this Specification or Special Specification, each submission shall be made by dates to be agreed with the Engineer, taking due account of the approved programme and the need to give the Engineer adequate time to consider each submission.

Documents shall be submitted in English. Drawings shall be A1 in size to the ink border, with the title of the Contract followed by the title of the drawing in the right hand corner. They shall be signed by the Contractor and dated. Scales shall be shown. Amendments shall be noted and dated. Other documents shall be A4 in size, except where otherwise approved. In addition to hard copies of drawings, CAD files shall be submitted.

Any approvals given by the Engineer in accordance with the requirements of the Contract shall not relieve the Contractor of any obligations and responsibilities under the Contract.

1.6. Programme

In accordance with the Conditions of Contract, the Contractor shall submit, within 28 days after receiving notice of the Commencement Date, a fully detailed and time related programme showing the order and manner in which he proposes to carry out the Works. The programme shall show:

- The order of work.
- Planned rate of progress.
- Amount and type of equipment proposed.
- Details of methods to be employed.
- Details of Temporary works.

The programme shall be deemed to have taken into account normal climatic conditions to provide for the completion of the Works in the order and within the times specified therein.

Should the Contractor fall behind with the programme submitted by him in terms of the relevant clause of the Conditions of Contract, which programme has been approved by the Engineer, the Engineer may, without prejudice to his rights in terms of the relevant clause of the Conditions of Contract, require the Contractor to submit, within seven days of the date on which he has received a notice to this effect, a revised programme in terms of this Clause, which indicates the manner in which the Contractor undertakes to complete the Works within the required time. Any proposal in the revised programme to accelerate the rate of progress shall be accompanied by positive steps to increase production by more and/or better labour and equipment being provided on the Site or by the available labour and equipment being utilised more effectively.

The approval by the Engineer of any programme shall have no contractual significance other than that the Engineer would be satisfied if the work is carried out in accordance with such programme and that the Contractor undertakes to carry out the work in accordance with the programme. Neither shall it limit the right of the Engineer to instruct the Contractor to vary the programme should circumstances so require. The above shall not be taken to limit the right of the Contractor to claim for damages or extension of time to which he may be fairly entitled in terms of the Conditions of Contract for delay or disruption of his activities.

1.7. Order of Work

Operations shall be generally carried out in a sequence that will achieve a continuous and consecutive output of fully completed roadworks, inclusive of structures, without leaving any isolated sections incomplete. All efforts should be made to minimise the disruption of traffic flow, and to immediately reinstate and/or rehabilitate borrow pits, quarries, stockpiles, spoil areas and retention ponds that are no longer used, in accordance with the Environmental Management Plan, as the Contractor completes work in a specific area.
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The Contractor shall give the Engineer not less than 24 hours notice in writing of his intention to set out or give levels for any part of the Works in order that arrangements may be made for attendance or checking.

1.8. Method of Construction

The Contractor shall submit to the Engineer not later than 28 days from the date of award of the Contract, a general description of the proposed arrangements and methods for the execution of the Works, including, inter alia, temporary offices, buildings, access roads, diversions, construction plant and its intended production output, working shift arrangements, labour strength, skilled and unskilled and supervision arrangements, power arrangements, supply of materials, stone crushing, aggregate production and storage, cement handling, concrete mixing and handling, methods of excavation, dealing with water, testing methods, facilities and the Environmental Management Plan (EMP).

During the execution of the Works, the Contractor shall also submit to the Engineer full and detailed particulars of any proposed temporary works and amendments to the arrangements and methods submitted in accordance with the foregoing.

1.9. Notice of Operations

No operation shall be carried out without full and complete notice having been given to the Engineer by the Contractor 48 hours prior to the time of the operation to enable the Engineer to make such arrangements as he may deem necessary for its inspection and checking.

1.10. Site

The Site of the Works shall be the area within the various road reserves, quarries, borrow pits, spoil areas, access roads and diversions. It includes the places where the Permanent Works are to be executed and to which Plant and Materials are to be delivered.

The Employer shall make available, free of charge, to the Contractor the land on which the Permanent Works are to be executed or carried out. The Contractor shall, unless otherwise specified, acquire land for the erection of the Engineer's offices, laboratories and accommodation.

It is the Contractor's own responsibility to obtain all land for the erection of his Plant Yard and installations, storage areas, camp sites, laboratories and accommodation, shown on the Drawings or established specifically for the Contract and any other land required for the working of quarries and other sources of materials nominated by the Engineer. Acquisition of such land shall be considered part of the Contractor's general obligations.

Negotiations for any additional land required outside the permitted working space which may be required by the Contractor for any purpose whatsoever shall be carried out by the Contractor.

The Contractor's Plant Yard or Quarries shall be used by the Contractor for his offices, stores, plant, workshops, latrines and messing accommodation. The erection of temporary buildings or structures on other parts of the Site will not be allowed without the permission in writing of the Engineer.

Before the erection of any building or plant in the Contractor's Plant Yard or quarries, the Engineer shall be supplied with a drawing showing the layout of the area. Areas which the Contractor uses for his installations shall be fenced. By the end of the Defects Liability Period, the area and its environs shall be cleared of all construction equipment, materials, buildings and the like and shall be reinstated as directed by the Engineer.

Where it is necessary for any reason whatsoever to enter on to land which does not form part of the Site, the Engineer shall be informed of the details and the land owner or occupier shall be consulted by the Contractor and written permission obtained. In the event of the owner or occupier withholding permission, full circumstances of the case shall be referred to the Engineer and no further action shall be taken until his instructions are received.

Under no circumstances is land to be interfered with whether for Permanent or Temporary Works until the evaluation of all compensation has taken place and the necessary permission to proceed has been received from the Employer or other appropriate Authority. When permission has been obtained and work is carried out, care shall be taken to ensure that no unnecessary damage is caused to the land, vegetation or water courses and that all reasonable precautions are taken to prevent soil erosion, mosquito breeding and pollution of ground and surface water.

On completion of any Temporary Works, the land shall be left in a tidy condition and shall be regraded and/or reinstated as directed by the Engineer in accordance with the Environment Management Plan. No payment shall be made for this reinstatement work.

Possession of the Site will normally be given for ten-kilometre lengths at a time, or lesser but appropriate lengths for urban and feeder roads. If required, bridge and culvert sites outside the ten-kilometre or lesser lengths may be included. The Engineer will consider giving possession of greater lengths if the Contractor so requests.

From the date of such possession of the Site until a certificate of completion has been given, the Contractor shall be responsible for maintaining the old and new roads on the Site in a satisfactory and usable condition.

Any royalties payable by the Contractor in respect of soils or rocks excavated, on land made available free under the Contract, for the construction of permanent works, shall be included in the unit prices.

No compensation will be paid to the Contractor for any delays due to negotiations with the owners of land required for Temporary Works.

1.11. Construction Generally

The Contractor shall acquaint himself with and observe all current Statutes, Ordinances, Bylaws or Regulations, both national and local.

Materials available on the Site or materials made available or supplied by the Employer shall be used exclusively in the execution of the Works.

The Contractor shall be absolutely and solely responsible for the adequacy, safety and security of Temporary Works.

The Contractor shall minimise the pollution of and disturbance to lands, roads, water courses and other places on and around the Site. No trees or other vegetation shall be removed except to the extent necessary for the carrying out of the Works.

Access shall be maintained and granted to all properties adjacent to the Site as included in the General Conditions of Contract. Temporary access tracks and footpaths shall be constructed as required and maintained for the duration of the Contract.

All buildings erected by the Contractor on the Site shall comply with all bye-laws in so far as they may be applicable.

The Contractor shall provide adequate lighting where work is being executed at night, and shall provide and install any additional lighting that the Engineer may require in order to gain access to, watch and supervise the Works and carry out any testing and examination of materials.

The Contractor shall comply with the current Government regulations with regard to the transport, storage and use of explosives and radioactive materials.

The Contractor shall take all reasonable precautions:

a) in connection with any rivers, streams, waterways, drains, watercourses, lakes and the like to prevent silting, flooding, erosion of beds and pollution of the water that will adversely affect the quality or appearance thereof or cause injury or death to human, animal or plant life;

b) in connection with underground water resources (including percolating water) to prevent any interference with the supply to or abstraction from such sources and to prevent pollution of water that will affect its quality.

The Contractor shall provide, maintain and remove on completion of the Works appropriate security measures at the Site and on access roads, but without prejudice to his obligations to maintain free access for the Employer, the Engineer, other contractors and any persons entitled to such access.

The Contractor shall be absolutely and solely responsible for the adequacy, safety and security of all Temporary Works including (but not limited to) all work yards, borrow pits, pilings, staging, dams, cofferdams, trenches, fencing or other works and for the plant in connection therewith, which may be erected or provided for the carrying out of the Contract and for Execution of the Works. This provision shall be applicable to all Temporary Works and construction plant whenever provided and erected by the Contractor and/or his Sub-contractors for the purpose of or in connection with the Works.

Examination by and approval of the Engineer of the Contractor's and or Sub-contractor's temporary Works or of the drawings connected therewith shall not absolve the Contractor from any liability imposed upon him by the provisions of the Contract.

1.12. Protection from Water

The Contractor shall keep the whole of the Works free from water according to his obligations in terms of the General Conditions of Contract. Except as otherwise specified, he shall be responsible for the provision of temporary drainage works to deal with water, whether from existing drainage systems, water courses, underground springs, precipitation or any other source or cause. This will be in addition to any permanent drainage works specified and installed. In discharging and diverting water he shall avoid flooding or damaging other works or services and causing erosion.

The Contractor's proposed preventive measures shall meet with the Engineer's approval and may include the necessary construction of cofferdams, sheet piling, shoring, relocation of river streams, construction of proper drainage channels, diversion channels, necessary grouting of rock fissures, sumps, the supply and operation of necessary bailing and pumping equipment. Any dewatering measures, with the exception of pumping, shall be maintained until backfilling has been completed. Between the various construction stages, pumping may be temporarily discontinued as permitted by the Engineer.

Any damage to the Works or to adjacent properties resulting from the Contractor's failure to take the necessary precautions shall be made good at the Contractor's expense.

1.13. Environmental Management

The Contractor shall abide by and implement the requirements of the Environmental Management Plan approved by the EPA, which is part of the Special Specification, thereby ensuring, so far as is reasonably practicable, sound environmental management as required by the Laws of Ghana. His responsibilities shall include, but not be limited to:

a) the provision of a qualified officer or designation as Environmental Officer of one of his senior staff who has specific knowledge of environmental management who shall advise on all matters affecting the environment and on measures to be taken to prevent and mitigate environmental impacts and to promote environmental stewardship;

(b) the execution of suitable arrangements for ensuring sound environmental management practices;

(c) the provision of regular information, instruction, training and supervision as are necessary to ensure sound environmental management on the Works all in accordance with the Laws of Ghana;

(d) the provision of adequate waterborne sanitation, refuse collection and disposal, complying with the Laws of Ghana, all local Bye-laws and to the satisfaction of the Engineer, for all houses, offices, workshops and laboratories erected on the camp site or sites. The Contractor shall not allow the discharge of any untreated sanitary waste to groundwater or any surface water course.

(e) the provision of an adequate number of suitable latrines and other sanitary arrangements at sites where work is in progress to the satisfaction of the Public Health Officer in the area;

(f) training of workers in environmental management, waste management, and minimization of noise, dust and vibration. Special attention should be given to training on the consequences of poaching, littering, fires, indiscriminate removal of vegetation, the use of provided ablutions, and polluting of water courses. Training should encourage environmental stewardship including issues such as sustainability, recycling and conservation of resources.

(g) the provision of waste disposal systems for all types of wastes (i.e. solid, liquid, hazardous, machinery, vehicles, materials, etc) on the Works, and safe transportation and disposal of such waste in such a manner as will not cause environmental pollution in any form, or hazard to human or animal health. If a sub-contractor is employed to dispose of waste, the Contractor shall still retain responsibility for waste disposal. The Contractor shall wherever feasible, recycle or reuse rather than dispose;

(h) the cleaning up of any environmental pollution resulting from his activities and for the negotiation and payment of compensation for any damage caused thereby;

(i) the collection and recycling or disposal in an appropriate manner of all used fuels, oils, lubricants, solvents, greases, and other hazardous substances;

The Contractor shall further ensure that his activities do not result in any contamination of land or water by polluting substances. The Contractor shall implement physical and operational measures, as detailed in the Environmental Management Plan, such as earth bunds of adequate capacity around aggregate treatment areas, and fuel, oil, and solvent storage tanks and stores; oil and grease traps in drainage systems from workshops, vehicle and plant washing facilities, service and fuelling areas and kitchens. The Contractor shall ensure that all of these measures are effectively maintained throughout the Contract, in accordance with normal good practice and to the satisfaction of the Engineer. The Contractor shall submit details of the pollution prevention measures to the Engineer for approval.

The Contractor shall ensure that dust-producing materials shall be transported in vehicles having properly-fitting side and tail boards, that the materials shall not be loaded higher than the side and tail boards, and that the vehicle shall be covered with a properly secured cover. The Contractor shall ensure that vehicle operators obey speed limits to limit the volume of dust generated.

The Contractor shall not use or permit the use of rubber tyres as fuel for the execution of any part of the Works, including but not limited to, the heating of bitumen and bitumen mixes.

All vehicles and plant operated by the Contractor or his Subcontractors shall at all times be maintained in accordance with the original manufacturers' specifications and service manuals, with particular regard to the control of noise and diesel particulate emissions. The Engineer shall have the right to require the Contractor to replace or repair any vehicle or plant, which in his opinion causes excessive noise or smoke emission, within two days of the Contractor being notified.

1.14. Protection of Existing Works and Services

The Contractor shall establish the position of existing services such as sewers, surface water drains, cables for electricity and telephones, ducts, overhead lines and water mains, before starting any excavation or other work likely to damage them.

Where work is to be carried out in the vicinity of overhead power lines, the Contractor shall ensure that all persons working in such areas are aware of the relatively large distance that high voltage electricity can "short" to earth when cranes, or other large masses of steel, are in the vicinity of power lines. The Contractor's attention is drawn to BS 7354, which gives safe clearances for the various voltages.

The Contractor shall take all reasonable precautions to protect existing services during construction and during their relocation and will be held responsible for any damage caused by him to existing works or services. He shall indemnify the Employer against any claims in this respect (including consequential damages). The Contractor shall be responsible for the reinstatement of services so affected, at his expense and to the satisfaction of the Engineer.

In all cases where works or services are exposed, they shall be properly shored, supported or otherwise protected. Special care shall be exercised in filling and compacting the ground under mains, cables, etc, and to leave uncovered exposed water meters, stopcock boxes and other accessories.

The Contractor shall ensure that no fence or gate, except where these are required to be removed or altered for the proper execution of the Works, is damaged and that no gates are left open which may allow livestock to stray.

Installations adjacent to the Works shall be kept securely in place until the work is completed and shall then be made as safe and permanent as before.

Notwithstanding the foregoing requirements, and without reducing the Contractor's responsibility, the Contractor shall inform the Engineer immediately if any existing works or services are exposed, located or damaged.

All costs that may be incurred by the Contractor as a result of programming and co-ordinating work to enable any alterations to services to be carried out, and the cost of any safety precautions that shall be deemed necessary due to the proximity of the Works to existing services, shall be at the Contractor's expense.

1.15. Diversion of Services

The Contractor shall be responsible for arranging, in liaison with the appropriate Authority, the relocation of or alterations to services such as power and telephone lines, water mains, sewers and surface water drains which are affected by the Works. The arrangements for such moving or alteration shall be subject to the approval of the Engineer and the appropriate Authority and in accordance with the current version of the Road Reservation Management Manual for Coordination.

When the Contractor details the programme of work as referred to in the relevant clause of the Conditions of Contract, the Contractor shall, in consultation with the Engineer, clearly indicate as to when the moving of each service shall start and conclude or when the Owner of the service will be required to start and conclude the moving of each service.

1.16. Materials and Manufactured Articles

The Contractor shall, before placing any order for materials and manufactured articles for incorporation in the Work submit to the Engineer the names of the firms from whom he proposes to obtain such materials and manufactured articles giving for each firm a description of the materials and manufactured articles to be supplied, their origin, the manufacturer's specification, quality, mass, strength and any other relevant details. The Contractor shall deposit with the Engineer samples of such materials and manufactured articles when requested and, where appropriate, manufacturer's certificates of recent tests carried out on similar materials and manufactured articles.

The Contractor shall provide the Engineer with copies of all orders for the supply of materials and manufactured articles required in connection with the Works as the Engineer may require.

When instructed by the Engineer, the Contractor shall submit to him certificates of test from such suppliers of materials and manufactured articles to be used for the Contract. Such certificates shall certify that the materials and manufactured articles concerned have been tested in accordance with the requirements of the Specification and shall give the results of all the tests carried out. The Contractor shall provide adequate means of identifying the materials and manufactured articles delivered to the Site with the corresponding Certificates. Where such certificate is not available a representative sample of the material shall be tested by an approved laboratory or, subject to the approval of the Engineer, by the Contractor and a copy of the test results submitted to the Engineer who shall decide if the material conforms to the required standards.

Should the Engineer at any time be dissatisfied with such materials or manufactured articles, or with the method of operations carried out by such sub-contractor at the Site or by such a manufacturer at his place of business, the Engineer shall be empowered to cancel his previous approval of such goods. The Contractor shall then obtain such materials or goods from alternative suppliers approved by the Engineer and shall bear any additional cost thereof.

Any delays arising from unsatisfactory supply of goods, materials or services by any sub-contractor will be the responsibility of the Contractor.

If during the Contract, for any reason, the supplier should increase the cost of materials or goods purchased by the Contractor directly on behalf of the Client above that of other equally reputable suppliers, the Engineer may, at his own discretion, ask the Contractor to change his supplier, or he may only authorise payment for materials at the rates of other suppliers.

1.17. Storage of Materials and Manufactured Articles

All materials and manufactured articles shall be stored on Site in a manner acceptable to the Engineer and the Contractor shall carefully protect from weather, sunlight and vermin all work, materials and manufactured articles which may be affected. Materials subject to deterioration from prolonged storage shall be used in the sequence of dates of delivery or dates of manufacture, whichever is more applicable.

1.18. Progress Photographs

Colour photographs as detailed in the Special Specification showing the progress of the Works shall be taken every month by the Contractor from positions to be selected by the Engineer. These shall be digital photographs from a camera with a resolution of at least 3-megapixels. Each photograph shall be indexed and a statement shall be submitted giving the location, date when taken and a brief description or title. The Contractor shall provide copies of the original photographs on a CD-ROM or DVD-ROM.

1.19. Signboards

The Contractor shall provide, erect and maintain signboards to the layout, colours and dimensions shown on the Drawings.

These signboards shall be erected at sites to be selected by the Engineer.

The signboards shall be erected within one month of the date of commencement of the Contract. The Contractor shall remove the signboards at the end of the Defects Liability Period or its equivalent.

The Engineer shall have the right to have any sign, notice or advertisement moved to a better position or to have it removed from the site of the Works if it should in any way prove unsatisfactory, inconvenient or dangerous to the general public.

1.20. Occupational Health, Safety and Accidents

The Contractor shall ensure, so far as is reasonably practicable, the occupational health, safety and welfare at work of his employees as required by the Labour Act, including those of his sub-contractors and of all other persons on the Site. His responsibilities shall include:

(a) The provision and maintenance of constructional plant, equipment and systems of work that are lighted, safe and without risks to health. This shall include maintaining equipment, engines, and electrical installations in good working order; maintaining a clean and tidy work space; providing proper guarding; installing proper railing, signals and lighting; enforcing work site rules and safe working procedures, and allocating appropriate places to carry out the work. The Contractor shall strive to minimize occupational hazards, through appropriate training and the provision of safety equipment, including, but not limited to:

i. Physical hazards (continuous noise and vibrations, prolonged stay in high temperatures)
ii. Chemical hazards (exposure to fumes, chemicals, and dust including solvents, paints, exhaust gases, and possible carcinogens such as hot bitumen)
iii. Mechanical hazards (unguarded or exposed moving objects and other dangers from the use and operation of machines)
iv. Risk of accidents with hand tools (slips, falls, eye injuries), heavy items (the accidental dropping of heavy items), and risk of accidents with vehicles
v. Thermal hazards (heat stroke from long hours working in direct sunlight and burns due to contact with hot items (e.g. heated bitumen or the burner)
vi. Electrical, fire or explosion hazards
vii. Ergonomic risk factors (personal injuries associated with poor working postures, heavy lifting, repetitive work, repetitive hand-arm vibrations, manual transport)
viii. Sanitation hazards (including contaminated drinking water, poor food practices, improper waste disposal, unhygienic toilet and washing facilities, or contact with solid and/or biological waste)

(b) The execution of suitable arrangements for ensuring safety and absence of risks to health in connection with the use, handling, storage, transport and disposal of articles and substances;

(c) The Contractor shall provide protective clothing and safety equipment to all staff and labour engaged on the Works to the satisfaction of the Engineer. Such clothing and equipment shall include at a minimum, high visibility vests and boots for workers directing traffic and conducting all categories of maintenance works (e.g., pothole patching, regravelling, drainage works, grass/bush clearing, and road furniture works). Workers handling concrete, bitumen, acids, or paints, or exposed to heavy dust or vibrating equipment (e.g., rollers) shall be provided additional equipment including gloves, goggles, masks, or ear protectors. The personal protection equipment (PPE) available to workers will be to the satisfaction of the Engineer.

If the Contractor fails to provide such clothing and equipment, the Employer shall be entitled to provide the same and recover the costs from the Contractor.

The Contractor shall ensure that workers use the safety equipment whenever required.

(d) the provision of a qualified officer or designation as Safety Officer of one of his senior staff who has specific knowledge of safety regulations, and experience of safety precautions on similar works and who shall advise on all matters affecting the safety of workmen and on measures to be taken to promote such safety, in accordance with, but not limited to, the Ghana Code of Practice, Signing at Roadworks. All employees shall be given training on how to ensure their own personal safety and on ways to reduce the accident risk on those sites where large, mobile heavy vehicles and equipment or equipment with moving parts are in use. The Safety Officer shall provide training in safe work practices and general awareness of potential danger situations to avoid injuries. In addition, all employees shall be trained in how to handle dangerous/toxic materials. At least one person with first aid training shall always be on Site.

(e) the provision and maintenance of access to all places on the Site in a condition that is safe and without risk of injury;

(f) the provision of adequate waterborne sanitation, refuse collection and disposal, complying with the Laws of Ghana, all local Bye-laws and to the satisfaction of the Engineer, for all houses, offices, workshops and laboratories erected on the camp site or sites;

(g) the provision of an adequate number of suitable latrines and other sanitary arrangements at sites where work is in progress to the satisfaction of the Public Health Officer in the area;

(h) the execution of appropriate measures in consultation with the appropriate Public Health Authority to control within the Site, including the camp sites, mosquitoes, flies and other pests including the application of suitable chemicals to breeding areas;

(i) advising all site staff and labour of the dangers and impacts of STD's in general and HIV/AIDS in particular. To this end, the Contractor shall conduct information, education and consultation campaigns at least every month, targeting the aforementioned site staff, labour and the immediate local communities. The Contractor's OHS and HIV/AIDS Management Plan shall include details of the measures proposed for adoption to combat the spread of HIV/AIDS and STD's between his site staff, labour and local communities. The Contractor shall also manage the risk of harassment and sexual assaults, especially for female workers.

(j) reporting details of any accident to the Engineer and the Ghana Police Service, if appropriate, as soon as possible after its occurrence.

(k) The Contractor shall ensure, as far as is reasonably practicable, the safety of road users during the Contract, as detailed in Section 9. The Contractor shall install all safety features included in the Drawings. The Engineer may request additional safety features, which shall be priced separately. Local requests for safety measures and other improvements shall as far as possible be met and shall be discussed with the Engineer.

1.21. Facilities for the Engineer and his Staff

The Contractor shall, as specified in the Special Specification, provide and maintain houses, offices, laboratories, survey and laboratory equipment and furniture for the Engineer and his staff, including senior staff, junior staff and technicians.

A description of the number and type of houses, office, laboratories, equipment and furniture required shall be given in the Special Specification.

On completion of the Contract, the ownership of all houses, offices, laboratories, equipment and furniture shall revert to the Employer, unless otherwise specified.

1.22. Time for Erection of the Engineer's Staff Houses, Offices and Laboratories

All houses, offices and laboratories to be provided under the Contract shall be handed over to the Engineer in finished and fully habitable condition in accordance with the timescale given in the Special Specifications.

The Contractor shall give the highest priority to the construction and/or supplying of the laboratory. The laboratory, as specified, shall be available and ready for use within 60 days from the date of the Order to Commence. No permanent work on any section of the Contract shall be paid for until the laboratory is made available for use unless otherwise approved by the Engineer.

Should the Contractor fail to hand over the houses and offices within the period specified, the Engineer will make such alternative arrangements as he considers necessary. These arrangements may include the use of hotels, rented accommodation and the hire or purchase of caravans, portacabins etc. The Contractor shall be responsible for all costs of such temporary arrangements made by the Engineer, including that of additional transport.

1.23. Maintenance of the Engineer's Staff Houses, Offices, Laboratories, Furniture and Equipment

The Contractor shall keep all buildings, accesses, services and facilities provided for the use of the Engineer and his staff, in a well maintained, clean and fully habitable condition, until the expiry of the Defects Liability Period.

The Contractor shall also provide constant electricity, water and an adequate refuse collection service for all houses, offices and laboratories.

The Contractor shall also maintain all furniture and equipment provided by him and/or the Employer in a reasonable state of repair and usable condition and shall replace promptly any item which becomes unserviceable or is lost.

The Contractor shall provide all tools, protective clothing, wooden pegs, steel pins and pickets, water, cement and aggregate for concreting and all assistance as may be required by the Engineer and his staff for setting out, measuring and checking the Works.

The Contractor shall provide adequate security by day and night for the Engineer's offices, laboratory, vehicles and houses, and for the Engineer's staff. This shall include the provision of suitable gates and fencing and the full-time attendance of permanent watchmen.

1.24. Provision of Vehicles

The Contractor shall, if so required in the Special Specification, supply new vehicles and maintain them for the exclusive use of the Engineer and his staff.

A description of the number and types of vehicles to be provided is given in the Special Specification.

Unless otherwise specified, the vehicles shall be owned by the Contractor and be licensed and comprehensively insured by the Contractor for use by any licensed driver authorised by the Engineer together with authorised passengers and the carriage of goods and samples. The Contractor shall pay all tolls, provide fuel, oil, maintenance including replacing defective parts and tyres whenever required, in conformity with the vehicle manufacturer's recommendations or as may be necessary. The vehicles shall be fuelled, oiled and maintained as aforementioned until released by the Engineer. Each vehicle shall be fitted with a fire extinguisher, first aid kit, tow hook and rope, tool kit, spare wheel, wheel wrench, jack and handle and seat belts all of which shall be maintained in working order or replaced by the Contractor as necessary.

The Contractor shall provide a similar replacement for any vehicle out of service for more than twenty four hours, and shall replace any vehicle by a similar new vehicle after it has completed 250,000 km, or if, in the opinion of the Engineer, such vehicle becomes unreliable and/or cannot be maintained in a satisfactory condition.

The Contractor shall provide, pay (including all overtime and night allowances) and house competent and licensed drivers approved by the Engineer for each of the vehicles indicated in the Special Specification. Sufficient drivers shall be available at night and at weekends whenever required by the Engineer.

On completion of the Contract the vehicles shall become the property of the Employer.

The Contractor shall give the highest priority to the supplying of the vehicles. No permanent work on any section of the Contract shall be commenced unless the vehicles are made available for use, or equivalent vehicles as approved by the Engineer are provided. The cost of such vehicles shall be borne by the Contractor.

1.25. Clearance and Reinstatement of Site

Land disturbed during construction shall be cleared of all temporary buildings, plant and debris and reinstated either to its original or a clean and workmanlike condition to the satisfaction of the Engineer and in accordance with the Environmental Management Plan, taking account of environmental conditions and safety.

No separate payment shall be made for any work related to clearance and reinstatement of the Site and the costs shall be deemed to be included in the rates of the relevant items entered in the Bill of Quantities.

1.26. Establishment, Management and Removal of Camps

The Contractor shall ensure that the work camps, as well as the facilities for the Engineer and Engineer's staff, are located an appropriate distance from nearby settlements and local community drinking water intakes. The local community shall be consulted on the appropriateness of the location of the camp.

The Contractor shall ensure that adequate measures are taken to avoid pollution, as stipulated in Section 1.13. The Contractor shall ensure sound Occupational Health and Safety practices as prescribed in Section 1.20, including fire prevention.

Unless otherwise instructed, upon completion of the Contract and, after receiving approval in writing from the Engineer, the Contractor shall take down and remove all structures forming part of his own camp and that of the Engineer, and shall arrange for the disconnection of all services, remove all drains and culverts, backfill trenches, fill in all latrine pits, soakaways and other sewage disposal excavations, with the exception of items and services that are required to revert to the ownership of the Employer and shall restore the Site, as far as practicable, to its original condition and leave it in a neat and tidy condition in accordance with the Environmental Management Plan. This shall include, but not necessarily be limited to, returning the land to at least its previous condition and, in the case of agricultural land, to its potential productivity. Clearance and reinstatement shall include, but not be limited to, tasks such as the removal and disposal of all wastes, disinfection of sewage disposal systems, demolition and removal of unwanted structures, removal of metallic and concrete debris, removal and disposal of any soil contaminated by diesel, bitumen, or other polluting material, ripping to relieve compaction, grading, replacement of topsoil, and establishment of vegetative cover, as appropriate and directed.

Stakeholders shall verify in writing that camp/workshop reinstatement is adequate.

The Contractor shall carry out similar reinstatement in the event that he relocates his camp and that of the Engineer.

1.27. Use of Explosives

The Contractor shall only use explosives for blasting in rock at such times and places and in such manner as the Engineer may approve and in accordance with Clause 5.3. Such approval shall not relieve the Contractor from his responsibilities for damage to the Works and adjoining or adjacent structures, roads, places and things, injury, loss, inconvenience and accident to persons, animals and property consequent on the use of such explosives. The Contractor shall be entirely liable for any such damage and shall indemnify the Employer from all claims arising therefrom.

1.28. Early Completion of Earthworks

The Contractor shall programme his operation such that earthworks are completed to formation level at least 6 months prior to construction of the pavement base course when there is a substantial risk of settlement of embankments (eg, on weak subgrades) in order to allow the main settlement to take place.

1.29. Engagement of Staff and Labour

The Contractor shall ensure that the conditions of employment for his staff are in accordance with those established in the Collective Agreement between the Association of Building and Civil Contractors of Ghana (ABCCG) and the Construction and Building Materials Workers' Union of TUC (CBMWU) and the current Labour Act.

The Contractor shall be encouraged to the extent practicable and reasonable to recruit a percentage of his work force from the local communities, as follows:

(a) Unskilled and semi-skilled labour locally rather than from distant regions of the country;
(b) Members of those families directly affected by land take for the Works;
(c) Women, if feasible.

The Contractor shall have a good record of paying worker's wages. Contractors who default in workers' payments shall be removed from the list of registered contractors. The Engineer shall recover wages due to workers from payment certificates.

The Contractor shall:

(a) Display notices informing workers of the provision of these clauses in suitable locations
(b) Pay fair wages, on time, that at least comply with Ghanaian labour laws and regulations for Official Minimum Wage
(c) Recognise freedom of staff to join unions
(d) Ensure equality of treatment, including the equality of treatment for casual labourers
(e) Apply social security regimes
(f) Restrict the employment of children and young persons below the age of 16
(g) Hire women, where appropriate and feasible, and pay them based on the principle of equal pay for work of equal value, as their male counterparts
(h) Regulate the number of working hours
(i) Recognise religious festivals and days of rest on Site
(j) Take reasonable precautions, including through education, to prevent any unlawful, riotous, or disorderly conduct by or amongst his employees and for the preservation of peace and protection of persons and property in the neighbourhood of the Works. This shall include:
    i. Restricting access to alcohol and drugs on the Site
    ii. Preventing trafficking in arms and ammunition on Site
    iii. Preventing riots and disorderly conduct on Site
    iv. Preventing all unauthorised felling of trees or harvesting of local wood resources, branch lopping, hunting, trapping or harassment of wildlife, purchase

of or trade in wildlife products, possession of traps, starting of fire, fishing with toxins or explosives, and land cultivation

(k) Return to the place where they were recruited or to their domicile all such persons as he recruited and employed for the purposes of or in connection with the Contract

(l) Make any arrangements with regard to funeral rites and burial of any of his local employees who may die while engaged upon the Works

(m) Keep proper records of workers including:

   i. Maintaining full records of numbers, working hours, wages for labour, safety health and welfare of persons, accidents, and damage of property and make such reports on these matters to the Engineer as he may from time to time prescribe or require

   ii. Reporting to the Engineer the details of any accident as soon as possible after its occurrence. In the case of any serious accident or fatality, the Contractor shall notify the Engineer immediately by the quickest available means.

The Contractor shall have a designated on-site Labour Officer responsible for ensuring compliance with the conditions relating to engagement of staff and labour. This Labour Officer, who maybe the same person as the Safety Officer shall have authority to issue instructions and shall take measures to protect the health and promote the welfare of staff and labour.

1.30. Relations with Local Communities

In siting and operating his plant and facilities and in executing the Works, the Contractor shall at all times take cognisance and to the extent practicable, minimise the biophysical and social impacts of his activities on existing communities.

The Contractor shall not locate any hot mix, screening, crushing plant, or similar potentially polluting plant closer than 200 m to any settlement. The plant shall be fitted with dust-suppression equipment or other pollution-control devices to minimize environmental and social impacts.

Where the communities are likely to be affected by project activities, the Contractor shall liaise closely with the concerned communities and their representatives, and if so directed, attend additional meetings arranged by the Engineer or Employer to resolve issues and claims to minimise impacts on local communities.

The Contractor shall at any time keep communities (or at least the people who are directly affected) informed about project changes, delays, and other relevant issues. The Contractor shall ensure that the local communities have full knowledge of potential dangers and other issues related to the works, for example danger to children through changes in traffic patterns and the movement of heavy machinery.

The Engineer shall resolve compensation and issues related to royalties in a fair manner.

1.31. Protection of Existing Natural Resources and Places of Cultural Value

The Contractor shall ensure that existing natural resources or places of cultural value near the Site are not adversely affected by the Works or by the actions of his staff. This shall include, but not necessarily be limited to:

1.31.1 Depletion of water resources

The Contractor shall liaise with the Water Resource Commission (WRC) on issues related to water use and water permits as detailed in the Special Specifications. The Contractor shall apply for all relevant water-use permits.

The Contractor shall finalize his own arrangements at his own expense for water supply for construction and other purposes. Only clean water free of deleterious substances and of appropriate quality for its intended use shall be used. In providing water, the Contractor shall ensure that the rights of, and supply to, existing users are not affected in quality, quantity, or timing.

In the event of a dispute over the effect of the Contractor's arrangements on the water supply of others, the Engineer shall be informed immediately and shall instruct the Contractor as to appropriate remedial actions to be undertaken at his expense.

In the event that there is a serious water shortage in the construction area, the Contractor shall indicate to the Engineer in writing how he intends to obtain adequate water supplies without causing undue disturbance to other water users (e.g., water shortages or siltation). The Contractor shall consult with local water users in an ongoing manner on issues related to water.

1.31.2 Conservation of land resources, e.g., quarry stone and gravel

The Contractor shall ensure the economic use of non-renewable resources such as gravel by conducting such Works to specification. Where feasible and appropriate, the Contractor shall use recycled aggregates.

1.31.3 Protection of trees

The Contractor shall strive to preserve as much of the natural vegetation as is possible. Protection of trees and other vegetation shall be detailed in the Special Specifications and the Environmental Management Plan.

1.31.4 Use of wood as fuel

The Contractor shall not use or permit the use of wood as fuel for the execution of any part of the Works, including but not limited to the heating of bitumen and bitumen mixtures, and to the extent possible, ensure that fuels other than wood are used for cooking and water heating in all his camps and living quarters. Any wood used for any other purpose shall have been harvested legally, and the Contractor shall provide the Engineer with copies of the relevant permits upon request.

1.31.5 Fire Prevention

In addition to the provision of adequate fire fighting equipment at the work camps to the satisfaction of the Engineer, the Contractor shall take all precautions possible to ensure that vegetation along the road alignment outside the area of the Works is not affected by fires due to his or his staff's actions. Should a fire occur in the natural vegetation or plantations adjacent to the road as a result of his or his staff's action, the Contractor shall immediately suppress it.

1.31.6 Use of agricultural land

The Contractor shall only use agricultural lands, where absolutely necessary and only after obtaining the written agreement from the owners and after resolving any compensation issues. The Contractor shall correctly reinstate such lands after use.

1.31.7 Protection of Environmentally Sensitive Areas

Where the road project crosses or is near a sensitive area (e.g., water body, tourism destination, or protected area), the Contractor shall contact the relevant agencies (e.g.; EPA, WRC, Wildlife Division) for any special measures that shall be required. The Contractor shall ensure that the location of his camps, quarries, borrow pits, stockpile, and spoil areas are not located in, and do not impact in any way, on Environmentally Sensitive Areas as defined in Regulation 30 920 of LI 1652. These areas include:

(a). All areas declared by law as national parks, watershed areas, wildlife reserves and sanctuaries including sacred groves
(b). Areas with potential tourist value
(c). Areas which constitute the habitat of any endangered or threatened species of indigenous wildlife (flora and fauna)
(d). Areas of unique historic, archaeological, or scientific interests
(e). Areas which are traditionally used by cultural communities
(f). Areas prone to natural disasters (geological hazards, floods, rainstorms, earthquakes, landslides, volcanic activity, etc)
(g). Areas prone to bushfire
(h). Hilly areas with critical slopes
(i). Areas classed as prime agricultural lands
(j). Recharge areas of aquifers
(k). Water bodies characterized by one of any combination of the following conditions:
   i. Water tapped for domestic purposes
   ii. Water within the controlled and/or protected areas
   iii. Water which supports wildlife and fishery activities
(l). Mangrove areas characterized by one or any combination of the following conditions:
   i. Areas with pristine and dense growth
   ii. Areas adjoining the mouth of major rivers systems
   iii. Areas near or adjacent to traditional fishing grounds
   iv. Areas which act as natural buffers against shore erosion, strong winds or storm floods

1.31.8 Poaching and other illegal activities

The Contractor shall inform workers that illegal activities, including poaching, will not be tolerated

1.31.9 Protection of cultural sites: national heritage, burial sites, and places of cultural value

The Contractor shall consult local leaders to identify cultural sites and how to best minimize negative impacts (e.g., from noise, dust, and access problems) as specified in the Environmental Management Plan.

All fossils, articles of value or antiquity, and structures and other remains or things of geological or archaeological significance discovered on Site are deemed to be the absolute property of the Employer.

1.31.10 Damage to local culture

The Contractor will advise his external/outside workers on how to behave within the local communities, so as to avoid cultural conflicts.

SECTION 2

TESTING OF MATERIALS AND WORKMANSHIP

CONTENTS

TABLES

2. TESTING OF MATERIALS AND WORKMANSHIP

2.1. Scope

This section covers the tests and methods of testing, which are required for the selection and control of the quality of materials and for control of workmanship, trials and construction control testing.

2.2. Testing by the Contractor

The Contractor shall produce work that conforms in quality and accuracy of detail to all the requirements of the Specifications and Drawings, and the Contractor shall, at his own expense, institute a quality control system and provide experienced engineers, foremen, surveyors, materials technicians, other technicians and other technical staff, together with all transport, instruments and equipment, to ensure adequate supervision and positive control of the Works at all times

The Contractor shall provide, use and maintain on the Site throughout the period of execution of the Works a suitable laboratory and adequate equipment operated by competent staff for carrying out on a regular basis, all tests required for the selection and control of the quality of natural and processed natural materials and products manufactured on site such as concrete and asphalt and for the control of workmanship in accordance with the Specification. The Contractor shall assume that tests will be required on all materials used in the Works and on all finished work. The intensity of control and of tests to be conducted by the Contractor in terms of these obligations is not specified but shall be adequate to ensure that proper control is being exercised.

The Contractor shall within 30 days after the notice to commence the Works, submit a Quality Management System, including the Work Method Statements and Quality Audit for major items of work.

The Contractor shall carry out all necessary tests and shall report to the Engineer the results of such tests before submitting materials and finished work to the Engineer for approval. In appropriate circumstances, tests may be carried out at the place of manufacture or at an independent laboratory acceptable to the Engineer. Although not a requirement for the Contractor to conduct regular tests on any commercially produced products such as cement, bitumen, steel and pipes, the Contractor shall remain fully responsible for any defective material or equipment provided by him.

Samples of all materials proposed to be used shall be submitted to the Engineer.

Full compensation for the above obligations, including the provision of all samples delivered to the Engineer, the repair of places from which samples were taken, and the provision of the necessary personnel and testing apparatus and facilities, shall be deemed to be included in the tendered rates of the Contractor for the various items of work to which these obligations apply.

2.3. Materials

All materials shall conform to the requirements of the Contract, the Drawings and the Specifications. No materials shall be used in the Works without the prior approval of the Engineer and any materials condemned as unsuitable for use in the Works shall be removed immediately from the Site by the Contractor at his own cost.

2.4. Soils and Gravels

2.4.1 Samples and sampling

Samples shall be prepared for testing as indicated in Clause 7 of BS 1377-1, except that:

(a) The mass (in g) of a sample required for sieve analysis is to be about 400D, D being the maximum particle size (mm).

(b) Samples containing particles larger than 19 mm shall be prepared for compaction and CBR tests as follows:

Sieve an adequate quantity of representative material over the 19 mm sieve. Weigh the material retained on the 19 mm sieve and discard. Do not replace this material with another fraction.

Note: Preparation of gravel samples

The aggregations of particles shall be broken with a wooden or rubber hammer or pestle.

Care shall be taken that no individual particles are crushed in the operation.

2.4.2 Standard methods of testing

Tests on soils and gravels shall be performed in accordance with the standard methods given in Table 2.1.

It is further specified that:

(a) Compaction testing using a 4.5 kg rammer is denoted GHA S1 (equivalent to AASHTO T 180). (Light compaction (AASHTO T 99) is not used in this Specification.

Wherever in the text of the Specification and the Special Specifications the term "x% of the MDD (GHA S1)" is used it shall mean that a standard of compaction shall be achieved such that the dry density of the compacted material is x% of the maximum dry density determined from the GHA S1 compaction test.

Samples for the GHA S1 compaction tests shall be taken before compaction of the layer begins unless in the opinion of the Engineer the compactive effort proposed or applied by the Contractor is such that the materials characteristics will change in which case the samples for the tests shall be taken after all compaction is complete.

(b) Compaction tests: when the material is susceptible to crushing during compaction, a separate and new sample shall be used in the determination of each point on the moisture/density curve.

(c) The dry density of material placed in the Works shall be determined by the Sand Replacement method (GHA S5) or the Nuclear method (BS 1377: Part 9). However, the Sand Replacement method (GHA S5) shall be used as the reference density in the case of dispute.

2.5. Stone and Aggregate for Pavement layers

2.5.1 Sampling and preparation of samples

Sampling shall be carried out and the samples prepared in accordance with BS EN 932-1 (ASTM C 702).

2.5.2 Standard methods of testing

Tests on stone, aggregate, sand and filler shall be performed in accordance with the standard methods given in Table 2.2.

Table 2.1: Test procedures applicable to disturbed samples of soils and gravels

Determination of	Test procedure	
Moisture content	BS 1377	Part 2: Clause 3.2, Oven drying method
Liquid limit	GHA S6	(Casagrande Method or Cone Penetrometer Method)
Plastic limit	GHA S6	
Plasticity Index	GHA S6	
Linear Shrinkage	GHA S6	
Density of particles	GHA S1	Clause 3.3
Particle size distribution	GHA S7	Wet sieving
	GHA S9	Hydrometer
Organic matter content	BS1377	Part 3: Clause 3
Total sulfate content	BS1377	Part 3: Clause 5
pH value	BS1377	Part 3: Clause 9
Reference density for compaction	GHA S1	Cohesive soils and gravels
	GHA S3	Graded crushed stone subbase and base
Reference density for compaction (vibrating hammer)	GHA S4	Cohesionless sands and fine gravels
California Bearing Ratio	GHA S2	
Sand Equivalent	AASHTO T 176	Mechanical shaker or manual shaker method
Field Dry Density	GHA S5	
	BS 1377	Part 9: Clause 2.5
	AASHTO T 238	Clause 9.4.6 (Moisture determination in accordance with BS 1377:Part 2, Clause 3.2)
10% Fines Aggregate Crushing test	BS 812-111	
Plastic Modulus		PI x % material passing 0.425 mm sieve
Uniformity Coefficient		D_{60}/D_{10} where : D_{60} is particle size at which 60% of soil mass is finer D_{10} is particle size at which 10% of soil mass is finer

Table 2.2: Test Procedures Applicable to Stone and Aggregate

Determination of	Test Procedure
Particle size distribution	BS EN 933-1
Clay, silt and dust in aggregate	BS 812-103.2
Flakiness Index	BS EN 933-3
Relative density- water absorption	BS EN 1097-6
Bulk density, voids and bulking	BS EN 1097-3
Moisture content	BS 812-109 (Standard method – oven drying)
Aggregate Crushing Value	BS 812-110
Organic impurities in sands	AASHTO T 21
Los Angeles Abrasion	AASHTO T 96 (ASTM C 131) (coarse aggregate) ASTM C 535 (Large size coarse aggregate)
Sand equivalent	AASHTO T 176 (Mechanical shaker or manual shaker method)
10% Fines Aggregate Crushing Value	BS 812-111

2.6. Stone, Aggregate, Sands and Filler for Concrete

2.6.1 Sampling and preparation of samples

Sampling shall be carried out and the samples prepared in accordance with BS EN 932-1 (ASTM C 702).

2.6.2 Standard methods of testing

Tests on stone, aggregate, sand and filler shall be performed in accordance with the standard methods given in Table 2.2.

(a) Acceptance testing

The Contractor shall deliver to the Engineer samples containing not less than 50 kg of any aggregate that he proposes to use in the Works and shall supply such further samples as the Engineer may require. Each sample shall be clearly labelled to show its origin and shall be accompanied by all the information called for in BS EN 12620.

Tests to determine compliance of the aggregates with the requirements of Subclause 18.3.3 shall be carried out by the Contractor in a laboratory acceptable to the Engineer. If the tested materials fail to comply with the Specification, further tests shall be made in the presence of the Contractor and the Engineer and acceptance of the material shall be based on such tests.

A material shall be accepted if not less than three consecutive sets of test results show compliance with the Specification.

(b) Compliance testing

The Contractor shall carry out routine testing of aggregates for compliance with the Specification during the period that concrete is being produced for the Works. The tests shall be performed on aggregates from each separate source on the basis of one set of tests for each day on which aggregates are delivered to Site provided that no set of tests shall represent more than 250 tonnes of fine aggregate nor more than 500 tonnes of coarse aggregate, and provided also that the aggregates are of uniform quality. If the aggregate from any source is variable, the frequency of testing shall be increased as instructed by the Engineer.

2.7. Cement

The composition of Portland Cements (CEM I) shall comply with GS 22 or BS EN 197 and be sampled and tested in accordance with BS EN 196. Cements with more than 6% extender shall comply with GS 766 or BS EN 197.

2.8. Lime

Building limes shall be sampled and tested in accordance with BS 6463. Lime for treatment of road materials shall be Hydrated Calcium Lime and, unless otherwise specified, shall comply with BS EN 459-1 and the following requirements:

Fineness	
Residue on 0.18 mm sieve – Maximum	5%
Residue on 0.075 mm sieve – Maximum	15%
Chemical requirements	
Available lime content (as CaO) – Minimum	50%

2.9. Cement or Lime Treated Materials

2.9.1 Samples and sampling

Samples shall be prepared for testing as indicated in BS 1924: Part 1, except that:

Samples containing particles larger than 20 mm shall be prepared for compaction and CBR tests as indicated in Clause 2.4.1 (b).

2.9.2 Standard methods of testing

The tests on cement or lime treated materials shall be performed in accordance with the standard methods given in Tables 2.1 and 2.3.

It is further specified that:

(i) Compaction tests: when cement is used, compaction shall start within one hour and be completed within two hours after the material and cement mixture first comes into contact with water.

(ii) Determination of the Unconfined Compressive Strength (UCS): the specimens shall be statically compacted to a predetermined density.

(iii) Determination of the California Bearing Ratio (CBR): the specimens shall be dynamically compacted with a 4.5 kg rammer, the number of blows being governed by the relative compaction chosen. If it is required to soak the specimen, the mould shall be immersed in water to allow free access of water to top and bottom of the specimen. During the four day soaking period, the water level in the mould and the soaking tank shall be maintained approximately 10 mm above the top of the specimen.

(iv) Curing and soaking temperature: during the curing and soaking periods, the specimens shall be kept at a temperature of 27°C ± 2°C.

Table 2.3: Additional Test Procedures Applicable to Cement and Lime Treated Materials

Determination of	Test Procedure	
Moisture content	BS 1924-2	Clause 1.3.3 Oven drying method
Density-Moisture Content relationship (2.5 kg rammer)	BS 1924-2	Clause 2.1.3
Density-Moisture Content relationship (4.5 kg rammer)	BS 1924-2	Clause 2.1.4
Density-Moisture Content relationship (Vibrating rammer)	BS 1924-2	Clause 2.1.5
Unconfined Compressive Strength (UCS)	BS 1924-2	Clause 4.1
Effect of immersion on UCS	BS 1924-2	Clause 4.3
California Bearing Ratio	BS 1924-2	Clause 4.5 Dynamic compaction (Soaking as AASHTO T 193)
Cement Content	BS 1924-2	Clause 5.1
Lime Content	BS 1924-2	Clause 5.2
Initial Consumption of Lime	Clause 2.9.3	
Field Dry Density	AASHTO T 310	
Methylene Blue Value	BS EN 933-9	

2.9.3 Gravel Initial Consumption of Lime (ICL) test

Deficiencies in the BS 1924 ICL test have led to a revision as follows:

(a) Method

Determination of the initial consumption of lime in soil (gravel ICL)

(b) Scope

This method tests the construction material as a whole, and not only that passing the 0.425 mm sieve fraction. The objective of the test is to control the pH of lime or cement stabilized materials in order to allow the formation of cementitious materials and to ensure the stability of the reaction products. During the initial testing, standard lime would normally be used for the ICL test. Once the source of the lime or cement to be used on the project has been decided, this lime or cement will be used for all further testing for that project.

(c) Equipment

1. Balance (accuracy : 0.1 gram)
2. Calibrated pH meter (accuracy : 0.02 units)
3. 5 plastic beakers (150 mℓ tall)
4. 200 ml glass beaker
5. Distilled water
6. Calcium hydroxide or cement
7. Water bottle
8. Spatula or pallet knife
9. Soft tissues
10. Distilled water
11. Sample splitter (25 mm)
12. Jet bottle (for spraying electrode)
13. Drying oven (105 – 110°C)
14. Thermometer (accuracy 0.5°C)
15. 20 mm sieve

(d) Method

Sample preparation

The test is carried out on material finer than 20 mm. Any oversize material is lightly crushed to pass the 20 mm sieve. The samples are dried overnight in the oven at 105-110°C. The samples are then reduced to 200 g quantities using a sample splitter and placed into 150 mℓ or larger plastic containers.

Testing procedure

Since most materials require between 2 and 7% stabilizer, it is advisable to set up six beakers with stabilizer percentages of 2, 3, 4, 5, 6, 7 and 8 respectively, of the dry soil mass. A control test using 10% lime is also prepared to indicate the expected upper pH limit. Weigh the lime to the nearest 0.1 g and add to the soil. Mix the soil and dry lime.

Slightly oversaturate the samples with CO_2-free distilled water. The material shall be judged oversaturated when the pores of the material are water-filled and free water can be observed on the surface of the mix. The surface particles need not be submerged completely.

Mix the soil-stabilizer and water until there is no evidence of dry material on the bottom of the beaker. Mix for a minimum time of 30 seconds.

Mix for 30 seconds every 10 minutes.

After one hour, measure the pH of the paste by inserting the pH electrode gently into a hole made in the material with the spatula to a depth of about 20 to 30 mm and gently covering this part of the electrode with the material. Tap the beaker gently to ensure contact between the electrode and material.

Record the pH of each sample to the nearest 0.02 of a unit. The lowest percentage stabilizer at which the pH of the soil paste remains constant (this should be equal to the pH value obtained from the 10% lime control mix) is the saturation stabilizer content of this particular material. A change in pH of less than 0.02 units can be considered as constant. The saturation pH of pure lime at 25°C is usually 12.4.

Recording of Results
The results are recorded to the nearest 0.5% stabilizer required to produce the maximum pH in the paste.

Preparation of pH Meter
The calibration procedures of the manufacturer of the pH meter shall be strictly followed. The temperature-asymmetry and slope adjustment are of particular importance. The efficiency of the electrode must be assured.

2.10. Concrete

2.10.1 General

Sampling and testing of concrete shall be carried out in accordance with BS EN 12350 and BS EN 12390:

BS EN 12350-1, Testing fresh concrete — Part 1: Sampling
BS EN 12350-2, Testing fresh concrete — Part 2: Slump test
BS EN 12350-3, Testing fresh concrete — Part 3: Vebe test
BS EN 12350-4, Testing fresh concrete — Part 4: Degree of compactability
BS EN 12350-5, Testing fresh concrete — Part 5: Flow table test
BS EN 12350-6, Testing fresh concrete — Part 6: Density
BS EN 12350-7, Testing fresh concrete — Part 7: Air content of fresh concrete — Pressure methods
BS EN 12390-1, Testing hardened concrete — Part 1: Shape, dimensions and other requirements for test specimens and moulds
BS EN 12390-2, Testing hardened concrete — Part 2: Making and curing specimens for strength tests
BS EN 12390-3, Testing hardened concrete — Part 3: Compressive strength of test specimens
BS EN 12390-6, Testing hardened concrete — Part 6: Tensile splitting strength of test specimens
BS EN 12390-7, Testing hardened concrete — Part 7: Density of hardened concrete

It is further specified that the test specimens shall be cured at a temperature of 27°C ± 2°C.

Water to be used in concrete shall be tested as specified in BS EN 1008.

Strength testing of concrete for small structures on Feeder Roads may be undertaken using appropriate in situ non-destructive techniques with the approval of the Engineer. Such techniques could include for example Schmidt rebound hammer strength testing according to ASTM C 805.

Note: As a Schmidt Hammer is very sensitive to local variations in the concrete, the Schmidt hammer reading should be taken as the average of a large number of readings (≥12) taken in the area of interest. The general calibration curves relating rebound number to strength, as provided by equipment manufacturers should not be used and strength calibrations shall be based on the particular mix under investigation. The hammer shall be calibrated on laboratory specimens that correspond as closely as possible to the in-place concrete as far as mould surface, curing and age is concerned. Calibrations prepared for one hammer should not be used for another hammer. The rebound hammer should be regularly checked against a standard steel anvil of known mass to ensure that the spring and internal friction characteristics have not been affected by wear. All use of the Schmidt hammer shall be with the approval of the Engineer after calibration.

2.10.2 Quality control of concrete production

(a) Sampling

For each class of concrete in production at each plant samples of concrete shall be taken at the point of mixing or of deposition as approved by the Engineer, all in accordance with the sampling procedures described in BS EN 12350-1 and with the further requirements set out below.

Six 150 mm or 200 mm cubes or 150 mm diameter cylinders, as appropriate, shall be made from each sample and shall be cured and tested in accordance with BS EN 12390-2 and BS EN 12390-3, two at seven days and the other four at 28 days. An additional two samples shall be prepared for testing after three days, if required by the Engineer.

Each sample shall be taken from one batch selected at random and at intervals such that each sample represents not more than 50 m^3 of concrete unless the Engineer agrees to sampling at less frequent intervals.

Until compliance with the Specification has been established the frequency of sampling shall be three times that stated above or at such lower frequency as may be approved by the Engineer.

(b) Testing

(i) The consistency of the concrete shall be determined for each batch from which samples are taken and in addition for other batches at the frequency instructed by the Engineer.

The consistency of the concrete in any batch shall not differ from the value established by the trial mixes by more than the values listed in Section 18.5.5.

(ii) The water/cement ratio as estimated from the results of (a) above, determined by samples from any batch shall not vary by more than 5% from the value established during the trial mixes.

(iii) The air content of air entrained concrete in any batch shall be within 1.5 units of the required value and the average value of four consecutive measurements shall be within 1.0 unit of the required value, expressed as a percentage of the volume of freshly mixed concrete.

(iv) The compressive strength of specimen shall be recorded in N/mm^2 (to the nearest 0.5 N/mm^2).

Where two or more specimens are made from one sample and the range of the test values is more than 15% of the mean, then the results shall be disregarded unless an investigation reveals an acceptable reason to justify disregarding an individual test value.

The concrete strength of a sample is recorded as the mean of the acceptable strength results.

The 7-day concrete strength result may be used as an early strength indicator, at the discretion of the Engineer but this does not relieve the Contractor of his obligation to ensure that the 28 day strength is achieved.

(v) The criterion for adoption of trial mixes for structural concrete is:

$$f_{cm} = f_{ck} + 12$$

where:

f_{cm} = Mean compressive strength of concrete
f_{ck} = Characteristic compressive strength

The Contractor can decide to reduce the margin to less than 12 but the margin should be about twice the expected standard deviation, ie, at least a margin of 6 to 12 N/mm^2 depending on the production facilities, the constituent materials and the available background information about the variation.

(vi) Conformity of concrete is based on counting the number of results obtained in the assessment period that lie outside the specified limiting values, class limits or tolerances on a target value and comparing this total with the maximum permitted number (method of attributes).

Until such times as sufficient test results are available to apply the method of control described in (vii) below, the compressive strength of the concrete at 28 days shall be such that no single result nor the average value of any three consecutive results is less than the value shown in Table 2.4.

Table 2.4: Compressive strength conformity criteria of BS EN 206

Production	**Number of test results for compressive strength in Group** (n)	**Mean of n results** f_{cm} (N/mm^2)	**Any individual test result** f_{ct} (N/mm^2)
Initial	3	$\geq f_{ck} + 4$	$\geq f_{ck} - 4$
Continuous	> 15	$\geq f_{ck} + 1{,}48\ \sigma$	$\geq f_{ck} - 4$

(vii) When test results are available for at least 15 consecutive batches of any class of concrete mixed in any one plant, the mean of any three consecutive results at 28 days shall exceed the characteristic strength by the value indicated in Table 2.4 (column 3) and no individual result shall be less than the value indicated in the individual test result column of Table 2.4 (column 4).

The standard deviation (σ) shall be calculated from at least 15 separate consecutive batches produced from one plant over a period exceeding five days but not exceeding six months or on at least 50 separate consecutive batches produced from one plant over a period not exceeding 12 months. If both figures are available, the smaller shall be taken.

The current margin shall in any case not be less than the figure given in Table 2.5 below.

Table 2.5: Current Margins

	Minimum Current Margin		
Nominal Concrete Strength	**10 N/mm^2**	**15 N/mm^2**	**20 N/mm^2 and above**
After 20 batches	3.3	5.0	7.5
After 50 batches	1.7	2.5	3.8

2.10.3 Failure to comply with requirements

If any one strength test result in a group of three consecutive results is less than the individual value in Table 2.4 but the mean of the group of which it is part satisfies the strength requirement, then only the batch from which the failed cube was taken shall be deemed not to comply with the Specification.

If more than one result in a group of three consecutive results is less than the individual value in Table 2.4, or if the mean strength of the group fails to satisfy the strength requirement then all the batches between those represented by the first and last strengths in the group shall be deemed not to comply with the Specification, and the Contractor shall immediately adjust the mix design subject to the approval of the

Engineer to restore compliance with the Specification. After adjustment of the mix design the Contractor will again be required to comply with Sub-Clauses 18.5.2 and 18.5.3 of the Specification.

The Contractor shall take necessary action to remedy concrete that does not comply with the Specification. Such action may include but is not necessarily confined to the following:

(i) Increasing the frequency of sampling until control is again established.

(ii) Carrying out non-destructive testing such as load tests on beams.

(iii) Cutting test cores from the concrete and testing in accordance with BS EN 12504-1.

(iv) Where there is still non-compliance with the confirmation tests, the Contractor may carry out strengthening or other remedial work to the concrete where possible or appropriate with the approval of the Engineer.

(v) Otherwise the concrete shall be removed.

2.11. Grout

The fluidity of grout shall be measured with a flow cone, immersion apparatus or viscometer. The instrument shall be accurately calibrated in a laboratory so that the specified viscosity of the grout can be controlled satisfactorily.

The procedure shall be according to ASTM C 939.

The bleeding of grout shall be measured in a metal or glass container with an internal diameter of approximately 100 mm and a height of approximately 120 mm. The grout and water levels in the container shall be controlled with a metal bridge into which two adjustable studs A and B are secured. See Figure 2.1 (at end of the Section) for details of the apparatus.

The procedure for determining the bleeding of grout shall be as follows:

(i) Studs A and B in the metal bridge shall be adjusted and locked so that the distance from the lower tips of the studs to the bottom of the container will be approximately 100 mm and 107 mm respectively. The volumes V_A and V_B for the container at the respective levels of the stud settings shall then be determined to the nearest millilitre.

(ii) The container shall be filled with freshly mixed grout to a level where the grout will just touch the tip of stud A, which points downwards. The bridge shall then be removed and the container tightly sealed to prevent evaporation. The container shall then be stored at 20°C and kept free from vibrations for the entire duration of the test.

(iii) Three hours after the grout has been mixed, the container shall be opened and the free (bleed) water poured off. The bridge shall be placed over the container with the tip of stud B pointing downwards and water poured onto the grout with a measuring apparatus until the water level touches the tip of stud B. The volume of water added shall be determined to the nearest millilitre and designated as ΔV.

(iv) The percentage of bleeding shall be calculated from the following formula:

$$\%Bleeding \quad = \left\{1 - \left(\frac{V_B - \Delta V}{V_A}\right)\right\} \times 100$$

2.12. Silicone Sealants

The following tests on silicone sealants will apply as determined in Subclause 24.6.1.

2.12.1 Bond to cement mortar

Three briquettes, shaped in accordance with AASHTO T 132 and moisture-cured for at least 28 days, are sawn in half, cleaned and dried to a constant mass in an oven at a temperature of 110°C ± 5°C. After having cooled off, they are bonded with approximately 0.25 mm of silicone sealant and tested with clamps which comply with AASHTO T 132.

They are tested under stress at a loading rate of 7.62 mm/min.

2.12.2 Non-adhesive period

Prepare the specimens in a mould with an area exceeding that of the brass weight described below, and which is 6.35 mm thick. Place a 30 g brass weight with dimensions of 41.28 mm x 25.4 mm x 3.18 mm on a polyethylene strip applied to the sample after the specified curing period. After the weight has been removed, the polyethylene strip is removed by pulling it off at an angle of 90° to the mix and at a rate of 25.4 mm in five seconds. No material may adhere to the polyethylene while it is non-adhesive.

2.12.3 Deformability and adhesion

Prepare concrete blocks of 25.4 mm x 25.4 mm x 76.2 mm in accordance with ASTM C 719. A sawn surface is used as the bonding surface. Seal 50.8 mm of the block and leave 12.7 mm at each end of the specimen unsealed. The sealant shall be 9.5 mm thick and 12.7 mm wide. Cure the specimen for seven days in air at 25°C ± 1.7°C, and for seven days in water at 25°C ± 1.7°C. Subject the sealant to deformation in accordance with ASTM C 719. The ductility or compressive rate shall be 3.18 mm per hour. One cycle is defined as extension to a width of 25.4 mm and returning to the initial width of 12.7 mm.

2.13. Bituminous Binders

2.13.1 Samples and sampling

Sampling of straight-run and cutback bitumens shall be carried out in accordance with AASHTO T 40 (ASTM D 140).

Sampling of bitumen emulsion shall be carried out in accordance with BS 434: Part 1, except that where a delivery is made in drums or barrels, the number of samples shall be as indicated in AASHTO T 40 (paragraph 11.1 in ASTM D 140)

2.13.2 Standard methods of testing

(a) Straight-run bitumen

Tests on straight-run bitumen shall be carried out in accordance with the following test procedures:

Penetration	AASHTO T 49 (ASTM D 5)
Viscosity	AASHTO T 316 (ASTM D 4402)
	(NB. some differences exist between these two tests)
Softening point (Ring and Ball)	AASHTO T 53 (ASTM D 36)
Flash and fire points (Cleveland open cup)	AASHTO T 48 (ASTM D 92)
Loss on heating	AASHTO T 47 (ASTM D 6)
Ductility	AASHTO T 51 (ASTM D 113)
Water	AASHTO T 55 (ASTM D 95)
Thin film oven test	AASHTO T 179 (ASTM D 1754)
Solubility in organic solvents	AASHTO T 44 (ASTM D 2042)
Specific gravity	AASHTO T 228 (ASTM D 70)

(b) Cutback bitumen

Tests on cutback bitumen shall be carried out in accordance with the following procedures:

Kinematic viscosity	AASHTO T 201 (ASTM D 2170)
Flash point (Tag open cup)(RC-MC)	AASHTO T 79 (ASTM D 1310)
Flash point (Cleveland open cup) (SC)	AASHTO T 48 (ASTM D 92)
Distillation	AASHTO T 78 (ASTM D 402)
Water	AASHTO T 55 (ASTM D 95)
Specific gravity	AASHTO T 228 (ASTM D 3142)
Asphalt residue of 100 pen (SC)	(ASTM D 243)
Tests on residue from distillation	
Penetration	AASHTO T 49 (ASTM D 5)
Ductility	AASHTO T 51 (ASTM D 113)
Solubility	AASHTO T 44 (ASTM D 2042)
Viscosity	AASHTO T 201 (ASTM D 2170)

(c) Bitumen emulsion

Tests on bitumen emulsion shall be carried out in accordance with AASHTO T 59 (ASTM D 244) test procedures:

Water Content
Residue and oil distillate by distillation
Residue by evaporation
Consistency :
  Viscosity (Saybolt Furol)
Stability:
  Demulsibility
  Settlement
  Cement mixing
  Sieve test
  Aggregate coating
  Miscibility with water
  Freezing
  Coating ability and water resistance
  Storage stability of asphalt emulsion
Particle charge of cationic emulsified asphalts
Examination of residue
Identification test for rapid setting cationic emulsified asphalt
Identification of cationic slow set emulsions
Field coating test on emulsified asphalts
Emulsified asphalt/Job aggregate coating test
Density of emulsified asphalt
Residue by low temperature vacuum distillation

2.14. Bituminous Mixes

2.14.1 Samples and sampling

Sampling of bituminous mixtures shall be carried out in accordance with AASHTO T 168 (ASTM D 979).

2.14.2 Standard methods of testing

Tests on bituminous mixtures shall be carried out in accordance with the following test procedures.

Moisture and volatile distillates	AASHTO T 110 (ASTM D 1461)
Quantitative extraction of bitumen	AASHTO T 164 (ASTM D 2172)
Bulk specific gravity of compacted mixture	AASHTO T 275 (ASTM D 1188) or AASHTO T 166 (ASTM D 2726)
Recovery of bitumen from solution	AASHTO T 170 (ASTM D 1856)
Coating and stripping	AASHTO T 182 (ASTM D 4867)
Degree of particle coating	AASHTO T 195 (ASTM D 2489)
Theoretical maximum specific gravity	AASHTO T 209 (ASTM D 2041)
Marshall stability	AASHTO T 245

2.15. Geotextiles

Geotextiles shall be supplied with Manufacturers certification of compliance with ASTM D 4759.

2.16. Concrete/sandcrete paving blocks

Precast paving blocks from concrete shall comply with SABS 1058 and sandcrete blocks shall comply with GS 297. The latter shall have a minimum strength of 7 N/mm^2 when used for erosion protection works (Section 8.14).

2.17. Trials to Confirm Compliance with Specifications

2.17.1 Laboratory trials

Laboratory trials shall be carried out by the Contractor and submitted to the Engineer for acceptance on earthwork and pavement materials that are to be used in the Works in their natural state to establish a relationship between their specified end product requirements and properties which can be readily determined in the field for construction control purposes.

Laboratory trial mixes and site trials for bituminous mixes shall be carried out in accordance with the requirements of Section 17 of this Specification.

For mixed materials, the composition that meets the specified requirements shall be used in site trials. Laboratory trials on mixed materials shall be undertaken, and the Contractor's proposals based thereon submitted to the Engineer at least two weeks before the site trials. The number and type of testing shall depend on the mixture application and shall be as specified in the Special Specification.

2.17.2 Site trials

Full scale laying and compaction trials shall be carried out by the Contractor on all earthwork and pavement materials proposed for the Works using the plant and methods proposed. The trials shall be carried out in the presence of the Engineer.

The trials shall demonstrate the suitability of the mixing and compaction equipment to provide and compact the material to the specified density and to confirm that the other specified requirements of the completed earthwork or pavement layer can be achieved.

For any specified compaction effort, each trial shall be at least 100 m long and to the full construction width and shall be laid to the depth specified for the material. It may form part of the Works provided it complies with the Specification.

The Contractor shall allow in his programme for conducting site trials and for carrying out the appropriate tests. The trial on each pavement layer shall be undertaken at least 21 days prior to full scale work starting, at a location to be agreed with the Engineer.

The Contractor shall compact each section of trial area over the range of compactive effort proposed and, if appropriate, the following data shall be recorded and reported for each level of compactive effort at each site trial:-

(i) The composition and grading of the material before the site trial.

(ii) The composition and grading of the material including the cement, lime or bitumen content.

(iii) The moisture content at the time of compaction and the optimum moisture content for the specified compaction.

(iv) The type, size, tyre pressures, amplitude and frequency of vibration and the number of passes of the compaction equipment.

(v) The maximum dry density or target density as appropriate measured on a sample before and at intervals through the site trials.

(vi) The density achieved using nuclear density measurements that have been calibrated against sand replacement densities for that material.

(vii) The compacted thickness of the layer.

(viii) Any other relevant information as directed by the Engineer.

At least eight sets of tests (each set including all of the relevant test properties defined above) shall be made by the Contractor and submitted to the Engineer for acceptance on each 100 m of trial for each level of compactive effort and, provided all eight sets of results over the range of compactive effort proposed by the Contractor meet the specified requirements for the material, the site trial shall be deemed successful. The above data recorded in the trial shall become the agreed basis on which the particular materials shall be provided and processed to achieve the specified requirements.

If, during the execution of the Works, the construction control tests indicate that the requirements for a material are not being consistently achieved, then work on that layer shall stop until the cause is investigated by the Contractor. Such investigation may include further laboratory and site trials on the material to determine a revised set of data as above which, when agreed, shall be the basis on which all subsequent material will be provided and processed to achieve the specified requirements.

Approval by the Engineer of a set of data recorded in a site trial shall not relieve the Contractor of any responsibility to comply with the requirements of the Specification and the Special Specifications.

2.18. Construction Control Testing for Earthwork Layers, Pavement Layers, and Backfill to Drainage Works and Structures

All earthwork and pavement layers and backfill to drainage works and structures will be subject to construction control testing by the Engineer, and the Contractor shall allow for any disturbance or delays to the sequence of his operations occasioned by such control testing.

The Contractor shall request, in writing, the Engineer's approval for each layer of each section of subgrade and pavement construction and backfill to drainage works and structures. Such requests shall be made only when the Contractor is fully satisfied that the section of the work concerned is in the condition required by the Specification. Such requests shall be accompanied by the Contractor’s test results for that section. Provided the visual aspects are satisfactory the Engineer shall test the section of the works submitted and inform the Contractor in writing of the results of the tests at the same time accepting or rejecting the section or layer concerned.

Work on layers shall under no circumstances commence until the preceding layer has been approved and accepted by the Engineer in writing. The Contractor is wholly responsible for protecting and maintaining the condition of the work that has been submitted for approval.

Should any layer be left unprotected for more than 24 hours subsequent to approval, the Contractor shall request re-approval of the layer and the layer will again be subject to proof rolling, construction control testing, and tolerance checks in accordance with the Specification.

Notwithstanding the Engineer's approval of a layer, the Contractor shall be responsible for making good any subsequent damage due to traffic, ingress of water or any other cause and should any damage occur, the layer will again be subject to proof rolling, construction control testing and tolerance checks in accordance with the Specification.

2.19. Load test on foundation piles

The head of the test pile shall be exposed for checking position and slope. Where necessary, the head shall be cut further back so as to expose a full bond length of main reinforcing steel, and a suitable pile head slab for applying an axial load to the pile shall be cast. As an alternative, the head may be cut at right angles and the load applied directly to the pile.

The test load shall be applied to the top of the pile with a hydraulic jack. Where more than one jack is used for applying the load, all the jacks in the circuit shall be activated by the same pumping unit. The jack(s) shall be placed so as to ensure that the load is applied axially.

The applied load shall be calculated in accordance with the hydraulic pressure which is being monitored by two pressure meters in the circuit. The pressure meter shall be calibrated in divisions not exceeding 2% of the maximum pressure applied, and the range of the meters shall not exceed 150% of the maximum pressure. The jack(s) and meters shall be calibrated by an approved testing laboratory not more than four weeks before the tests will commence.

The deflection of the pile head shall be measured with two scale rulers and two dial extensometers. The scale rulers shall be fixed to the pile and placed on both sides of the pile on a diameter line, and the dial extensometers shall be similarly placed but on a diameter line at right angles to that in which the scale rulers have been mounted.

Level measurements shall be taken on the scale rulers, and reduced as a level mark to a similar scale ruler placed at a distance from the test pile. All three scale rulers shall be calibrated in millimetres and the level-indicating instrument shall be capable of taking readings to 0.5 mm, and approximate readings of up to 0.1 mm.

The dial extensometers shall have a range of 50 mm, and shall be marked in 0.1 mm divisions to enable measurements to 0.05 mm to be taken. The plungers of the extensometer shall rest on a machined metal or glass surface.

The extensometers shall be supported by one or more beams kept in the shade. The supports for the beams shall be so placed as to limit the effect of earth movements around the test pile on the deflection readings.

The test load shall be applied in increments of 20% of the specified working load to a maximum test load equal to twice the specified working load or the ultimate test load, whichever is the smaller. A load increment may not be applied before the subsidence or heave rate has stabilized at a rate of not more than 0.10 mm in 20 minutes under the load applied. After the loading has been completed, the maximum test load shall be maintained until the movement is less than 0.2 mm within a period of 24 hours. The load shall be removed in decrements of 20% of the specified working load at intervals of not less than 20 minutes.

After the load has been removed, the readings on both meters registering the movement of the pile shall be recorded accurately to 0.1 mm, at intervals of 5, 10 and 20 minutes, and then every 30 minutes until the load is changed. The final recovery shall be recorded 24 hours after the maximum test load has been removed.

During the test, the pile shall be loaded with up to 100% of the specified working load, and the load shall then be removed. It shall then be loaded to the maximum test load after which the test load shall be removed.

2.20. Frequency of Testing

The frequency at which the Contractor shall undertake construction control tests on the earthwork layers, pavement layers and backfill to drainage works and structures shall depend on the quality control method, as approved by the Engineer. Where a statistical judgement plan is used, the details in Section 2.21 shall apply. If not the frequency of testing shall be as follows:

(a) Original ground

The MDD and OMC according to GHA S1 shall be determined for each new material encountered, and at intervals of at least once per 1 000 m^2 on compacted ground but at a maximum interval of 200 m along the alignment. Field dry density shall be determined once every 1 000 m^2 at points as close as possible to those from which the corresponding laboratory MDD samples were obtained.

(b) Bulk earthworks

The GHA S1 MDD and OMC shall be determined for each new material encountered, and at intervals of at least once per 1 000 m^3 of compacted material placed. The field dry density shall be determined at least once per 250 m^3 of compacted material placed or at least three tests per section, whichever is the more frequent. Testing shall be at points as close as possible to those from which the laboratory MDD samples were obtained.

(c) Upper 300 mm of earthworks

The GHA S1 MDD and OMC shall be determined for each new material encountered, and at intervals of at least once per 250 m^2 of each layer of compacted subgrade.

The field dry density shall be determined at least once per 250 m^2 of each layer of compacted subgrade but with a minimum of three tests per section. Testing shall be at points as close as possible to those from which the laboratory MDD samples were obtained.

The soaked CBR of material in the upper 300 mm of earthworks shall be determined at least once per 2 000 m^2 of each layer.

(d) Backfill/fill to culverts and structures (including excavated surfaced to receive culvert or structure)

The GHA S1 MDD and OMC shall be determined for each new material encountered.

The field dry density shall be determined at least twice per 10 m^3 of material placed and compacted but with a minimum of two tests per section.

(e) Gravel wearing course

The GHA S1 MDD and OMC shall be determined for each new material encountered and at intervals of at least once per 350 m^2 of each layer of compacted material.

The field dry density shall be determined at least once per 350 m^2 of each layer of compacted material but with a minimum of three tests per section. Testing shall be at points as close as possible to those from which the laboratory MDD samples were obtained.

The soaked CBR and Plasticity Index of material used for gravel wearing course shall be determined on opening up each new source of material and at least once per 150 m^3 of compacted material taken from that source. The grading of the material shall be determined at least once per 300 m^3 of compacted material.

(f) Natural materials in subbase and base

The GHA S1 MDD and OMC shall be determined for each new source of subbase or base course material used and at intervals of at least once per 350 m^2 of each layer of compacted subbase or base course laid.

The field dry density shall be determined at least once per 350 m^2 of each layer of compacted subbase or base but with a minimum of three tests per section. Testing shall be at points as close as possible to those from which the laboratory MDD samples were obtained.

The soaked CBR and Plasticity Index of gravel for subbase or base shall be determined on opening up each new source of gravel and at least once per 75 m^3 of compacted gravel taken from that source.

The ACV, LAA and 10% Fines of a gravel used for base and subbase shall be determined on opening up each new source of gravel and whenever the Engineer considers that its quality may have altered. The grading and Plasticity Modulus shall be determined at least as often as the CBR.

(g) Crushed stone subbase and base

The MDD (Vibrating Hammer Method GHA S4) of Class D crushed stone (Section 13.3) and the Apparent Density (GHA S3) of Class A, B and C graded crushed stone (Section 13.3) shall be determined at least once per 2 000 m^2 of each layer of compacted subbase or base course laid.

The field dry density shall be determined at least once per 350 m^2 of each layer of compacted subbase or base but with a minimum of three tests per section. Testing shall be at points as close as possible to those from which the laboratory MDD or Apparent Density samples were obtained.

The LAA, ACV, (or 10% Fines) and CBR shall be determined on opening up and crushing material from each new source for subbase or base and whenever the Engineer considers that the material has altered.

The grading, PI and Flakiness Index (FI) of crushed materials for subbase or base shall be determined at least once per 300 m^3 of material produced.

(h) Cement or lime treated materials in subgrade, subbase and base

The GHA S1 MDD and OMC shall be determined for each new treated material used for subgrade and at intervals of at least once per 1500 m^2 of each layer of compacted subgrade.

The GHA S1 MDD and OMC shall be determined for each new treated material used for subbase or base and at intervals of at least once per 350 m^2 of each layer of compacted treated subbase or base layer.

The field dry density shall be determined at least once per 350 m^2 of each layer of compacted treated subgrade, subbase or base course, but with a minimum of three tests per section. Testing shall be at points as close as possible to those from which the laboratory MDD samples were obtained.

The following properties shall be determined on opening up of each new source, and when, in the opinion of the Engineer, the nature of the material has changed and once per 300 m^3 of subbase or base laid and compacted:

Grading
Atterberg Limits
CBR or UCS as indicated in the Special Specification.

(i) Bituminous surface treatments

(i) Aggregates, sand, gravel

The properties listed below, as appropriate to the type of surface treatment specified, shall be determined on opening up of each new source and when the Engineer considers that the properties may have altered but also at least once every two weeks:-

FI
LAA
10% Fines
PI
Sand Equivalent
ALD

The properties listed below, as appropriate to the type of surface treatment specified, shall be determined twice daily when surface dressing or slurry seal work is in progress:-

FI
Grading
Angularity
Cleanliness
PI
Deleterious matter
Spread Rate (Tray Test or other means)
Sand Equivalent

(ii) Binder

Compliance with Clause 2.13 of this Specification shall be determined once per 20 000 litres delivered to Site, or as otherwise directed by the Engineer.

Binder spray rate shall be determined once per section sprayed. The rate of application of slurry seal shall be determined once per load of slurry applied.

(j) Bituminous mixes

(i) Aggregates

The aggregate properties listed below, as appropriate to the type of mix specified, shall be determined on opening up of each new source of aggregate, every second week and whenever the Engineer considers that the aggregate properties may have altered:

Grading
LAA
10% Fines
FI
Sand Equivalent
Uniformity Coefficient
Atterberg Limits
Soluble Salts and Deleterious Matter
Bulk and Apparent Specific Gravity and Absorption in the mixed aggregate
Voids

The grading of cold and hot feed mixed aggregates shall be determined at least once per day during mixing.

(ii) Mineral filler

The grading and bulk density in toluene shall be determined once per 100 tonnes of filler used, and when the source of filler is changed.

(iii) Bituminous mixture (from the mixing plant)

The properties of the bituminous mixture, as appropriate to the type of mix specified shall be determined every 4 hours or part thereof of mixing time on samples taken from the mixing plant:

Bitumen Content
Grading
Marshall Stability
Flow
Voids
Water absorption

(iv) Bituminous mixture (on cores from the compacted layer)

The properties of the bituminous mixture, as appropriate to the type of mix specified, shall be determined at least once for every 1 000 m^2 of mix laid from core samples cut from the compacted layer:

Bitumen Content
Grading
Density
Voids
Thickness

Table 2.6 summarises typical lot (section) and sample sizes used in practice.

Table 2.6: Typical lot and sample sizes

Element	Property	Lot size	Sample size (n)
Earthworks	Density and thickness	12 000 m^2	4
	Indicator tests	12 000 m^2	4
Selected layers	Density and thickness	12 000 m^2	4
	Indicator tests	12 000 m^2	4
Subbase	Density and thickness	10 000 m^2	5
	Indicator tests	10 000 m^2	4
Gravel base	Density and thickness	9 000 m^2	6
	Indicator tests	9 000 m^2	5
Crushed stone base or subbase	Density and thickness	6 000 m^2	6
	Indicator tests	9 000 m^2	6
Treated layers	Binder content	10 000 m^2	20

2.21. Statistical Quality Control

This statistical quality control scheme is used for determining, by means of tests and measurements and by applying statistical judgement plans, whether certain requirements in regard to the properties of materials and workmanship are being complied with. It also covers the requirements in regard to the control to be exercised by the Contractor for monitoring the quality of his work and materials and the routine tests and inspections to be carried out by the Engineer and its use will be specified in the Special Specification.

2.21.1 Judgement plans: General

Certain requirements and limit values are laid down in the Specifications in regard to the properties of materials and workmanship to be supplied. Tests shall be conducted and measurements taken for controlling the relevant properties of the workmanship and materials supplied, and the results of such tests and measurements shall be assessed on the basis of the prescribed criteria for compliance with the specified requirements.

Wherever possible, acceptance criteria shall be determined by way of statistical principles described in this Section. Wherever impracticable and where no statistical judgement criteria have been prescribed, the specified requirements and limit values shall be fully complied with.

Despite acceptance of those properties judged by these statistical methods, the materials or work submitted will be rejected when other properties (which are not controlled by statistical methods) fail to comply with the requirements of the Specifications, or where there are other causes for rejection such as obviously defective workmanship or excessively variable properties, visible signs of poor workmanship, and similar considerations which constitute sufficient grounds for rejecting the work without any further testing.

The Engineer shall be entitled to assess separately any specified portion of a lot if, in his opinion, it exhibits significant deviations as compared with the remainder of the lot.

In order not to change the Contractor's or the Employer's risks, the statistical judgement plans shall be strictly adhered to in all cases where they are used, and decisions based on these plans shall not be altered. It shall be a condition of the Contract that the theoretical validity of the various statistical judgement plans be accepted and that the validity of the decisions made on the basis of these judgement plans cannot be disputed on the grounds of statistical theory or a specified or implied producer's risk, or unjust on the grounds of enrichment.

2.21.2 Definitions

For the purposes of this Section the following words and symbols shall have the following meanings:

(a) Lot

A lot is a sizeable portion of work or quantity of material which is assessed as a unit for the purposes of quality control, and selected to represent material or work produced by essentially the same process and from essentially the same materials.

(b) Random sample

A random sample is a group of "n" test measurements at "n" separate test positions or on "n" sample portions obtained from the lot in an unbiased manner. Random sampling shall mean stratified random sampling, unless inconsistent with the context.

(c) Sample mean ($\bar{x}_n$)

$\bar{x}_n$ is the arithmetic mean of a set of "n" test results constituting the sample.

(d) Sample standard deviation (S_n)

The sample standard deviation S_n is defined by:

$$S_n \equiv \sqrt{\frac{\Sigma x^2 - n\bar{x}_n^{\,2}}{n-1}}$$

where $\bar{x}_n$ is the sample mean

x is the value of an individual sample portion, ie, an individual test result or measurement n is the sample size, ie, the number of individual test results or measurements.

(e) Specification limit (L_s)
This is the limit value of the property of any product outside which not more than a specified percentage (φ) of the population of values representing an acceptable product property is allowed to lie. The specification limit may be a single lower limit L_s, or a single upper limit L'_s, or a double limit consisting of a lower limit L_s and an upper limit L'_s.

(f) Acceptance limit for sample mean (L_a)
This is the limit value of a product property within which the sample mean shall lie for a product to be acceptable. For a lower-limit specification, this acceptance limit is denoted by L_a. For an upper-limit specification, this acceptance limit is denoted by L'_a. For a double-limit specification, the lower and upper limits are denoted by L_a and L'_a.

(g) Acceptance limits for individual test values (L_e)
These are the limit values of a product property within which the sample values representing a product shall lie for the product to be acceptable. The limit values will depend on the sample sizes "n" and may be a lower limit L_e, an upper limit L'_e, or double limits L_e and L'_e.

(h) Conditional acceptance
This is the acceptance of a lot at reduced payment in lieu of rejection. Conditional acceptance shall be subject to the provisions of Clause 2.21.6.

(i) Outliers
Where, in a sample, one or more test results differ significantly from the other values obtained, this difference could be ascribed to an assignable cause, in which case such test result shall be regarded as an outlier and disregarded when assessing the lot.

To determine whether or not a test result is an outlier, the method given in Subclause 2.21.3(d) shall be adopted.

(j) First submission
The submission of a lot for approval will be classified as a first submission when actually submitted for the first time or when submitted for a second time on the basis of a second set of test values which shall be regarded as a first submission in terms of Subclause 2.21.3(e), because the properties of the first and the second sets of test values differ significantly.

(k) Resubmission
The submission of a lot for approval for a second time shall be classified as a resubmission should it be regarded as a resubmission in terms of Subclause 2.21.3(e), as the properties of the first and second sets of test values do not differ significantly.

(l) Payment-reduction factor (f_r)

This is the factor by which payment at Contract rates shall be multiplied for calculating payment for conditionally accepted work.

2.21.3 General Requirements

(a) Determining the lot size

(i) Road-construction layers

The lot size shall normally be a section compacted in one process where essentially the same materials and construction equipment have been used. Where production is on a continuous basis, a lot shall normally mean the product of one day's work and shall not exceed the product of two full days' work. However, a lot of any smaller size may be ordered by the Engineer where:

- the properties under investigation exhibit abnormal local variation within the normal lot size;
- an area is obviously of a different quality than the rest;
- the rate of production is very high.

(ii) Concrete

The lot size shall be determined by the Engineer, with due regard being given to the size and the type of structure in which the concrete is placed, the specific portion of the structure, and the total quantity of concrete placed in a day. The lot sizes in concrete structures could therefore vary considerably, and, particularly in the case of small structures, it could be necessary to combine samples of the same grade of concrete from different structures, provided that the concrete has been obtained from the same concrete plant and has been cast in the same period.

(iii) Other

In other cases, as for example in material stockpiles where the definition of a lot in accordance with Subclause 2.21.2(a) does not apply directly, the Engineer will determine lot sizes in accordance with circumstances pertaining to each case.

(b) Random sampling

When any lot is tested, whether a normally sized lot or an isolated section which clearly exhibits an abnormal variation of the properties under consideration, all samples shall be taken in a stratified random pattern. For this purpose use shall be made of tables of random numbers (Appendix 2-A).

(c) Sample sizes

For purposes of acceptance control, the Engineer will, in advance, determine sample size "n". The larger the sample, the more reliable the result will be, and no sample sizes may be smaller than those given in Clause 2.21.4.

(d) Outliers

Test results shall be scanned for possible outliers. Where there is reason to believe that a test result may be erroneous it shall, if possible, be re-examined by further testing, and, if there is reasonable evidence to suggest that the test result is erroneous, it shall be regarded as an outlier, rejected, and replaced with a fresh test result. Where repeating a test or re-examining a test result is impossible, the method described below shall be used for identifying outliers:

Calculate the value of T_o from

$$T_o = \frac{x_o - \bar{x}_n}{S_n}$$

where

$\bar{x}_n$ = arithmetic mean
S_n = sample standard deviations
x_o = value of the test result differing most from the mean.

Compare the value of T_o with the value of T for the applicable value of "n", from Table 2.7.

Table 2.7: Critical values (T)

No of observations (n)	Critical values (T)
4	1.46
5	1.67
6	1.82
7	1.94
8	2.03
9	2.11
10	2.18
11	2.23
12	2.29
13	2.33
14	2.37
15	2.41
16	2.44
17	2.47
18	2.50
19	2.53
20	2.56

If the absolute value of T_o is greater than T, then x_o is an outlier.

(e) Resubmission
Where a lot has been accepted conditionally or has been rejected, the Engineer may agree to its resubmission for approval if:

(i) it has been reworked and the Engineer is satisfied that a proper attempt was made to improve the properties which were unacceptable; or

(ii) where, in his opinion there are valid technical reasons therefore.

In both cases a fresh sample shall be taken, and a fresh (second) set of test values determined. The first and second sets of test values shall then be compared with each other to determine whether their properties differ significantly.

Where in the opinion of the Engineer a significant difference does occur, the submission of the lot shall be regarded as a first submission and assessed as such, and only the second set of test values shall then be used for this purpose.

Where in the opinion of the Engineer no significant difference occurs, the submission of the lot shall be regarded and assessed as a resubmission. Where a lot is resubmitted, it shall be assessed on the same basis as a first submission, except that the original and the second set of sample results shall be combined for purposes of assessment.

2.21.4 Procedures

The statistical judgement procedures described below will apply to the corresponding product properties for purposes of acceptance control.

(a) Surface levels of fills and pavement layers
At least 50, but preferably more, level measurements shall be taken according to a stratified random pattern of each lot of completed layer work, and the specified levels shall then be determined. Outliers shall be identified and examined. The lot will be considered to comply with the requirements in respect of surface levels if, before any repair work is undertaken, at least 90% of the level measurements show a deviation from the specified levels which is smaller than the H_{90} tolerance specified in the relevant sections in regard to each layer. Isolated spots, where the surface levels deviate by more than the appropriate H_{max} tolerance of the specified levels shall be repaired to bring the deviation to within the H_{90} tolerance.

(b) Layer thicknesses of pavement layers
At least 30, but preferably more, layer thicknesses shall be determined in accordance with a stratified random pattern for each lot of completed layer work. Layer thicknesses may be determined by means of level measurements taken before and after construction of the layer in exactly the same position, but may be augmented by thicknesses measurements taken by means of holes made in the layer. In the case of asphalt layers, the Engineer may require thickness determinations to be made only by means of measurements on drilled cores, in which case the minimum number of cores per lot shall be 20 instead of 30.

Outliers shall be identified, disregarded, and, if possible, replaced and the average thickness of the layer ($\bar{D}$) calculated.

The lot will be considered to comply with the requirements for layer thicknesses if :

(i) at least 90% of all the thickness measurements taken before any thickness repairs are made are equal to or greater than the specified thickness, minus the D_{90} tolerance specified in the appropriate section; and

(ii) the average layer thickness ($\bar{D}$) of the lot is not less than the specified thickness (D), minus the $D_{average}$ tolerance, ie, $\bar{D} \not< D - D_{average}$

Isolated spots where the actual thickness is less than the specified thickness minus the D_{max} tolerance shall be repaired so as to fall within the D_{90} tolerance.

(c) Relative compaction of pavement layers

At least four relative density determinations shall be taken in the case of selected layers and at least six in the case of all other pavement layers in accordance with a random pattern. After outliers have been examined and replaced, compliance with the specified density requirements shall be determined as in Table 2.8.

Table 2.8: Acceptance limits in respect of compaction

Layer	Prescribed density	Unit of measurement	Minimum average density for the following sample sizes						Minimum value for any single test for the following sample sizes					
			4	5	6	7	8	9	4	5	6	7	8	9
Selected layer	90%	GHA S1	90.1	90.4	90.6	90.7	90.9	91.0	86.4	86.2	86.0	85.9	85.8	85.7
	93%	GHA S1	93.1	93.4	93.6	93.7	93.9	94.0	89.4	89.2	89.0	88.9	88.8	88.7
	95%	GHA S1	95.1	95.4	95.6	95.7	95.9	96.0	91.4	91.2	91.0	90.9	90.8	90.7
	100%	GHA S1	100.1	100.4	100.6	100.8	100.9	101.0	96.4	96.2	96.0	95.9	95.8	95.7
Subbase	95%	GHA S1	95.1	95.4	95.6	95.7	95.9	96.0	91.4	91.2	91.0	90.9	90.8	90.7
	96%	GHA S1	96.1	96.4	96.6	96.7	96.9	97.0	92.4	92.2	92.0	91.9	91.8	91.7
	97%	GHA S1	97.1	97.4	97.6	97.7	97.9	98.0	93.4	93.2	93.0	92.9	92.8	92.7
Gravel base	100%	GHA S1	100.1	100.4	100.6	100.7	100.9	101.0	96.4	96.2	96.0	95.9	95.8	95.7
	98%	GHA S1	98.1	98.4	98.6	98.7	98.9	99.0	94.4	94.2	94.0	93.9	93.8	93.7
	97%	GHA S1	97.1	97.4	97.6	97.7	97.9	98.0	93.4	93.2	93.0	92.9	92.8	92.7
Crushed-stone base and subbase (Class A, B, C)	88%	Particle density (GHA S3)	88.1	88.4	88.5	88.7	88.8	88.9	84.7	84.6	84.4	84.3	84.2	84.1
	86%	Particle density (GHA S3)	86.1	86.4	86.6	86.7	86.9	87.0	82.4	82.2	82.0	81.9	81.8	81.7
Asphalt base and surfacing	100%	(97 - design voids in mix) % of max theoretical density OR 97% of Marshall density[a]	100.1	100.3	100.5	100.6	100.7	100.8	97.1	96.9	96.8	96.7	96.6	96.5
Shoulders and wearing course	93%	GHA S1	93.2	93.6	93.8	94.0	94.2	94.3	87.9	87.6	87.4	87.2	87.0	86.9
	95%	GHA S1	95.2	95.6	95.8	96.0	96.2	96.3	91.4	91.2	91.0	90.9	90.8	90.7

Note a: As the design density of asphalt is usually a function of the voids in the final mix, varying between 3 and 7% for surfacing asphalt concrete and 4 and 8% for dense bitumen macadam (see Chapter 17), the compaction specification is expressed as a function of the voids, typically 97-design voids as a percentage of maximum theoretical density (G_{mm}) in mix. The compaction control above thus takes the design density as 100% of this specification and specifies the average and minimum on this basis.

The sample mean $\bar{x}_n$ shall be at least equal to or higher than the acceptance limit (L_a) for the sample mean as given in Table 2.8, and no single test value shall be lower than the acceptance limit (L_e) for single values.

(d) Cementitious-binder content of stabilized layers and uniformity of mix

(i) Method

Take 50 samples according to a random pattern and determine their cementitious-binder content. Examine the results for outliers and replace them if any.

(ii) Analysis

The test results shall be adapted to make provision for the presence of minerals, which may affect the test results, in the raw material to be stabilized. If the standard deviation of the natural CaO plus MgO content of the raw material exceeds 0.35%, any determination of the cementitious binder content shall be ignored.

The quantity of cementitious binder in the mixed material determined by taking 50 samples per lot and testing them as specified shall fall within the following limits:

(1) The mean cementitious-binder content shall be not less than 91% of the specified binder content.
(2) The cementitious binder content in not more than 12 of the 50 samples may be lower than 70% of the specified binder content.

The requirements for uniformity of the mix shall apply only on condition that the variation of these adjustments falls within the limit specified for the CaO plus MgO above.

(e) Binder content of asphalt

(i) Method

Take at least four specimens of asphalt in a random pattern and determine the binder content. Examine the results and replace any outliers as specified.

(ii) Analysis

Determine the sample mean and assess the lot by using the following criteria:

The binder content of asphalt mixes shall not deviate from the specified binder content by more than the values given in Table 2.9.

Table 2.9: Acceptance limits for bituminous binder content

Sample size (number)	Maximum deviation of the sample mean from the specified binder content (% of binder)	Maximum deviation of any single test value from the specified binder content (% of binder)
	Continuous and open-graded mixes	
2	0.37	0.54
3	0.33	0.58
4	0.30	0.60
5	0.28	0.62
6	0.27	0.64
7	0.26	0.65
8	0.25	0.66

(f) Concrete : 28-day compressive strength

(i) Method
At least the minimum number of samples given in Table 2.10 shall be taken according to a random pattern and test specimens for compressive strength testing cast.

Table 2.10: Minimum sample sizes for strength concrete (structural)

Volume of lot (m^3)	Minimum sample size
0 - 20	4
21 - 40	6
41 - 70	9
71 - 100	12
101 – 150	14
> 150	16

The specimens shall be tested for compressive strength after 28 days curing. A lot will comply with the requirements for the characteristic strength if it meets the requirements as indicated in Section 2.10 of this Specification.

2.21.5 Controlling More Than One Property

Where more than one property of a lot is being controlled, the lot shall be accepted if all the properties comply with the specified requirements, but if one or more of the properties do not comply with the requirements, the lot shall be rejected, or it may be conditionally accepted subject to the provisions of Clause 2.21.6.

2.21.6 Conditional Acceptance

(a) General
Where a lot is rejected under a statistical judgement plan described in this Section, but the test results are such that the lot complies with the requirements

for conditional acceptance specified hereafter, the Engineer may accept the lot conditionally, that is, the lot may be accepted at reduced payment in lieu of complete rejection, provided that:

(i) conditional acceptance shall be the sole discretion of the Engineer and is not an option which may be exercised by the Contractor or a right he may claim;

(ii) the lot is approved in respect of all other requirements not judged by a statistical judgement plan;

(iii) the Contractor shall have the option to remove and reinstate at his own cost conditionally accepted work with work which complies with the requirements for acceptance at full payment;

(iv) conditional acceptance and the corresponding reduced payment shall apply only in respect of the work and properties listed in Subclause 2.21.6 (b) below.

(b) Properties to which conditional acceptance applies

Conditional acceptance may be applied in respect of the properties of structures listed below in Table 2.11.

Table 2.11: Properties to which conditional acceptance may apply

Property	**Structure**
Relative compaction	(i) Asphalt base or surfacing (ii) Chemically stabilized layers (iii) Plant mixed paver laid layers
Bituminous binder content	Asphalt base or surfacing
Cementitious binder content	Chemically stabilized layers
28-day compressive strength	All structural concrete (except concrete pavements)

Note: Conditional acceptance shall not apply to crushed stone layers, but, where compaction to 88% of apparent density has been specified but cannot be attained, the Engineer may accept the layer at payment at the rate for compaction to 86% of apparent density on condition that the layer complies with the requirements for this compaction standard.

The same provisions shall apply mutatis mutandis where a specified density of 102% of GHA S1 density cannot be attained, but 100% of this density has in fact been attained.

(c) Criteria for conditional acceptance

In terms of the respective judgement plans relating to the properties to which conditional acceptance applies, two requirements shall always apply, viz one in relation to the sample mean ($\bar{x}_n$), and one in relation to individual test values x_n. A lot may be conditionally accepted when it complies with one of the two requirements for acceptance, but not with the second requirement provided that it complies with the requirements for conditional acceptance in relation to the second requirement. There are therefore always two cases:

(i) Case 1

The lot complies with the requirement for sample mean, but not in all cases with the requirement for individual test values.

The lot may be accepted conditionally, subject to the following additional conditions:

(1) In regard to the relative compaction of pavement layers, the bituminous-binder content of asphalt and the concrete cube compressive strength, not more than one test value may not comply with the requirements of individual test values.

(2) In regard to the cementitious-binder content, the binder content may be below 70% of the specified binder content in not more than 12 cases.

(ii) Case 2

The lot complies with the requirements for individual test values but not with the requirements for sample mean.

The lot may be accepted conditionally on condition that the sample mean $\bar{x}_n$ lies within the rejection limit L_r given in Table 2.12.

Table 2.12: Rejection limits (L_r and L'_r) for the sample mean ($\bar{x}_n$)

Property	**Structure**	**Rejection limits (L_r and L'_r)**
Relative compaction	(a) Chemically stabilized layers in accordance with Section 14 (b) Asphalt base or surfacing	$L_r = (L_a - 2.000)$ % relative compaction $L_r = (L_a - 1.000)$ % relative compaction
Compressive strength	All strength concrete (excluding pavement concrete)	$L_r = 0.85\ L_a$
Bituminous binder content %	Asphalt	$L_r = (L_a - 0.200)$ % binder $L'_r = (L'_a + 0.200)$ % binder
Cementitious binder content	Chemically stabilized layers	$L_r = 0.80$ La

(d) Determining the payment reduction factor (f_r)
Where a lot is conditionally accepted, compensation will be reduced by multiplying the tender rates for the items concerned, as set out below, with the payment reduction factor f_r.

The factor f_r is determined as follows in regard to the two cases set out in Subclause 2.21.6(c) above.

(i) Case 1

The lot complies with the requirements for sample mean, but not in all cases with the requirements for single values.

f_r is always taken as being equal to 0.85.

(ii) Case 2

The lot complies with the requirements for single values, but not with the requirements for sample mean ($\bar{x}_n$).

For conditional acceptance at a lower limit

$$f_r = 0.67 + 0.3\left\{\frac{\overline{\bar{X}_n - L_r}}{L_s - L_r}\right\}$$

For conditional acceptance at an upper limit

$$f_r = 0.67 + 0.3\left\{\frac{\overline{L_n' - \bar{X}_n}}{L_r' - L_s'}\right\}$$

(See Subclause 2.21.2 for definitions of symbols).

(e) Applying the payment-reduction factor

The payment-reduction factor shall be applied to the following payment items as may apply and be described in the Specifications.

Chemically stabilized layers
Asphalt base and surfacing
Concrete

No reduction shall apply to payment items for formwork, reinforcing or tendons.

2.22. Process Control by the Contractor

The requirements of this section shall apply in respect of the Contractor's obligation to institute and implement a control system for monitoring the quality of the work and materials supplied.

For continuous concrete and asphalt-production processes, the Engineer may order the Contractor to augment the above control system by introducing a process-control system for monitoring the various properties to be controlled. The specific system to be applied shall be subject to the Engineer's approval.

The Contractor shall take immediate steps to rectify any deviation from the specified requirements indicated by his process-control system, and the Engineer shall have the right to inspect and be given all details of tests and testing procedures in order to satisfy himself that the Contractor is implementing an adequate process-control system.

2.23. Routine Tests and Inspection by the Engineer

The Engineer will at regular intervals inspect and test materials and completed work for compliance with the specified requirements, and, where applicable, the various specified judgement plans will be applied. The testing frequencies and sample and lot sizes for routine testing shall be at the Engineer's discretion.

All sections of completed work shall be submitted to the Engineer for routine inspection and testing, and the Contractor shall not cover up or construct any work on top of sections of completed work before being advised by the Engineer of the outcome of his tests and inspection. The Contractor shall arrange the submission of work for testing in a manner as will afford the Engineer reasonable opportunity for inspecting and testing.

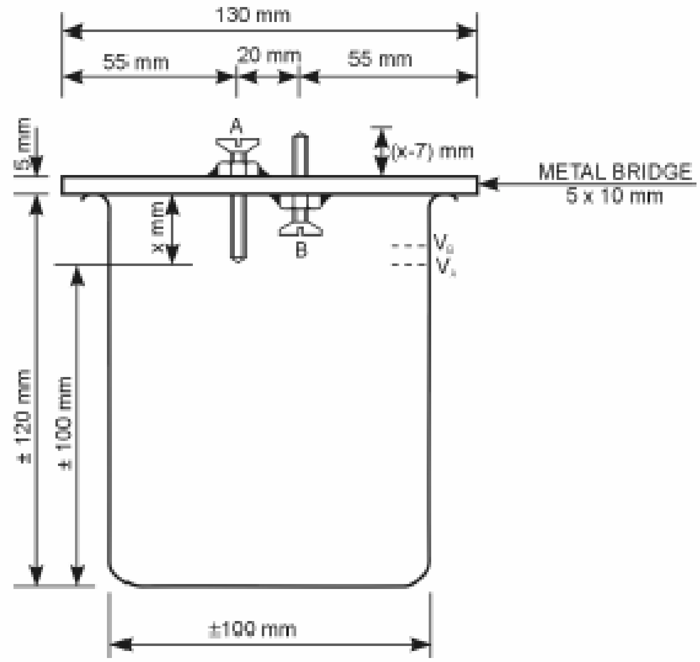


Figure 2.1: Apparatus for determination of bleeding of grout

APPENDIX 2-A: RANDOM SAMPLING FOR ROAD CONSTRUCTION QUALITY CONTROL

2A-1 SCOPE

Random sampling is a statistically oriented process in which samples are taken from a lot in a predetermined pattern so that each part of the lot has an equal chance of being included in the sample. For practical reasons the procedure described here can only be applied to samples taken from a completed layer of a road.

2A-2 CHOICE OF LOT SIZE

By definition a lot of a material is a discrete specific quantity of the material that can for all practical purposes be regarded as a separate entity and which does not inherently vary disproportionately in respect of the determining characteristics.

In the case of a completed pavement layer, the lot size will therefore depend on the characteristic to be tested. For density control, a section that has been processed and compacted in a single operation will count as one lot. With asphalt, for example, a day's work can count as a lot. The choice of lot size will therefore depend on the sampler's judgement, but must comply with the requirements set out in the definition.

2A-3 PROCEDURE

Once the lot size has been decided on, determine the length and width of the section to be tested. The length and width are recorded as L' and W' respectively.

Determine the number of samples to be taken by using the specified sampling frequencies or by referring to Chapters 6 and 7. The number of samples is recorded as N. Starting with the first column of the attached table of random numbers write down the first N pairs of figures.

Calculate $L = L' - 0.40$
$W = W' - 0.40$

Now multiply the length L by every number in the first column, and the width W by every number in the second column of the N pairs of random numbers. Now arrange the product in column 1 in numerical sequence, keeping the pairs of numbers together. These numbers give the test points measured from a point 0.20 m from the beginning of the section along its length, and the corresponding distances measured from a point 0.20 m from the side of the section over the width.

If only the distances along the length are required for a specific sample, only one column is used at a time.

When the next section is to be sampled, the next N pairs of figures are used, and so on until the whole table has been worked through. Thereafter begin again with the first column.

The table is used from the beginning again for each sample type

2A-4 EXAMPLE

Suppose that five laboratory density samples have to be taken and that five field densities have to be measured at the same places on a section of subbase 725 m long and 12.8 m wide.

Now take the first five pairs of random numbers from the table:

0.397	0.040
0.420	0.366
0.631	0.507
0.290	0.081
0.210	0.414

L = 725 - 0.4 = 724.6 m
W = 12.8 – 0.4 = 12.4 m

Multiply the first column of figures by L and the second column by W. This gives:

287.7	0.5
304.3	4.5
457.2	6.3
210.1	1.0
152.2	5.1

The tests are now done and samples taken at:

Distance from beginning of section*	Distance from side*
152.2 m	5.1 m
210.1 m	1.0 m
287.7 m	0.5 m
304.3 m	4.5 m
457.2 m	6.3 m
*Measured in both cases from 0.2 m from the beginning of the side of the section.	

1	0.397	0.040	0.722	0.015	0.373	0.274
2	0.420	0.366	0.622	0.003	0.758	0.207
3	0.631	0.507	0.878	0.001	0.169	0.205
4	0.290	0.081	0.595	0.777	0.215	0.690
5	0.210	0.414	0.837	0.720	0.856	0.305
6	0.436	0.596	0.384	0.659	0.897	0.584
7	0.347	0.940	0.855	0.005	0.083	0.996
8	0.884	0.233	0.322	0.085	0.529	0.144
9	0.424	0.864	0.660	0.748	0.662	0.593
10	0.957	0.765	0.137	0.850	0.550	0.678
11	0.463	0.209	0.250	0.893	0.379	0.724
12	0.884	0.773	0.461	0.962	0.893	0.393
13	0.772	0.255	0.401	0.188	0.929	0.346
14	0.551	0.024	0.157	0.268	0.618	0.096
15	0.432	0.146	0.577	0.015	0.547	0.800
16	0.301	0.723	0.958	0.614	0.008	0.821
17	0.350	0.167	0.215	0.145	0.595	0.181
18	0.951	0.573	0.464	0.996	0.631	0.490
19	0.100	0.098	0.055	0.081	0.443	0.615
20	0.882	0.068	0.380	0.255	0.141	0.261

21	0.652	0.667	0.227	0.993	0.455	0.681
22,	0.143	0.305	0.172	0.304	0.274	0.024
23	0.354	0.264	0.341	0.876	0.777	0.334
24	0.982	0.898	0.999	0.809	0.574	0.842
25	0.231	0.521	0.648	0.687	0.906	0.132
26	0.099	0.245	0.856	0.487	0.870	0.790
27	0.742	0.248	0.664	0.669	0.696	0.463
28	0.195	0.488	0.343	0.874	0.390	0.716
29	0.588	0.519	0.315	0.954	0.530	0.754
30	0.088	0.976	0.363	0.511	0.698	0.964
31	0.103	0.345	0.722	0.830	0.884	0.315
32	0.704	0.940	0.308	0.952	0.309	0.921
33	0.971	0.482	0.261	0.717	0.372	0.556
34	0.787	0.336	0.011	0.899	0.909	0.603
35	0.739	0.384	0.389	0.004	0.650	0.785
36	0.008	0.533	0.784	0.035	0.607	0.103
37	0.669	0.203	0.997	0.342	0.239	0.700
38	0.453	0.564	0.365	0.812	0.505	0.850
39	0.931	0.003	0.772	0.905	0.390	0.925
40	0.149	0.174	0.467	0.526	0.177	0.108
41	0.036	0.055	0.080	0.398	0.629	0.679
42	0.355	0.739	0.905	0.509	0.291	0.982
43	0.698	0.134	0.405	0.243	0.453	0.678
44	0.849	. 0.455	0.964	0.116	0.731	0.534
45	0.966	0.257	0.219	0.514	0.974	0.923
46	0.289	0.837	0.729	0.492	0.021	0.250
47	0.561	0.130	0.488	0.605	0.953	0.831
48	0.040	0.669	0.611	0.779	0.756	0.198
49	0.852	0.906	0.636	0.554	0.770	0.524
50	0.515	0.023	0.149	0.486	0.014	0.699
51	0.749	0.487	0.930	0.173	0.333	0.703
52	0.163	0.840	0.480	0.260	0.391	0.188
53	0.092	0.729	0.694	0.864	0.839	0.649
54	0.731	0.850	0.511	0.121	0.426	0.270
55	0.803	0.343	0.639	0.042	0.552	0.387
56	0.279	0.290	0.960	0.574	0.595	0.603
57	0.122	0.209	0.894	0.583	0.452	0.875
58	0.750	0.951	0.845	0.627	0.003	0.348
59	0.755	0.062	0.998	0.599	0.697	0.426
60	0.517	0.568	0.950	0.860	0.123	0.418
61	0.622	0.214	0.178	0.110	0.319	0.198
62	0.476	0.462	0.025	0.166	0.661	0.596
63	0.188	0.054	0.733	0.872	0.430	0.695
64	0.676	0.595	0.183	0.651	0.662	0.927
65	0.023	0.527	0.226	0.697	0.541	0.701
66	0.400	0.903	0.023	0.475	0.494	0.413
67	0.342	0.700	0.448	0.079	0.225	0.932
68	0.859	0.836	0.510	0.087	0.183	0.167
69	0.723	0.786	0.831	0.820	0.479	0.986
70	0.367	0.531	0.488	0.393	0.900	0.629
71	0.114	0.685	0.013	0.644	0.591	0.856
72	0.919	0.905	0.018	0.872	0.030	0.346
73	0.499	0.175	0.806	0.438	0.205	0.324
74	0.607	0.247	0.389	0.527	0.387	0.099
75	0.275	0.370	0.640	0.866	0.574	0.070
76	0.148	0.566	0.745	0.871	0.560	0.812
77	0.486	0.940	0.868	0.575	0.643	0.181

78	0.122	0.031	0.730	0.771	0.317	0.802
79	0.518	0.873	0.985	0.076	0.703	0.040
80	0.155	0.315	0.463	0.114	0.219	0.375
81	0.764	0.233	0.900	0.691	0.831	0.248
82	0.401	0.547	0.412	0.700	0.311	0.658
83	0.022	0.441	0.873	0.613	0.223	0.322
84	0.128	0.840	0.423	0.648	0.826	0.862
85	0.092	0.117	0.620	0.216	0.769	0.375
86	0.105	0.051	0.234	0.917	0.316	0.810
87	0.103	0.350	0.346	0.235	0.959	0.881
88	0.774	0.524	0.307	0.169	0.504	0.681
89	0.585	0.600	0.191	0.306	0.235	0.901
90	0.853	0.005	0.653	0.330	0.437	0.379
91	0.192	0.068	0.587	0.645	0.404	0.825
92	0.109	0.849	0.644	0.653	0.195	0.831
93	0.233	0.478	0.581	0.328	0.623	0.757
94	0.521	0.889	0.454	0.992	0.488	0.771
95	0.885	0.690	0.985	0.694	0.718	0.180
96	0.929	0.009	0.877	0.248	0.966	0.299
97	0.019	0.428	0.560	0.903	0.304	0.370
98	0.531	0.582	0.725	0.654	0.922	0.510
99	0.046	0.721	0.060	0.529	0.224	0.367
100	0.313	0.362	0.919	0.627	0.388	0.046
101	0.096	0.282	0.102	0.382	0.352	0.918
102	0.510	0.349	0.628	0.415	0.252	0.243
103	0.085	0.194	0.250	0.394	0.624	0.977
104	0.751	0.390	0.535	0.620	0.160	0.862
105	0.944	0.692	0.636	0.527	0.499	0.728
106	0.358	0.972	0.340	0.980	0.392	0.050
107	0.341	0.754	0.664	0.101	0.687	0.070
108	0.588	0.752	0.147	0.475	0.831	0.276
109	0.705	0.471	0.084	0.846	0.096	0.711
110	0.264	0.830	0.198	0.873	0.381	0.456
111	0.257	0.846	0.751	0.257	0.398	0.739
112	0.350	0.666	0.760	0.350	0.935	0.354
113	0.014	0.775	0.885	0.504	0.526	0.607
114	0.460	0.817	0.595	0.669	0.909	0.649
115	0.441	0.407	0.550	0.223	0.666	0.942
116	0.214	0.350	0.572	0.708	0.159	0.713
117	0.457	0.987	0.293	0.032	0.002	0.478
118	0.619	0.862	0.416	0.765	0.571	0.248
119	0.045	0.565	0.634	0.433	0.558	0.689
120	0.319	0.533	0.512	0.215	0.230	0.375
121	0.532	0.611	0.121	0.106	0.946	0.379
122	0.659	0.500	0.915	0.499	0.574	0.704
123	0.936	0.690	0.169	0.227	0.708	0.557
124	0.971	0.127	0.448	0.360	0.082	0.127
125	0.427	0.798	0.787	0.569	0.254	0.426
126	0.393	0.434	0.798	0.506	0.509	0.821
127	0.034	0.867	0.562	0.580	0.018	0.174
128	0.780	0.018	0.055	0.535.	0.560	0.972
129	0.228	0.199	0.961	0.552	0.599	0.537
130	0.969	0.273	0.957	0.081	0.192	0.245
131	0.861	0.308	0.081	0.243	0.078	0.808
132	0.741	0.630	0.448	0.587	0.380	0.910
133	0.245	0.684	0.465	0.015	0.629	0.012
134	0.287	0.754	0.782	0.992	0.307	0.712

135	0.833	0.509	0.486	0.631	0.778	0.463
136	0.877	0.397	0.528	0.930	0.365	0.785
137	0.019	0.212	0.067	0.308	0.387	0.816
138	0.707	0.607	0.268	0.675	0.298	0.275
139	0.099	0.048	0.197	0.542	0.484	0.969
140	0.585	0.535	0.715	0.177	0.028	0.190
141	0.264	0.548	0.777	0.463	0.559	0.879
142	0.186	0.915	0.194	0.016	0.446	0.674
143	0.818	0.786	0.816	0.200	0.828	0.439
144	0.093	0.614	0.171	0.944	0.489	0.540
145	0.471	0.861	0.867	0.758	0.234	0.016
146	0.724	0.289	0.547	0.016	0.330	0.895
147	0.640	0.921	OJ83	0.460	0.641	0.145
148	0.514	0.298	0.938	0.956	0.363	0.264
149	0.180	0.267	0.352	0.820	0.761	0.180
150	0.417	0.480	0.043	0.491	0.973	0.012

SECTION 3

SETTING OUT, GEOMETRIC TOLERANCES AND RECTIFICATION

CONTENTS

TABLES

3. SETTING OUT, GEOMETRIC TOLERANCES AND RECTIFICATION

3.1. Scope

This section covers the setting out of the Works and gives the permitted geometric tolerances for line and level, depth, slope, thickness and surface regularity of the earthworks and pavement layers followed by rectification of those parts of the Works outside permitted tolerances.

3.2. Setting Out

3.2.1 General

The Engineer will provide sufficient basic survey information to enable the Contractor to set out the Works and the Contractor shall be responsible for setting out all necessary reference points and for their maintenance throughout the Contract, including the Defects Liability Period or its equivalent.

The Contractor shall satisfy himself as to the accuracy in line, level and dimension of the basic survey and setting out details provided and should the Contractor discover any error in the survey information, he should at once notify the Engineer. The Engineer will issue amended drawings or instructions for correction of the error.

Prior to commencing construction, the Contractor shall establish road reserve boundary and chainage marker posts at 100 m intervals on both sides of the centre line of the road. Where the presence of a horizontal curve will result in the shoulder breakpoint being closer than 9 m from the boundary line so defined, the Contractor shall establish intermediate boundary marker posts at spacings that are such that the minimum acceptable distance between the shoulder breakpoint and the boundary line is maintained.

In the case of provision having to be made in the verge for utilities such as water, electrical or sewerage reticulation, the distance between the toe of fill or top of cut and the reserve boundary may not be less than 3 metres. If the height of fill or depth of cut and the selected pavement cross-section result in the verge being less than 3 m wide and provision has not previously been made for widening of the road reserve, the Contractor shall immediately bring the matter to the attention of the Engineer.

The Contractor shall establish temporary benchmarks along the road at intervals not exceeding 200 m and shall provide the Engineer with a schedule of their levels and locations.

The Contractor shall not remove, damage, alter or destroy plot beacons or survey beacons installed by statutory authority.

The Contractor shall demarcate sensitive areas in accordance with the requirements of the Environmental Management Plan, and erect signs notifying the sensitivity of the site and actions that need to be taken in the vicinity of the site.

3.2.2 Detailed setting out

The Contractor shall set out the line and level of the Works at intervals of not more than 20 m or such intervals as are required to construct the Works to the tolerances specified in Clause 3.3. Reference pegs and batter rails clearly and indelibly marked with all the relevant information shall be provided clear of the road and at right angles to it such that the centreline and shoulder breakpoint levels and batter slope can be directly established.

After completion of the setting out and site clearance, the Contractor shall take ground cross sections at intervals of 20 or 25 m as directed by the Engineer along the road centreline and along the centreline of all culverts and structures. These shall be plotted to a natural scale of 1:100 and shall be provided as a CAD file using AutoCAD 2600 or later in addition to provision of the required hard copy and a copy of the plot submitted to the Engineer for approval. If the Contractor fails to take requisite levels, levels determined by the Engineer shall be taken as correct.

The Contractor shall allow 30 days in his programme between submitting the ground cross-section and being issued with final road, culvert and structure levels. A minimum 5 km section of road or the full length of the project whichever is the lesser shall be submitted but, where the Contractor submits cross-sections for more than 10 km of road within the same 30 day period, the initial 30 day period shall be extended by 30 days for each additional 10 km or part thereof. Final road, culvert or structure levels will be determined by the Engineer and may be different from the levels shown on the Drawings.

On receipt of the final road levels the Contractor shall mark up the details on the cross-sections. The original and one print of the cross-sections shall be provided by the Contractor for the Engineer. The CAD files shall be updated with the new information and resubmitted to the Engineer.

On completion of the earthworks but before starting formation or pavement layers the Contractor shall establish steel pins at a constant offset to the edges of the carriageway shoulders. The offset may however vary between sections in cut and those in fill. The steel pins will be clearly and indelibly marked with all the relevant information necessary to establish the centreline and level at any point across the carriageway by using either boning rods or a string line.

The interval between pins shall be 20 or 25 m as directed by the Engineer and the pins shall be maintained by the Contractor for as long as they are needed by the Engineer to check the work.

3.3. Geometric Tolerances

3.3.1 Horizontal alignments

Horizontal alignments shall be determined from the centreline of the pavement surface as shown on or calculated from the Drawings. The centreline of the pavement surface as constructed, and all other parallel alignments, shall be correct within a tolerance of ± 13 mm therefrom.

3.3.2 Thickness of pavement layers

Layer thicknesses may be determined by means of level measurements taken before and after construction of the layer in exactly the same position but may be augmented by measurements taken by means of holes made in the layer.

The average thickness of any pavement layer measured at five points in any length of 100 m shall not be less than 100% nor more than 120% of the thickness specified or ordered by the Engineer. In addition the thickness of any pavement layer measured at any point shall not be less than 98% nor more than 125% of the thickness specified or ordered by the Engineer.

3.3.3 Surface levels of pavement layers and formation

The level measured at any point on the surface of a pavement layer or the formation level shall not deviate from the corresponding level calculated from the Drawings by more than the tolerances shown in Table 3.1.

For checking compliance with Table 3.1 measurements of surface levels will be taken at points to be selected by the Engineer at 20 m centres longitudinally and at 2 m centres transversely. At junctions, the grid point spacings shall be determined by the Engineer.

For the purposes of acceptance, no layer may exceed either the thickness or the level tolerances. Correction of a selected layer level that is 50 mm low shall therefore, in the case of design layers thicknesses of 150 mm, be corrected by providing a subbase layer that is 180 mm thick and a base course layer that is 170 mm thick.

Table 3.1: Surface Tolerances

Layer	Level (mm)	
Trunk & Urban Roads		
Bituminous Wearing Course	+ 10	- 10
Bituminous Binder Course	+ 0	- 15
Gravel Wearing Course	+ 15	-15
Base	+ 0	-25
Subbase	+ 0	-35
Formation	+ 0	-50
Footpath Paving Slabs	+ 15	- 15
Feeder Roads		
Gravel Wearing Course	+ 25	-25
Base	+ 10	-30
Subbase	+ 10	-40
Formation	+ 10	-60

3.3.4 Surface regularity

The surface regularity of pavement layers and the formation shall be tested at points decided by the Engineer with a rigid, steel straightedge 3 m long placed parallel to or at right angles to the centreline of the road. The maximum allowable deviation of the surface below the straightedge in the case of the transverse measurement shall not exceed 6 mm.

In addition the longitudinal slope between two successive cross-sections shall not deviate from that shown on the Drawings by more than 0.25%.

3.3.5 Shoulders

Shoulders shall be constructed to the same thickness, level and surface regularity requirements as for the adjacent pavement layers.

3.3.6 Cutting and embankment slopes

In the final trimmed slopes of cuttings or embankments a tolerance of + 0.25 will be permitted, i.e. if a slope of 1: 2 is specified, the acceptable slope shall be not steeper than 1 : 2 or slacker than 1 : 2.25, unless otherwise specified.

3.3.7 Width of cuttings and embankments

The width of the bottom of cuttings between the centreline of the road and the toe of the cutting slope and the width of embankments measured as the horizontal distance from the centreline of the road to the edge of the embankment shall not be less than that shown on the Drawings nor more than that shown on the Drawings plus 200 mm.

3.3.8 Profile of side drains

The depth of side drains measured as the vertical height difference between the shoulder break point of the finished pavement and the invert of the side drain shall not be more than 0.3 m.

The sides of the side drain should have a slope not steeper than 1:2. Where space is restricted, the Engineer may rule that the back slope be steepened but to not more than the slope of the adjacent cut face.

3.4. Rectification of Earthworks and Pavements Outside Permitted Geometric Tolerances

Where any geometric tolerances in Clause 3.3 are exceeded, the Contractor shall determine the full extent of the area which is out of tolerance and shall make good the surface of the pavement course, earthworks or formation in the manner described below.

3.4.1 Earthworks

Where a cutting slope is steeper than the specified slope then the slope shall be trimmed to the specified slope. Where an embankment slope is slacker than the specified slope, the Engineer may elect to accept the out-of-specification slope but the Contractor shall not be entitled to payment for material placed outside the designed road prism. Where an embankment slope is steeper than the specified slope then the slope shall be benched and fill material placed and compacted and the slope shall be trimmed all in accordance with the requirements of Section 5 of the Specification.

Where the width of a cutting is less than the specified width then the cutting shall be trimmed to the specified width. Where the width of an embankment is less than the specified width then the embankment shall be benched and fill material placed and compacted and the slopes shall be trimmed all in accordance with the requirements of Section 5 of the Specification

Where the depth of a side drain is less than that specified, the side drain shall be trimmed to the specified depth. Where the depth of a side drain is more than specified, the side drain shall be backfilled with fill material compacted to a dry density of at least 95% MDD (GHA S1) up to the specified depth.

3.4.2 The 300 mm layer below formation level

Where the levels or widths are out of tolerance then the full depth of the layer shall be reworked to specification. The area treated shall be at least 12.5 m long and 3 m wide or such area to be determined by the Engineer as necessary to obtain compliance with this Specification.

3.4.3 Base and subbase

Where these consist of unbound (i.e. natural or graded stone) material the full depth of the material shall be removed from the pavement and replaced to specification and to within the tolerances specified in Table 3.1. The area treated shall be at least 30 m long and 3 m wide or such area to the determined by the Engineer as necessary to obtain compliance with this Specification.

Where the courses consist of cement or lime treated material or lean concrete the full depth of the layer shall be removed from the pavement and replaced to specification. The area treated shall be at least 5 m long and the full width of the paving laid in one operation. If areas are corrected within 7 days of laying, no construction traffic or compaction plant shall use the surrounding satisfactory areas.

For bituminous bases the full depth of layer shall be removed and replaced with fresh material laid and compacted to specification. Any area so treated shall be at least 5 m long and the full width of the paving laid in one operation.

3.4.4 Wearing course

These shall have the full depth of the layer removed and replaced with fresh material laid and compacted to specification. The area rectified shall be the full width of the paving laid in one operation and at least 15 m long.

SECTION 4

SITE CLEARANCE

CONTENTS

4. SITE CLEARANCE

4.1. Scope

This section covers general site clearance, stripping of topsoil and removal of trees, structures and other obstructions necessary for the construction of the Works, in accordance with these Specifications.

4.2. Site Clearance

4.2.1 General

When all compensation has been evaluated and agreed each part of the Site shall be cleared at such time and to an extent acceptable to the Engineer.

No clearance of or alteration to any main service or apparatus shall be done unless specifically ordered by the Engineer.

Site clearance is defined as the clearing, grubbing, removal and disposal of all vegetation, grass, debris, bushes, scrub, dense bush, trees, hedges, undergrowth, stumps, roots, shrubs plants and other objectionable materials and backfilling of holes left by the removal of stumps and roots.

It shall also include the removal and disposal of structures that obtrude, encroach upon or otherwise obstruct the work and which can be cleared by means of a bulldozer with a mass of approximately 20 tonnes and an engine developing approximately 145 kW at the flywheel. Structures which cannot be cleared in this manner shall be broken down in accordance with the requirements of the Special Specification for the removal and disposal of structures.

The Contractor shall remove gates, gate posts, fences, walls, manhole covers, existing street-lighting columns and other items to the extent directed by the Engineer. Where in the opinion of the Engineer, such items can be re-used they shall be delivered to the Engineer for storage in accordance with his instructions, otherwise all such items removed by the Contractor shall be disposed of to spoil.

The width and length over which site clearance is to be carried out shall be shown on the Drawings or instructed by the Engineer.

Site clearance over the area of quarries, borrow pits, stockpiles, spoil tips, road junctions, ditches and drains and other areas shall be carried out where shown on the Drawings or instructed by the Engineer.

The clearing of vegetation by burning shall not be allowed.

The Engineer may give instructions that specific trees, stumps or objects shall not be removed during the site clearance operation.

Where specified in the Environmental Management Plan, the Contractor shall carefully remove plants and/or seeds for later rehabilitation and store it at a designated nursery site at the office or other appropriate site.

4.2.2 Clearing, except trees

Where site clearance is required, the defined area shall be cleared and all materials thus cleared shall become the property of the Employer.

In the roadway all stumps and roots exceeding 75 mm in diameter shall be removed to a depth of no less than 600 mm below the finished road level and a minimum of 75 mm below the original ground level. Where the roadbed has to be compacted, all stumps and roots, including matted roots, shall be removed to a depth of at least 200 mm below the cleared surface.

No payment will be made for the moving of soil or gravel material which may be inherent in or unavoidable during the process of clearing. Clearing shall also include the removal of all rocks and boulders of up to 0.15 m^3 in size which are exposed or lying on the surface.

The clearing of vegetation by burning shall not be allowed.

Vegetation, perishable material and other debris shall be carted to spoil areas provided in accordance with the requirements of Section 6 of the Specification and covered with soil or gravel. Disposal by burning may be authorized by the Engineer if specified in the Environmental Management Plan, provided no fire hazard would result. All statutory provisions in regard to air pollution shall be carefully observed.

4.2.3 Removal of trees

Trees outside the construction width but within the road reserve having a trunk girth of more than 450 mm at a point 600 mm above the ground shall not be cut down without the prior approval of the Engineer.

Where site clearance is required, trees not designated to remain shall be uprooted or cut down as near to ground level as possible and shall be either burnt, or where the Engineer instructs that they shall be saved, the trunk and branches shall be cut into convenient lengths and stacked neatly off the line of the road and shall become the property of the Employer. They shall be preserved and protected by the Contractor until removed by the Employer or until the expiry of the Defects Liability Period or its equivalent. The remainder of the trees shall be disposed of as in 4.2.2 above.

Individual trees designated in writing by the Engineer shall be left standing and uninjured. A penalty of US$100.00 or the equivalent in local currency shall be imposed for every such tree that is unnecessarily removed or damaged.

The Contractor shall take the necessary precautions to prevent damage to structures and other private or public property. If necessary, the trees shall be cut in sections from the top downwards. The branches of trees to be left standing shall be trimmed so as to leave a 7 m clearance above the carriageway.

Stumps and tree roots shall be grubbed up. All holes left by removal of stumps and roots shall be backfilled with approved material compacted to a density of at least the surrounding ground up to the existing ground level or up to the formation level if the area is in cut.

Where the borrow site contains large trees (having a girth of 600 mm or more at a point 600 mm above the ground), endangered, or economic trees, the Contractor shall excavate around those trees. Where this is not possible, the appropriate felling permit shall be obtained.

Should the Contractor become aware during the period of the Contract that any tree, vegetation, or other item designated for clearance has cultural or religious significance, he shall immediately inform the Engineer and await the Engineer's instructions before proceeding.

The Contractor shall prevent damage to trees, which the Engineer may designate to be preserved. Such designated trees shall be protected from damage during the implementation of the Contract.

In the event that trees or other vegetation not designated for clearance are damaged during construction, the Contractor shall replace them to the satisfaction of the Engineer. Trees that need to be felled shall only be removed after obtaining environmental permission and with EPA approval.

The local community shall be consulted when trees need to be felled and replaced.

4.2.4 Conservation of vegetation

Where provided for in the Project Specifications, certain designated plants encountered in the road reserve and borrow areas shall be carefully protected by the Contractor. He shall include, in his tendered rates for clearing and grubbing full compensation for the careful removal and planting of the plants in a protected and fenced-off area, and, on completion of the road, the replanting of the plants in suitable positions in the road reserve in accordance with the Engineer's instructions.

4.2.5 Reclearing of vegetation

When portions of the road reserve, borrow or other areas have been cleared in accordance with the Specifications, but vegetation grows again in the course of time during construction, the Engineer may, if he considers it necessary, order that the area be recleared at the Contractor's expense.

Such reclearing of areas previously cleared includes the removal and disposal of grass, shrubs and other vegetation in the same manner as for the first clearing operation.

4.3. Topsoil Stripping

Where shown on the Drawings or directed by the Engineer the Contractor shall remove all topsoil as defined in 5.2(g) together with any grass and other suitable vegetation. The depth of the topsoil shall be as directed by the Engineer but shall not exceed 250 mm.

The Contractor shall, prior to removal of topsoil, excavate trial holes of a depth sufficient to enable the Engineer to measure the depth of topsoil. Where topsoil is found to depths greater than 250 mm that portion below 250 mm shall, if required by the Engineer, be treated as fill or spoil in accordance with the requirements of Section 5 of this specification.

Topsoil shall be stripped, loaded, transported and deposited in well-defined approved and designated stockpile areas, provided in accordance with the requirements of Section 6 of the Specification. Stockpiles of topsoil for re-use shall be protected against erosion by means of appropriate seeding and surrounded by barriers to prevent erosion loss into watercourses. Topsoil shall in all instances be stockpiled for rehabilitation purposes and shall not be removed from the site or sold.

Should the Contractor strip to depths greater than those instructed by the Engineer then the Contractor shall replace the material with fill materials at the Contractor's expense.

4.4. Removal of Structures, Fences and Obstructions

When instructed by the Engineer, the Contractor shall demolish wholly or in part, remove and dispose of all buildings, foundations, bridges, drainage structures, underground chambers, pits, tanks, structures, fences and any other obstructions which have not been designated to remain. Prior to demolition the Contractor shall ensure that services have been disconnected and/or relocated to the satisfaction of the appropriate authorities and/or owner. All holes resulting from the removal of structures below ground shall be backfilled with approved material compacted to 93% MDD (GHA S1) up to existing ground level or up to formation level if the area is in cut.

The Contractor shall carefully take down such buildings, structures, fences etc. and the components shall be dismantled, cleaned and stacked in separate heaps. All materials which, in the opinion of the Engineer, are not fit for re-use shall be removed from the Site to spoil areas provided in accordance with the requirements of Section 6 of this Specification. All materials which are re-usable shall remain the property of the Employer and shall be preserved and protected by the Contractor until removed by the Employer or until the expiry of the Defects Liability Period or its equivalent.

Bridges, culverts and other drainage structures shall not be removed until satisfactory arrangements have been made to accommodate traffic and the flow of water.

All existing surface water drainage facilities within the extent of the Permanent Works shall be demolished and removed to spoil unless retention of any particular existing facility is specifically noted in the Drawings, subject to confirmation by the Engineer prior to demolition.

Where directed by the Engineer, pits, tanks, underground chambers, culverts, foundations and the like below the Original Surface shall be demolished to a depth of 1.0 m below either the stripped ground level or the formation level, whichever is the lower, and the remainder shall be properly cleaned out to the satisfaction of the Engineer.

4.5. Protection of Fences, Trees, Hedges, etc

All existing paths, fences, walls, hedges, trees, shrubs, lawns and other features which are not removed or otherwise dealt with, shall be protected from damage for the duration of the contract, including the Defects Liability Period.

SECTION 5

EARTHWORKS

CONTENTS

5. EARTHWORKS

5.1. Scope

This section covers all excavation of cuttings including side drains and benches, the placing and compaction of hard and soft material for fill in embankments, ground compaction, formation of the subgrade, excavation and rock fill to swamps, topsoiling and grassing.

5.2. Definitions and Classifications

(a) "Original Surface or Ground Level": means the surface of the ground before any work has been carried out.

(b) "Stripped ground level": means the surface of the ground after completion of the clearing operations, and removal of topsoil.

(c) "Formation level": means the level at the completion of earthworks for roadworks prior to the laying of the pavement and surface soiling. The earthworks immediately below formation level are known as the subgrade.

(d) "Unsuitable material" shall include the following:

- material from swamps, marshes and bogs, peat, logs, stumps, roots and other perishable or combustible material
- surface soil and highly organic clay and silt
- material having a liquid limit above 65% or more than 80% passing the 75 micron sieve to BS 410-1
- such other material as the Engineer may decide.

(e) "Suitable material": shall exclude unsuitable material as defined previously, and shall comprise all other natural materials acceptable to the Engineer for use in the Works.

(f) "Selected Fill": shall be material having liquid limit below 30% and not more than 30% passing the 75 micron sieve to BS 410-1. The CBR swell (GHA S2) should not exceed 1.5%.

(g) "Topsoil": shall mean soil from the surface layers of ground with sufficient humus content to support vigorous plant growth. Topsoil will be only that material that lies within 250 mm of the surface of the Original Ground Level.

(h) "Hard material": shall be material that cannot be ripped to an average depth of rip greater than 300 mm by a track type crawler tractor complying with the following:

(i) in good order complete with all equipment and accessories as supplied;
(ii) rated 220 kW flywheel power or over;

(iii) an operating mass of not less than 35 tonnes;
(iv) equipped with a hydraulically operated single tine ripper compatible with the tractor used; and
(v) operated by a qualified operator in accordance with the manufacturer's recommendations and to the satisfaction of the Engineer.

Where it is impracticable to prove hard material by the above method then the quantity of hard material, if any, shall be determined by the Engineer.

Where excavation contains individual boulders of hard material greater than 0.2 m^3 each in volume then such boulders shall be classified as hard material.

Hard material shall not be placed within 600 mm of the formation level in embankments and shall be removed to a depth of 300 mm or as otherwise instructed by the Engineer below formation level in cuttings.

(i) "Soft Material": Soft material shall be all materials other than hard material, except for material within swamps covered by Clause 5.6 of the Specification.

5.3. Explosives and Blasting

The Contractor shall not use or bring onto the Site explosives of any kind without the prior consent in writing of the Engineer. The explosives shall be stored in a manner and quantities acceptable to the Engineer and in compliance with prevailing statutory requirements for storing and handling explosives covered by the Mines Act, in magazines provided by the Contractor at suitable positions. The Contractor shall be responsible for the prevention of unauthorised issue or improper use of explosives brought on the Works, and shall employ only experienced, licensed and responsible personnel to handle explosives for the purpose of the Works.

The shots shall be properly loaded, tamped and where necessary, the Contractor shall use heavy blasting nets. Blasting shall be restricted to such periods as the Engineer may agree to. If in the opinion of the Engineer, blasting would be dangerous to persons or property, or to any finished work, or is being carried out in a reckless manner, he may prohibit it and require excavation by other means. Use of explosives by the Contractor in large blasts as in seams, drifts, shafts, pits or large holes is prohibited unless authorised in writing by the Engineer.

The purchase, transport, handling, storage and use of explosives shall be in conformance with the regulations in force and any Explosives Ordinance and rules issued by the Government.

Blasting shall not be carried out in excavations for structures without the written permission of the Engineer. Such permission shall not relieve the Contractor of his responsibilities including the responsibility to avoid damage to rock, which is to support a structure.

The greatest care shall be taken in the use of explosives, the charges being so placed and of such amount as in no way to deleteriously shake or loosen the permanent foundation or sides of the excavation. Special care shall be taken as the foundation level is approached, and a thickness of not less than 750 mm above this level shall be completed with small charges not exceeding 600 mm in depth. The last 150 mm of rock above foundation level shall be removed by use of power tools or by hand.

Explosives shall not be used within 10 m (or greater or lesser distance as the Engineer may direct) of concrete placed for the permanent structure.

The cost of supplying and using explosives shall be included in the payment for excavation in rock.

Where blasting could cause damage to adjacent properties, these properties should be inspected and any existing cracking or damage measured, recorded (including appropriate photographs with a suitable scale) and reported prior to any blasting. Any claims for damage resulting from the blasting shall then be assessed on the basis of the report.

The Contractor shall notify neighbouring communities in writing of any planned blasting activities five days prior to the event and take all necessary precautions to ensure that no unauthorized individuals enter the blasting area during blasting activities.

5.4. Preparation Prior to Forming Embankments

The Contractor shall excavate benches in existing ground that has a side slope greater than 1 in 5 or as instructed by the Engineer. The existing slopes, after the removal of topsoil shall be benched in accordance with the Drawings prior to the construction of embankments. The material that is excavated to form benches shall either be taken to spoil or, if suitable, used as fill. The actual bench widths shall be as shown on the Drawings or as instructed by the Engineer.

The existing ground under embankments and bench surfaces where appropriate, shall be compacted over the full width of construction to 93% MDD (GHA S1) to a depth of 150 mm.

Where the existing ground is unsuitable for receiving fill, the Contractor shall excavate to the depth instructed by the Engineer, remove the material to a spoil area and replace it with suitable material compacted as for embankment earthworks.

5.5. Construction of Embankments and Cuttings

The dimensions of all cuttings and embankments shall be constructed in accordance with the details of the typical cross-sections, and of the interchange and intersection as shown on the Drawings and shall further be defined or amended during the course of construction by instructions from the Engineer. Before starting construction, the Contractor shall obtain instructions regarding the required slope of each fill, any roadbed preparation or subsoil drainage required, details of earthworks at interchanges and intersections, the selection of materials, the method and classification of compaction, and any other matter that may affect the construction of the fill or sequence of operations.

Material obtained from cuttings shall be used to construct embankments. Material from borrow pits shall be used only where the Contractor has demonstrated and the Engineer agreed that there is not an adequate quantity of material of the required quality obtainable from cuttings. Where a local surplus of cut material or material which is unsuitable or oversize occurs, payment will be made for the removed material as for the disposing of cut material to the extent in which such material or an equal volume of other material would in any case have to be spoiled.

The Contractor may, to suit his method of working and with the approval of the Engineer, take suitable fill material obtained from cuttings to spoil provided he substitutes an equivalent quantity of suitable fill material from a borrow pit or other source. The Contractor shall be solely responsible for the acquisition of land for the spoil and borrow areas required in these circumstances and any additional costs due to the substitution over and above the cost of taking the material from cuttings or benches to fill shall be at the Contractor's expense. Any environmental rehabilitation costs associated with such additional activities will also be at the Contractor's expense.

The Engineer may order that particular materials in cuts be selected for specific purposes. Where selection is ordered, the method of excavation and the programme of work shall be so arranged as to avoid, in so far as is possible, double handling and to meet the requirements of the Engineer. If selected materials designated by the Engineer are contaminated, used incorrectly or become unavailable through injudicious planning of borrow pit or excavating operations, the Contractor will be required to replace the shortfall with material of at least equal quality, excavated and transported from borrow pits at his own expense.

In general the excavated materials shall be placed directly in their final positions in the fill.

Coarse rock encountered in cuttings shall be utilised for the construction of the lower layers of fills high enough to accommodate thick layers, or, where so required, shall be conserved and used as directed for constructing the sides of embankments or for serving as protection against embankment or channel erosion.

When the stability of a fill may be materially improved by the controlled placing of earth and rock-fill in successive layers, a concurrent supply of both types of material shall be arranged.

When ordered by the Engineer, the better class fill material available from cuttings shall be selected for use in the top layer of the fills and in the lower layers of high fills.

Material for use in the 300 mm below formation level in both embankments and cuttings shall not contain particles larger than 50 mm, unless permitted by the Engineer. In addition the material shall have a CBR of not less than 15% measured after 4-day soaking on a laboratory mix compacted to a dry density of 95% MDD (GHA S1), a swell of less than 1% and a Plasticity Index of less than 30%. In-situ material in the 300 mm below formation level in cutting that does not meet these requirements shall either be cut to spoil or if suitable, placed in the embankment and replaced with material from cuttings or borrow pits that does meet the requirements for soft material for use in the 300 mm below formation level.

Where materials of differing quality are available for placing in embankments the Engineer may instruct that certain materials should be excluded from the upper 300 mm of fill and he may instruct that certain materials should be set apart, or obtained from borrow pits, for use in these upper layers.

Soft material as fill shall be deposited in layers not exceeding 150 mm compacted thickness unless, as a result of site compaction trials, the Contractor has satisfied the Engineer that his compaction plant is capable of consistently achieving the specified densities at a greater thickness; which in no case shall exceed 250 mm. Each layer shall extend over the full width of the embankment and shall be compacted in accordance with Clause 5.8.

Hard material used for fill shall be of maximum dimension 250 mm, shall be deposited in horizontal layers not exceeding 400 mm loose depth and shall extend over the full width of the embankment except for any specified external cover to slopes. The material shall be spread and levelled by a crawler tractor weighing not less than 15 tonnes. Each layer shall consist of reasonably well graded rock and shall be blinded with smaller rock fragments and gravel so as to fill as many of the voids as possible before the next layer is placed. The top 600 mm of the earthworks below formation level shall be formed using soft material.

During the construction of embankments the Contractor shall control and direct construction traffic uniformly over the full width. Fill material shall not be stockpiled on embankments without the permission of the Engineer.

When constructing embankments up to bridges and up to and over culverts, the Contractor shall raise the embankment equally on each side of such structures and shall unless otherwise instructed by the Engineer carry out this work concurrently with the filling to the structure as is feasible without damaging the structure.

The Contractor shall take all necessary precautions to ensure that no material enters any watercourses and that suitable protective measures are taken to prevent erosion until worked areas are adequately revegetated.

5.6. Swamps

Areas that are to be classified as swamps will be identified and the treatment thereof specified in the Special Specification and Environmental Management Plan.

The Contractor shall, however, programme his works so that, wherever possible, removal of unsuitable materials and compaction of material in swamps is carried out in the dry season.

The Contractor shall also programme his works so that any rock excavated in cuttings shall be available for filling in swamps when instructed by the Engineer.

In swampy or marshy areas, the Contractor shall, unless otherwise instructed by the Engineer, carry out the following:

(a) Drain the area, where practicable, by the excavation of ditches and if necessary, the construction of temporary culverts or pipes through the existing road embankment.

(b) Remove vegetation and unsuitable material from the sites of embankments, to depths to be determined by the Engineer.

5.7. Rock fill on Swamps and Soft Ground

Where specified in the Special Specification or instructed by the Engineer the Contractor shall place rock fill in shallow swamps and on soft clayey ground exhibiting excessive movement under normal compaction equipment and haulage trucks. The rock fill shall be obtained from a rock quarry and shall be loaded, transported, placed in uniform layers, rolled and trafficked until it is fully embedded over the whole area instructed.

If after excavation of unsuitable material, the embankment formation is:

(a) Firm to dry: The Contractor shall construct the embankment of rock fill up to a level 500 mm above the normal wet season standing water level.

(b) Below standing water: The Contractor shall form the lower layer, up to standing water levels, of the embankment of free draining rock fill of maximum size not greater that 400 mm, which complies with the following grading:

Sieve size (mm)	% by mass passing
5	not more than 85
0.6	not more than 45
0.075	not more than 5

Such material may be deposited below water without the associated use of compaction plant. The embankment shall then be completed up to 500 mm above wet season standing water level with normal rock fill.

(c) Soft and at or above standing water level: The Contractor shall place a geotextile separation membrane in compliance with Clause 2.15 and as specified for use in AASHTO M 288 transversely over the entire width of the embankment base or widening, with minimum overlaps of 300 mm. The membrane shall then be covered by a layer of free-draining granular material with a thickness of not less than 500 mm.

The embankment shall then be completed up to a level of 500 mm above the normal wet season standing water level with rock fill and constructed to formation level with normal fill.

If the embankment has been constructed over soft ground, the Contractor shall place a surcharge of 1.0 m deep over the whole embankment and the level of embankment crest shall be monitored regularly over a period of not less than three months. If at the end of this period all settlement has ceased (slope of last two weeks settlement curve is less than 2% of the steepest portion of the curve), the Contractor shall remove the surcharge to formation level and pavement construction may commence. If, however, settlement has not ceased the Contractor shall allow the embankment to settle further until written approval to proceed is given by the Engineer.

The rock fill shall be of maximum dimension 250 mm, reasonably well graded and with not more than 5% finer than 10 mm. The layer thickness and number of layers shall be agreed with the Engineer who may vary the requirement during the rock fill operation. Each layer shall be blinded with smaller rock fragments so as to fill as many of the voids as possible before the next layer is placed. Before additional layers are placed or before normal earthworks resume the Contractor shall proof roll each layer in accordance with Clause 5.11 of this Specification.

Where instructed by the Engineer, the Contractor shall place an approved geotextile under or around the rock fill. Where the geotextile is placed around the rock fill the final layer of rock fill shall be blinded with gravel so as to present a smooth surface to receive the fabric. Geotextiles shall be installed in accordance with the manufacturer's instructions.

5.7.1 Separation Membrane

Separation membrane material shall be a polypropylene or polypropylene mixture geotextile conforming to the AASHTO M 288 specification for geotextiles for highway applications. The Contractor shall provide evidence that the material proposed will be sufficiently durable, when installed, to maintain its integrity for at least 30 years.

5.8. Compaction of Earthworks

The moisture content of fill material shall be adjusted immediately prior to compaction by either uniformly mixing in water or drying out the material such that the moisture content during compaction is within the range shown by field trials or laboratory tests to be suitable for obtaining the required densities.

Each layer of material shall be compacted at a moisture content within the above limits to a dry density equal to at least the percentage of the Maximum Dry Density (MDD) specified below:-

(a) All fill material in embankments, except the 300 mm below formation: 93% MDD (GHA S1)

(b) The 300 mm below formation in embankments: 95% MDD (GHA S1)

(c) The 300 mm below formation in cuttings under the carriageway and shoulders: 95% MDD (GHA S1).

Each layer of hard material used as fill in embankments shall be systematically compacted by at least 8 passes of a towed vibrating roller weighing not less than 5 tonnes dead weight or a grid roller weighing not less than 13 tonnes dead weight or other approved plant. During compaction of blinding layers on the surface of the layer of hard material, the material shall be watered as necessary to facilitate the filling of the voids with the blinding material.

At the beginning of the Works and from time to time as may be necessary in the opinion of the Engineer, the Contractor shall carry out, to the satisfaction of the Engineer, field trials, supplemented by any necessary laboratory investigations to determine types of compaction equipment, appropriate layer thicknesses and moisture contents within the requirements of the Specification for the effective placing and compaction of the materials to be used in the earthworks. The sites of the trials shall be agreed between the Contractor and the Engineer. If compaction trial fill is placed as part of the Permanent works, such fill shall conform to the requirements of the Specification. If it does not, it shall be removed or reworked until it does conform.

The Contractor shall submit to the Engineer his proposals, based on the results of trials for the placing and compaction of each type of material to be used in the earthworks, including proposals in relation to types of plant, number of passes and loose thickness of layers. Work (other than trials) shall not commence on any particular type of material until the Engineer has signified in writing his approval of the Contractor's proposals for that material. The Contractor shall not modify the approved methods without the consent of the Engineer.

Compaction of fill material shall be carried out only when the moisture content is within the range shown by the field trials or by laboratory tests on the material to be suitable for the attainment of the densities specified. The moisture content shall not lie outside the range between 85 and 100% of OMC at GHA S1 density. The moisture content shall be kept within the limits (or any narrower limits instructed by the Engineer in accordance with any field and/or laboratory trials) until compaction has been satisfactorily completed.

If any fill material is, on excavation, too wet or too dry for satisfactory compaction, the Contractor shall carry out such operations as may be necessary to adjust the moisture content to an acceptable value.

Work shall be carried out until a state of compaction is reached throughout the embankment including the slopes and the immediate approaches to culverts and bridges such that the dry density of the compacted materials immediately after compaction complies with the specification.

The use of compaction meters fitted to the compaction plant to identify the optimum compaction effort, ie, no further increase in density with additional rolling, shall be employed when instructed by the Engineer.

5.9. Spoil Material

Spoil material shall be material originating from construction operations, which is not utilised for construction purposes and which the Engineer has instructed to be excluded from use as fill in embankments or below formation level in cuttings. It shall also include unsuitable material from beneath embankments. However, no material shall be spoiled without written instructions from the Engineer.

Spoil material shall be deposited in spoil areas located by the Contractor, subject to the approval of the Engineer. The Contractor shall give the Engineer at least 48 hours notice of his intention to commence placing spoil material at a particular location. Spoil material shall not require compaction but shall, if required, be spread, shaped and given a smooth surface as may normally be obtained by careful bulldozer operations. Where appropriate and in accordance with the Environmental Management Plan, spoil material shall be stockpiled for use in the rehabilitation of borrow areas.

5.10. Borrow Pits

Fill material which is required in addition to that provided by the excavation or widening of cuttings shall be obtained from borrow pits provided and operated in accordance with Section 6 of this Specification.

5.11. Proof Rolling

All subgrade and embankment layers, cuttings, benches and original ground shall be proof rolled with a loaded scraper or truck with a minimum axle load of 8 tonnes in the presence of the Engineer. The equipment and method of operation shall be as directed by the Engineer. Proof rolling shall be satisfactorily completed before the layer is submitted to the Engineer for approval. All such proof rolling shall be at the Contractor's expense and he shall make the required equipment available for proof rolling at any time as required by the Engineer.

5.12. Trimming of Slopes

The slopes of cuttings and embankments shall be trimmed to uniform batters as shown on the Drawings or as instructed by the Engineer. Such trimming shall be completed before the commencement of subbase construction. The tops and bottoms of all slopes including the slopes of drainage ditches shall be rounded as shown on the Drawings or as ordered by the Engineer.

Any rock or boulder appearing in the face of a cutting or embankment shall be trimmed back to within the tolerance specified and, in addition, any such rock or boulder which is loose or likely to dislodge when wet shall be completely removed and the resulting void filled with suitable material compacted to the same standard as the surrounding earthworks.

Fill slopes shall be finished to neat lines with all loose and uncompacted material removed. The degree of finish required shall depend on the nature of the material used for the fill slope but shall be as smooth as is consistent with the material involved and good workmanship to the satisfaction of the Engineer.

The final appearance of cuts and fill slopes shall be one of uniform appearance without any noticeable break that can be readily discerned from the road. The slopes shall be in harmony with existing landscape features as far as practically possible.

5.13. Topsoiling and Grassing

Where specified or instructed by the Engineer, the Contractor shall provide protection to embankment slopes, cut faces, side drains, shoulders, guiding dams and spoil or borrow areas by one of the following means:-

(a) Grassing
(b) Topsoiling and grassing
(c) Sodding, turfing, shrubs, etc

The Contractor shall plant grass of an approved type on slopes, cut faces and side drains in accordance with the Environmental Management Plan unless directed otherwise by the Engineer. The Contractor shall plant sprigs of approved indigenous 'runner' type grass at 150 mm centres and shall care for and water the grass until it is fully established to the satisfaction of the Engineer.

Where topsoiling is required prior to grassing the minimum compacted thickness of topsoil shall be 100 mm and the quality of the topsoil shall be to the approval of the Engineer. Light compaction shall be carried out to the approval of the Engineer.

The Contractor shall ensure that his watering, rainfall or rainfall runoff from adjacent areas does not wash out the topsoil or grass. Any damage before the grass is firmly established shall be rectified at the Contractor's expense.

5.14. Soil Stabilization

Where improvement of the upper layers of earthworks is required by the Special Specification or is shown on the Drawings, it shall be carried out in accordance with Section 14.

SECTION 6

QUARRIES, BORROW PITS, STOCKPILE, SPOIL AREAS AND EXISTING LAYERS

CONTENTS

6. QUARRIES, BORROW PITS, STOCKPILES, SPOIL AREAS AND EXISTING LAYERS

6.1. Scope

This section deals with the contractual and operational procedures to be followed in the provision and working of quarries, borrow pits, stockpiles and spoil areas. It also includes the breaking up of existing pavement layers and the removal thereof to spoil dumps or to stockpiles for later recycling.

6.2. General

Unless stated otherwise in the Special Specification, it is the responsibility of the Contractor to select the sources of aggregate for concrete, stone for bases, subbases, bituminous mix bases, binder courses and wearing courses, chippings for surface dressings and rock fill for swamps. Such sources shall be designated as quarries as defined in Clause 6.3 (a). Such potential quarry sites as may have been identified prior to commencement of the Contract and were available for inspection at the time of Tender will also be the responsibility of the Contractor should he elect to use them.

The sources of natural materials such as fill materials for the construction of embankments, and gravel for subbase, base, surfacing and shoulders shall be designated as borrow pits as defined in Clause 6.3 (b). Certain borrow pits may have been identified prior to commencement of the Contract and the Engineer will instruct the Contractor as to which of these are to be utilised for the extraction of natural materials.

Provisions are included in subsequent clauses of this Section of the Specification for additional borrow pits to be identified and located by the Contractor during the Contract. Stockpile and spoil areas shall be located by the Contractor subject to the approval of the Engineer. Any information supplied to the Contractor regarding possible sources of construction materials shall not absolve the Contractor of his responsibility to locate suitable sources and to ensure that the material obtained from those sources complies with the requirements of the Specification.

All quarries, borrow pits, stockpiles and spoil areas shall be located such that overhaul requirements are minimised.

6.3. Definitions

(a) Quarry

A quarry is an open surface working from which rock is removed by drilling and blasting for use on the Works.

(b) Borrow pit

A borrow pit is a site from which material, other than rock, is removed for use in the Works.

A borrow pit may have been selected by the Engineer and be available for inspection at the time of Tender or alternatively it may be one proposed by the Contractor and approved by the Engineer during the Contract.

(c) Stockpile area

A stockpile area is an area where material such as topsoil, fill material, gravel or aggregate is heaped prior to use in the Works.

(d) Spoil area

A spoil area is a site upon which surplus or unsuitable materials arising out of the Works are dumped. Surplus or unsuitable material shall not be dumped within the road reserve or outside it without the approval of the Engineer.

6.4. Provision of Land

Unless otherwise specified, all land that may be required by the Contractor outside the road reserve for opening of borrow-pits and quarries including access roads will be the sole responsibility of the Contractor. However, the approval of the Engineer shall be obtained before entry upon such land. Any royalties, compensation or other costs in respect of land acquired or in respect of soil or rock excavated therefrom shall be paid by the Contractor, and such expenses shall not be reimbursed by the Employer.

The Contractor shall satisfy himself that all necessary negotiations have been made with the Owner or Legal Occupants of the land on which any borrow pit or quarry is situated, prior to the entry upon such area. The Contractor shall not enter the land until compensation to owners or legal occupants is effected and the approval of the Engineer has been given.

The location and size of quarries, borrow pits, spoil and stockpile areas proposed by the Contractor shall be subject to the approval of the Engineer. The Engineer's approval may be withheld for any of the following reasons:-

If the quarry, borrow pit, spoil or stockpile area or access into them:

(a) is less than 3 km from the next quarry, borrow pit, spoil or stockpile area;
(b) will have a significant visual impact, or will likely result in excessive erosion, sedimentation, slope instability or other environmental impact that will be difficult to control, or has been excluded in the Environmental Impact Assessment and Environmental Management Plan;
(c) will incur relatively high land acquisition costs or would be very difficult to acquire;
(d) is in or near an urban centre;
(e) will require an access road which is excessively long;
(f) has excessively thick layers of overburden;
(g) covers too large an area;
(h) would constitute a danger to the public;

(i) is an excessive distance from the location where the material is to be used;
(j) if a source of suitable material is closer at hand;
(k) is located within the road reserve (i.e. 45 m from the centre line);
(l) is located in or near a village (where near is defined in the Special Specification or by the local stakeholders);
(m) is located within 200 m of a drinking water intake (stream or water pump);
(n) is in or adjacent to a Sensitive Area as defined by the EPA, or
(o) cannot be rehabilitated in accordance with the requirements of the Environmental Management Plan.

Where the Contractor uses a quarry or borrow pit identified or instructed by the Engineer he shall obtain the Engineer's approval of the areas required for the quarry or borrow pit. The Engineer may require the Contractor to modify his requirements for any of the reasons outlined in (b), (c), (d), (e) or (g) above.

The Contractor shall inform the Engineer in writing not later than 60 days after the Engineer's order to commence work of all quarries, borrow pits, spoil and stockpile areas that will be required for the whole of the Works. The Contractor shall programme for a period of 60 days from the date of the Contractor's written notice to the date when the Engineer makes the quarries, borrow pits, spoil and stockpiles areas available to the Contractor. Prior to the submission of written notice the Contractor shall set out each quarry, borrow pit, spoil and stockpile area with concrete beacons clearly identifying working areas, stockpile areas, blasting safety zones and access routes. The Contractor's written notice shall include the following for each quarry, borrow pit, stockpile and spoil area:-

(a) A plan at 1:250 scale in ink on a stable transparent material or a paper and electronic copy giving details of:

    (i) plot boundaries;
    (ii) owners' names and addresses, and, if appropriate, ID numbers;
    (iii) the District, Location, Registration Section and Number for each plot;
    (iv) local details such as buildings, fences, graves, types and areas of cultivation and services, all agreed with the land owners;
    (v) areas to be used for working areas, stockpile areas, blasting safety zones etc.

(b) Cadastral maps covering the areas to be acquired.

(c) Details of the proposed access road route.

(d) Results of investigation and laboratory tests

(e) Documentation confirming acquisition of right of way where necessary.

(f) Details of measures for controlling runoff and sediment from the Site during operations

(g) Plan for Site rehabilitation as detailed in the Environmental Management Plan

Where the use of borrow pits, available for inspection at the time of Tender, is instructed by the Engineer, the Contractor shall satisfy himself as to the quality and quantity of material available before providing the information required in this Clause. Should such investigations reveal that there is insufficient suitable material for the use for which the borrow pit was intended, the Contractor shall immediately inform the Engineer in writing and the Engineer shall either direct that the borrow pit be extended or that a new borrow pit shall be used.

The Contractor shall be responsible for any delays in the land acquisition which occur due to any of the above information being incorrect and the 60 day period of land acquisition shall be extended by the period of any such delay.

When a quarry, pit, spoil or stockpile area has insufficient suitable material or area for the use for which it was intended the Contractor shall propose in writing that either an existing quarry, borrow pit, spoil or stockpile area be extended or that a new quarry, borrow pit, spoil or stockpile area shall be used. The approval and acquisition of such new or extended quarries, borrow pits, spoil or stockpile areas shall be in accordance with all the above provisions of this Clause for the acquisition of the original quarries, borrow pits, spoil or stockpile areas.

6.5. Entry Upon Land

The Contractor shall, before entering upon any land provided by the Employer, satisfy himself that legal rights of entry have been obtained.

Where it is necessary to agree levels for the calculation of quantities, the Contractor shall not enter the area until such levels have been agreed and the Engineer's approval obtained.

6.6. Access Roads

The Contractor shall comply with the provisions of Section 9 of this Specification for the construction and maintenance of access roads to quarries, borrow pits, spoil and stockpile areas and for traffic operations.

6.7. Obtaining Borrow Materials

6.7.1 General

Borrow materials shall be obtained from approved sources of supply listed and described on the borrow-pit plans submitted under Clause 6.4, or from such other sources as may from time to time be tested and approved by the Engineer. Borrow-pit material complying with the requirements of the Specifications for the use for which the material is intended shall be selected from these approved sources.

6.7.2 Use of borrow materials

The decision as to which source of supply the Contractor shall use at any time shall rest with the Engineer, and the Contractor shall at any stage of the work use that approved source of supply which in the opinion of the Engineer is the most suitable in regard to the quality and quantities of the various types of available materials and the ultimate cost of the work to the Employer. Unless otherwise determined elsewhere, payment will not be made for moving the Contractor’s plant from one location to another at any of the individual sources shown on the plans or subsequently approved by the Engineer.

Approval of borrow pits or borrow areas shall apply only to those portions of the pit or area from which acceptable material can be obtained or produced. The Contractor shall organise his operations in any approved pit or borrow area or portions thereof with a view to using the material for the purpose envisaged.

The Contractor shall plan his exploitation of the borrow pits in such a manner that the various types of materials excavated can be selected and loaded directly for use. When this is unfeasible for reasons beyond the Contractor's control, material to be stockpiled for later use shall be loaded, transported and temporarily stockpiled as ordered by the Engineer and as determined in Clause 6.9. No material reserved for a specific purpose shall be used for any other purpose without the written approval of the Engineer.

6.7.3 Borrow materials obtainable in the road prism or within the road reserve boundaries

Where suitable sources of materials are available in existing cuttings and side drains, or anywhere else in the road prism or within the road reserve boundaries, such materials may be used for the construction of fills, pavement layers and shoulders, if approved by the Engineer.

6.8. Opening And Working Borrow Pits And Haul Roads

6.8.1 Removing topsoil

The Contractor shall remove topsoil and/or overburden from the borrow pits and haul roads. Topsoil shall be stripped and stockpiled separately and stored in a well-defined and designated area. Where relevant, soil shall be taken out in horizons and each horizon stored in a separate pile, for return/re-use in a similar order. The piles shall be grassed over or covered to prevent erosion, all to the satisfaction of the Engineer.

The Contractor shall maintain a record of the volume and location of topsoil stockpiles.

Temporary ditches and/or settling basins shall be dug to collect runoff water and to prevent erosion and siltation and sedimentation of surface water.

6.8.2 Clearing and grubbing

Unless the clearing and grubbing of a borrow area have been prescribed by the Engineer in writing, no payment will be made for clearing and grubbing such borrow area. This applies particularly to areas opened for obtaining rock or sand used in the construction of stone-pitching, concrete work, crushed-stone base or subbase, permeable subsurface drain material or bituminous asphalt or surfacing.

6.8.3 Excess overburden

As instructed by the Engineer, excess overburden shall be moved to the outer limits of the proposed borrow area, and, if this area is enlarged later on, the excess overburden shall be moved further to the new outer limits, or, where possible at that stage, replaced into the borrow pits as described in Clause 6.10.

6.8.4 Excavating borrow material

Borrow material shall be excavated within the limits of depth and area shown on the borrow-pit plans or as directed by the Engineer, and in a manner that will not prejudice the use of the material for the intended purpose.

Where any borrow pit contains different types of materials in separate layers which require to be mixed to produce a suitable product, the materials shall be excavated over the full depth of the approved working face in one operation without the different types of materials being separated.

The Contractor shall take all reasonable precautionary measures so as to avoid contamination of the suitable borrow material by the inclusion of clayey or otherwise unsuitable material from the floor of the borrow pit, the overburden, any unsuitable layers, or areas beyond the approved limits of the borrow area. During loading, any hard oversize material which will not break down during processing on the road shall be excluded as far as is practicable.

During borrow operations, and especially when excavating material near the floor and outer boundaries of the borrow areas, the Contractor shall plan his operations so as to reduce, in so far as is possible, the amount of earth moving work that will be necessary for finishing-off the borrow pits. Indiscriminate excavation without due regard being given to the desired final shape of the borrow pit will not be permitted.

The material in borrow pits shall be blasted or ripped and excavated in a manner that will ensure the effective breaking-down of the material in the borrow pit before it is loaded. Rippable material which tends to break into large blocks shall be cross-ripped.

6.8.5 Control at borrow pit

The Contractor shall be responsible for controlling his operations at every borrow pit where material is being excavated to ensure compliance with all the requirements of Subclause 6.8.4.

He shall carry out sufficient tests on the material being excavated from the borrow pit to satisfy himself that the quality of the material will comply with the specified requirements for the particular layer for which it will be used.

If there is any doubt concerning the quality of the borrow material being excavated at any time, the Contractor shall notify the Engineer immediately, and in any case before such material is brought onto the road. The results of all the tests carried out by the Contractor shall be submitted to the Engineer on request. The Engineer will, after further testing or inspection if necessary, instruct the Contractor regarding the use of the material in the borrow area, or he may order the borrow pit to be finished off and abandoned.

6.8.6 Protecting borrow pits

Borrow pits shall be continuously protected against the ingress of surface water, and the Contractor shall construct such temporary banks as may be required for diverting surface water, and, in so far as is possible, his operations shall be planned in such a way that the borrow pit will be self-draining, provided that silt traps are installed in accordance with the Environmental Management Plan. Where this is not possible, borrow pits shall be dewatered by pumping, ensuring that water is filtered through vegetation or a suitable silt trap before being allowed to enter a water course. The Contractor shall be solely responsible for keeping borrow areas dry and ensuring that borrow material is sufficiently dry when required for use.

6.9. Stockpiling the Material

The Contractor shall so plan his activities that materials excavated from borrow pits and cuttings, in so far as is possible, can be transported direct to and placed at the point where it is to be used. However, where utilising materials in this manner is impracticable, and, if so instructed by the Engineer in writing, it shall be temporarily stockpiled for later loading and transportation to where it will be used. Compensation for stockpiling materials will be payable only in regard to material stockpiled in accordance with the Engineer's written instructions.

The temporary stockpiling of material within the borrow area in heaps with a view to loading, or any other stockpiling method used in connection with the loading method adopted by the Contractor in the cutting or borrow pit, will not be classified as temporary stockpiling. The costs for these processes will be deemed to be covered by the rates for the various items of work for which material so stockpiled is used.

Stockpiling areas and maximum heights of stockpiles shall be indicated or approved by the Engineer. Before any stockpiling of material may be done, the site shall be cleaned, and all loose stones or any vegetation or other material which may contaminate the material shall be removed. During use, the lower 100 mm of stockpiled material shall not be utilised for construction. After the stockpiled material has been removed, the site shall be reinstated as closely as possible to its original condition, and the surface shall be lightly scarified and seeded in accordance with the Environmental Management Plan.

Payment will be made for stockpiling the material from existing pavements only if the material is intended for re-use and if its stockpiling has been approved or directed by the Engineer.

6.10. Site Clearance

Unless otherwise directed by the Engineer the Contractor shall remove topsoil and/or overburden from quarries, borrow pits, spoil and stockpile areas and access roads. Topsoil and overburden shall be stripped and stockpiled separately solely for later rehabilitation of the excavations. Topsoil and overburden shall not be used in the Works.

6.11. Reinstatement of Borrow Sites, Quarries, Stockpile and Spoil Areas

On completion of work in any quarry, borrow pit, access road, spoil or stockpile area , the Contractor shall reinstate the entire area in accordance with the Environmental Management Plan so as to blend it with the surrounding area and to permit the re-establishment of vegetation. For this purpose the borrow area shall be shaped to even contours without any slopes being steeper than 1:3, except where the Engineer so permits in specified cases. The overburden and/or topsoil shall be pushed back, spread evenly to the prescribed thickness and landscaped over the area of the quarry, borrow pit, access road, spoil or stockpile area. Separately stockpiled topsoil shall be pushed back and spread over the quarry, borrow pit, access road, spoil or stockpile area after landscaping. After spreading, the topsoil shall be protected by seeding or revegetated in accordance with the Environmental Management Plan.

Any borrow pit, quarry, stockpile and spoil area that will no longer be used shall be reinstated within 14 days of last day of use.

If the local community requests that the borrow pit, quarry, spoil or stockpiled areas not be reinstated, the Contractor shall, upon approval from the Engineer and consensus from the EPA and the District Assemblies, obtain a signed agreement with the community leaders to that effect. Borrow pits and quarries shall not be used as landfill sites unless permission to do so has been granted by the relevant authorities and an Environmental Impact Assessment has been undertaken.

Solid waste and rubbish may not be dumped into the borrow area. Material incapable of supporting vegetation shall be buried and used for shaping the borrow area and shall subsequently be covered with soft material.

The shaping and finishing-off of the borrow pit shall be done in such a manner that the borrow pit will be properly drained wherever practicable, and, where required, the Contractor shall place earth banks to divert surface water from the borrow area. No standing water shall remain.

If so directed, the borrow area shall be fenced off and provided with gates as specified in Clause 23.3 and topsoiled and/or seeded. The finishing-off of the borrow areas shall be to the entire satisfaction of the Engineer and the Contractor shall submit to the Engineer a signed certificate from the landowner or relevant Government Agency stating that the finishing-off complies with all necessary legal provisions. The Contractor's attention is drawn to the provisions of Clause 1.25 in this respect.

All haul roads shall be obliterated and their surfaces scarified, earth banks shall be constructed to prevent erosion, and all damaged fences and other structures shall be reinstated to their original condition or to the satisfaction of the Engineer, unless otherwise specified.

Where materials from a borrow pit are hauled on private access roads, such roads shall be restored to their original condition to the satisfaction of the Engineer when borrow operations at the borrow pit are completed, unless otherwise specified. No additional payment will be made for this work, and full compensation for restoring private access roads used as haul roads will be regarded as being included in the rates tendered and paid for in the various items of work where the materials are used.

6.12. Disposal Of Borrow Material

The Contractor shall not have the right to use any topsoil, overburden or material obtained from borrow pits for any purpose other than for the execution of this contract. He shall not dispose of any borrow material whether processed or not either by sale or donation to any person without the written authorisation of the Engineer.

6.13. Breaking up of Existing Pavement Layers

In order to conserve and reuse materials it may be necessary to break up and excavate existing pavement layers by conventional means or by milling, selecting the material for possible reuse and removing it to stockpiles for later reprocessing and recycling or spoil dumps.

6.13.1 Selecting the material

Material from existing pavements may only be used for purposes approved by the Engineer. The material shall be so excavated that material from the various pavement layers will not be mixed unless so permitted by the Engineer, in writing.

6.13.2 Classifying the material

Material from existing pavements shall be classified as follows for excavation and processing purposes:

(a) Existing bituminous material

Existing bituminous material shall be asphalt or other bituminous seal or base material removed separately from the existing layers on the instruction of the Engineer. Where underlying material is broken down or excavated together with bituminous materials, the mixture will not be classified as bituminous material for payment purposes.

(b) Non-cemented material

Non-cemented material shall be existing pavement material that can be ripped with the teeth of a 140G Caterpillar or similar grader.

(c) Cemented material

Cemented material shall be existing pavement material which cannot be ripped with a Type 140G Caterpillar or similar grader. Existing stabilized material will not necessarily be classified as cemented material.

(d) Cemented crushed stone

Cemented crushed stone shall be existing cemented material consisting of crushed stone. Unless specified as such in the Project Specifications, cemented crushed stone will not be classified as concrete.

(e) Milled material

Milled material shall be bituminous material and/or cemented crushed stone excavated with an approved milling machine. Milled material will be classified as such only when milling is specified or ordered by the Engineer, in writing. Payment will normally distinguish between milling of asphalt and of cemented crushed stone.

(f) Pulverized material

Pulverized material shall be bituminous material and/or cemented crushed stone excavated with an approved pulverizing machine. Pulverized material will be classified as such only when pulverization is specified or ordered by the Engineer for the purpose of in situ recycling.

6.13.3 Plant and machinery

(a) Milling equipment

Only approved milling plant may be used. The plant shall be so equipped that it will be able to mill out asphalt and/or cemented material to the prescribed depth in one operation over the width specified in the Project Specifications. The milling depth shall be controlled electronically.

The direction and speed of the milling machine and the speed of rotation of the milling drum shall be adjustable so as to obtain the required grading of the milled material. The machine shall be capable of making a neat vertical cut at the outer edges when milling the layer and to leave the floor of the cut level and with a uniform texture.

Unless otherwise specified in the Special Specification, the milling machine shall be equipped with a self-loading conveyor belt that can be easily removed and installed and adjusted for slope and direction.

(b) Pulverization equipment
Only approved pulverizing plant may be used. The plant shall be so equipped that it will be able to pulverize asphalt and/or cemented material to the prescribed depth in one operation over the width specified in the Special Specification. The pulverization depth shall be controlled electronically.

The machine shall be capable of making a neat vertical cut at the outer edges when pulverizing the layer and to leave the floor of the cut level and with a uniform texture.

(c) General
The equipment to be used for the conventional breaking-up and excavation of existing pavement layers will be determined by the size and depth of the pavement section to be processed or excavated, taking consideration of the fact that work may have to be carried out in restricted areas.

Only approved cutting or sawing equipment may be used for cutting or sawing the asphalt layers. The equipment shall be capable of cutting the asphalt layers to the specified depth in one operation without fragmenting the material, and in straight lines within the required tolerances.

6.13.4 Construction

(a) General
Where all or a part of the existing surfacing material is to be reprocessed together with the underlying layer, the surfacing shall be properly broken down and mixed through the full depth of the existing base material to the satisfaction of the Engineer. Fragments of bituminous material shall be broken down to sizes not exceeding 37.5 mm.

Where specified in the Special Specifications or ordered by the Engineer, the existing bituminous material shall first be removed before the underlying layers are broken up.

Bituminous material may be milled out or otherwise broken up and removed to approved stockpile sites for recycling or to spoil sites, whichever is required. The exposed surface shall be cleaned to the satisfaction of the Engineer after removal of the bituminous material. Not more than 5% of the surface may be covered with bituminous material.

The existing pavement material shall be broken down to the specified depth and removed, or reprocessed in place, whichever may be required. The underlying layers may not be damaged, and material from one layer may not be mixed with that of another layer. Where such mixing occurs or where the material is contaminated in any other way by the actions of the Contractor, he shall remove such material and replace it with other approved material, all at his own cost.

Where a layer or layers require to be broken down over part of the pavement width only, the limit of the work shall be clearly demarcated, which limit shall not be exceeded by the Contractor by more than 100 mm. Pavement layers broken down outside the specified limits shall be repaired by the Contractor at his own cost, to the satisfaction of the Engineer.

Where so ordered by the Engineer, asphalt and cemented layers shall be cut or sawn through to the specified depth along the measured limit with approved equipment. Payment will be made for sawing only where specified on the Drawings or ordered, in writing, by the Engineer.

Payment will not be made for sawing or cutting work where the existing layer requires removal by milling.

Where existing roads have to be widened, the existing pavement layers shall be cut back to a firm, well-compacted or cemented material. Material so broken up, if acceptable, may be used together with imported material in the widening process, except in the case of crushed-stone base.

Where pavement layers are broken down over a section of the road width or where pavement layers are widened, the Engineer may order, in writing, that the various pavement layers be excavated in benches in accordance with his instructions. No additional payment will be made for excavating benches.

Where underlying layers are still structurally sound and are included as structural layers in the new design drawings, care shall be taken not to break them up during removal of the surfacing or underlying layers.

(b) Milling

(i) Preparing the pavement surface

Before milling may be commenced, the pavement surface shall be clean and free from soil or other deleterious material. Where only part of the pavement is to be milled out, the milling area shall be properly demarcated. Milling may not exceed the required width by more than 50 mm.

Payment will not be made for milling beyond the required width, which shall be backfilled with approved material in accordance with the provisions for the specified pavement material at the cost of the Contractor.

(ii) Trial milling

Where ordered by the Engineer, the Contractor shall execute trial milling on the various materials to be milled. During the trial work, the Contractor will be expected to vary the direction and speed of the milling machine, the speed of rotation of the milling drum, and also the milling depth, in order to obtain milled material of the required grade. No payment will be made for trial milling.

(iii) Asphalt

Where the asphalt and/or the cemented base must be reused, the asphalt shall be removed separately. Where the asphalt consists of layers of various mixes or grades, the Engineer may instruct the separate removal of the layers to different stockpiles. Where the milled material is not conveyed directly by conveyor belt and then loaded, and the Engineer so approves, the material shall first be cut to windrow and then loaded. During loading, the floor of the excavation or the underlying material shall not be damaged.

The milled material shall be inspected and classified in accordance with the various types of asphalt and its suitability for recycling. Different stockpiles shall be used for the different types of material as ordered by the Engineer. Contamination of the asphalt with underlying material will not be permitted, and the Contractor shall adjust the depths of milling in accordance with the thickness of the layer.

(iv) Milling in restricted areas

Extra over payment shall only apply to milling widths of less than 1.0 m.

(v) Cemented material

Unless otherwise specified milled cemented material to be reprocessed on the road shall first be windrowed with a view to inspecting the underlying surface for any patches of poor or unsuitable material. Where unsuitable material is encountered in the floor of the excavation, such material shall first be removed by further milling (where the underlying layer also consists of the cemented material), or by other approved methods, all to the satisfaction of the Engineer. The unsuitable material shall be replaced with approved material of the required type, which shall be placed in accordance with the specifications for the relevant underlying layer.

Where in the opinion of the Engineer it may be necessary, he may instruct the Contractor to taper the ends or edges of a milled excavation for which payment will be made, provided that the tapering is not the result of defective work. Payment for the milling-out of cemented crushed stone will distinguish between the various strengths of the cemented layer. Where the Engineer is of the opinion that the existing cemented layer has a compressive strength exceeding 10 N/mm^2, he may instruct the Contractor to drill cores from the layer and have them tested for compressive strength in accordance with Clause 2.9.2 or equivalent. The number of cores to be drilled out and the drilling locations will be determined on site by the Engineer.

(vi) General

The floor of the milled excavation shall be level and with an even texture. Any loose patches or patches of unsuitable material shall be remedied in accordance with the instructions of the Engineer. Payment for removing and replacing unsuitable material and remedying loose patches shall be as specified in the Special Specifications. Where such remedial work is done in restricted areas, the extra over payment concerned shall be in accordance with the provisions of the appropriate clauses.

Where the floor of an excavation is tested in the longitudinal direction with a 3 m straight-edge, and in other directions with a 3 m straight-edge or a straight-edge of such shorter length as fits in between the longitudinal sides of the excavation, the surface shall not deviate by more than 7 mm from the bottom edge of the straight-edge.

Payment for milling will distinguish between various types of milled material and between various milling depths.

6.13.5 Storing recovered pavement material

Excavated pavement material intended for reprocessing but which cannot be reprocessed in place or, in the opinion of the Engineer, cannot be windrowed next to the excavation, nor placed in position directly at any other place, and material intended for recycling or reprocessing in a plant, shall be transported to approved stockpiles with the written permission of the Engineer.

Stockpile sites for material intended for recycling or reprocessing in a plant shall be set out at the corresponding mixing or crushing plant or at such other locations as approved by the Engineer.

The stockpile site shall be cleaned, and all loose stones, vegetation and other materials that may cause contamination shall be removed. The site shall be graded smooth with an adequate slope to ensure proper drainage of water. Where so instructed by the Engineer, the surface shall be watered and compacted to a depth of at least 150 mm to a density of 90% of GHA S1 density. The compacted surface shall be firm without any loose patches. Where asphalt is recovered for recycling, the Engineer may order the surface to be chemically stabilized to a depth of 150 mm. Upon completion, this surface shall be swept clean.

Stockpile sites shall be sufficiently large to allow the placing of stockpiles of different types of material or types of recovered asphalt without the stockpiles overlapping or the limits of the prepared site being exceeded. The enlargement of the stockpile site after the stockpiles have already been placed will not be permitted without the approval of the Engineer.

Stockpiles of milled material shall be shaped in a manner that will limit segregation to a minimum. Stockpiling of asphalt shall be done in a manner that will limit consolidation to a minimum. Adequate approved covers shall be provided for recovered asphalt stockpiles to prevent them from becoming wet, or being contaminated by dust.

Stockpiles shall be surrounded by a suitable silt fence to prevent the loss of fines and pollution of surrounding areas and watercourses, in accordance with the Environmental Management Plan.

Upon completion of the work, the stockpile sites shall be broken up in accordance with the instructions of the Engineer.

The stockpiling of excavated material will not be paid for directly, but full compensation therefore shall be included in the rates for the various items of work in which the stockpiled material will be used. The stockpile sites shall be deemed to be included in the rates tendered.

SECTION 7

EXCAVATION AND FILLING FOR STRUCTURES

CONTENTS

TABLES

7. EXCAVATION AND FILLING FOR STRUCTURES

7.1. Scope

This section covers all excavation and filling operations to bridges, box culverts, retaining walls and other major structures. It includes all excavations not provided for elsewhere in these Specifications.

7.2. Classification of Excavated Material

(a) Hard material is material that can be excavated only after drilling and blasting with explosives or barring and wedging or by the use of pneumatic tools or a mechanical breaker fitted with a rock point in good condition and operated correctly. Boulders of more than 0.2 m^3 occurring in soft material shall be classified as hard material.

(b) Soft material is all material other than hard material.

7.3. Excavation of Foundations for Structures

7.3.1 General

Prior to commencing with any excavation, the Contractor shall notify the Engineer in good time to ensure that levels be taken of the undisturbed ground surface for determining a ground surface from where the excavation can be measured, and this ground surface shall be agreed on by the Engineer and the Contractor.

7.3.2 Excavation

Excavations for structures shall be kept to a minimum. Trenches and foundation pits for structures and any associated drainage works shall, unless otherwise approved by the Engineer, be excavated with vertical sides and shall be properly timbered or sheet piled, shored and strutted as necessary to prevent subsidence or slipping of the surrounding soil.

Where a concrete blinding layer is called for on the Drawings, or instructed by the Engineer, the excavated level shall allow an additional 50 mm for the blinding. A 50 mm thick blinding layer shall be used in all excavations for foundations in hard material.

Where excavation lines are indicated on the Drawings, the earthworks shall be carried out accordingly and for the purpose of measurement, the extremities of the excavation shall be deemed to be the lines defined on the Drawings.

Where in the opinion of the Engineer, the casting of concrete against the excavated earth faces is not advisable, or where formwork has to be provided, the extremities of the excavation, for purposes of measurement and payment, shall be deemed to be vertical planes parallel to and 0.5 m outside the perimeter of the member for which the formwork is provided, typically 0.5 m outside footings for structures.

No compensation shall be paid for over-excavation except where specifically ordered by the Engineer.

Hard material at founding level shall be cut and trimmed to a level, stepped or serrated firm surface as required.

Where, in the opinion of the Engineer, unsuitable material is encountered at the founding level, such material shall be removed to the depth and width instructed by the Engineer, and replaced with a suitable granular material, or concrete, as directed.

Where the approved founding material is of a type which quickly deteriorates on exposure, the excavation shall be taken to the final level, immediately before the blinding layer is placed.

If the volume of excavation must be increased in order to comply with the working methods of the Contractor, demands from Authorities or other reasons causing larger slopes than specified, the increase in excavation and correspondingly in backfilling shall be included in the tendered unit prices respectively.

Where suitable stable material is encountered during excavating, that part of the trench or foundation pit shall be excavated to the neat dimensions of the base, unless otherwise directed by the Engineer. Over-excavation (overbreak) in hard material shall be backfilled with the same class of concrete as that in the base or with mass concrete fill as specified or as directed by the Engineer.

Where blasting is required, the Contractor shall complete the entire foundation excavation before he commences with the construction of any permanent concrete work, unless otherwise approved by the Engineer. All blasting shall be carried out in accordance with the requirements of Clauses 1.27 and 5.3.

Subsurface and foundation exploratory data as shown on the Drawings or specified may not necessarily prove representative of all material encountered during excavation. If it is found during the course of excavation that the load bearing capacity differs from that shown on the Drawings, the Contractor shall notify the Engineer immediately.

The Engineer shall be entitled, as often as he may deem necessary during the course of excavation, to instruct the Contractor to perform additional foundation investigation and/or testing at or below the founding levels to establish safe bearing capacities and foundation depths.

It is the responsibility of the Contractor to control any groundwater, surface water or rainwater such that the bottom or sides of the excavations are not softened and/or the bearing capacity of the soil reduced. Any cost of such water control shall be included in the Contractor’s price. Where in the opinion of the Engineer, the bottom or sides of the excavation have become soft due solely to the Contractor's method of working or negligence on his part, the softened material shall be removed and replaced with foundation fill, granular material or lean concrete as directed by the Engineer at the Contractor’s expense.

The final levels of the bottom of excavations shall be undisturbed material cleaned free of unsound materials, flaking, dust and other contaminants. The excavation shall be inspected and approved by the Engineer before placing any foundation fill/mass concrete.

For foundations of structures, the following shall be noted:

(i) If it is found during the course of excavation that the material at the founding depths indicated on the Drawings does not possess the required bearing capacity, the excavations shall be extended at the discretion of the Engineer, until satisfactory foundation conditions are encountered;

(ii) If it is found during the course of excavation that the level to fresh rock is shallower than indicated on the Drawings, the Contractor shall inform the Engineer in order to decide on changes in the final foundation level;

All excavated surfaces, in material other than hard material, on which foundations for structures are to be placed shall be compacted to 93% MDD (GHA S1) to a depth of 150 mm immediately before concrete is cast.

Where a combination of hard and soft materials exist at the founding level, the Contractor shall, as instructed by the Engineer, either remove a minimum of 300 mm of soft material below the underside of the foundation and replace it with Class NS 10 (see Clause 18.5.4) concrete to the top of the blinding level or remove a minimum of 300 mm of hard material below the underside of the blinding concrete and replace it with a granular material compacted to 93% MDD (GHA S1).

Surplus excavated material shall be taken to spoil areas or preferably, be used in adjacent earthworks if possible. Boulders, logs or any other unsuitable material excavated shall be spoiled.

The Engineer's approval of any excavation shall be obtained prior to any construction thereon.

7.3.3 Excavation by hand

Where circumstances prevent the use of mechanical excavators and material can be removed only by hand implements, the Engineer shall authorise the supplementary payment to the Contractor for such work at the tendered rates for excavation by hand should he be satisfied that the Contractor had been unable to prevent the necessity for excavation by hand by proper planning and precautionary measures. The supplementary rate for excavation by hand shall not apply to minor finishing or clearing jobs in excavations which are otherwise being done by mass excavation plant.

7.3.4 Safety of excavations

The Contractor shall take the necessary precautions to safeguard the stability and safety of the excavations and adjacent structures as well as the safety of workers and the public (See Sec 1.20 and 9.7.

7.4. Foundations Cast Against In-situ Material

Where shown on the Drawings or instructed by the Engineer that a foundation, abutment and/or wall is to be cast against the excavated earth faces, the trench or foundation pit shall be neatly excavated to the dimensions and shape required and the surface cleaned of all loose material. Any over-excavation shall be backfilled with Class NS 10 concrete or with the same grade of concrete as the foundation, abutment and/or wall or as directed by the Engineer.

Backfill to any over-excavation resulting from the Contractor's neglect, or method of working shall be to the cost of the Contractor.

7.5. Backfilling and Filling Against Structures

No filling around a structure or backfill in a trench or excavation shall commence, neither shall a structure be loaded, without the approval of the Engineer.

The sequence of filling and backfilling behind and around a structure and the maximum difference in height at any time between fill levels shall be proposed by the Contractor and approved by the Engineer.

All filling and backfilling shall be selected materials brought up in horizontal layers not exceeding 150 mm compacted thickness. Each layer shall be moistened or dried to the optimum moisture content as appropriate and compacted to a minimum dry density of 93% MDD (GHA S1) for soils and gravels and not less than 100% MDD (GHA S1) for cohesionless sands, or to the density of the surrounding soil, whichever is less, except that in the road prism, the soil shall be compacted to not less than 93% MDD (GHA S1).

That part of the fill within a horizontal distance of 3 m from the vertical and inclined concrete faces of the structure and that part between the pillars of the spill-through abutments or that part shown on the Drawings, shall be termed "fill within restricted area".

Fill within the restricted area shall comply with the requirements of Section 5.5, except that it shall be compacted to a density of not less than 93% MDD (GHA S1). In order to achieve the specified density, the Contractor shall, where necessary, import material of suitable quality.

Unless otherwise directed by the Engineer, only mechanical compaction equipment that is pushed or drawn by hand shall be used to achieve the required density within a horizontal distance of 3 m from any concrete structure. Fill in spaces below concrete soffits that are inaccessible for mechanical compaction equipment shall be constructed by methods specified or approved by the Engineer.

Timbering and sheeting left in for the purpose of supporting the excavation shall be eased up 150 mm at a time in step with the backfill layer. Where instructed by the Engineer, timbering or sheeting shall be left in place.

Where instructed, or shown on the Drawings, a drainage layer comprising selected granular fill material and/or porous filter material shall be placed behind retaining walls and abutments. A sliding form or other approved means shall be used during backfilling such that the porous filter is brought up and compacted at least 150 mm ahead of the selected granular fill material: this selected granular fill, in turn shall be brought up and compacted at least 150 mm ahead of the adjacent earthworks fill.

7.6. Foundation Fill

Selected fill shall be used as foundation filling as well as within 0.6 m of walls, unless otherwise indicated on the Drawings. The fill shall be well-graded granular material, free of clay, silt and organic material (less than 1.0% loss of mass when heated in the furnace). Fill complying with the following gradation curve (Table 7.1) shall be considered acceptable.

Table 7.1: Gradation curve for fill

Sieve size (mm)	% Material passing
32	100
4	85 – 100
0.25	0 – 50
0.125	0 – 15
0.075	0 - 8
Coefficient of uniformity $U_c = d_{60}/d_{10} > 2.5$	

where d_{60} and d_{10} are the respective particle sizes (read off the particle size distribution curves) at which 60 and 10% of the material pass.

Material that has been demonstrated to be free-draining but is of a different gradation may be used with the approval of the Engineer, but shall be separated from the selected granular fill by an appropriate geotextile.

The fill should be placed in the dry. Fill placed under water shall be allowed only under exceptional circumstances, where it is, in the opinion of the Engineer, not practically feasible to dewater before filling, and the necessary approvals have been granted by the Environmental Protection Agency. No fill shall be placed in flowing water. The fill to be placed in water shall comply with the above mentioned gradation curve as well as the following:

Material finer than 0.125 mm shall not exceed 5%
Coefficient of uniformity $U_c = d_{60}/d_{10} > 3.0$

Where indicated on the Drawings, filter material shall be placed along concrete walls. The materials shall comply with the requirements of Clause 8.10.

7.7. Access, Drainage and Protection Works

The Contractor shall furnish, construct and maintain all necessary access platforms and protection works. Drawings for temporary banks, artificial islands, cofferdams and other proposed temporary installations shall be submitted to the Engineer for approval before commencement of the work. All such structures shall be removed on completion of the works unless otherwise instructed by the Engineer.

The Contractor shall apply suitable and effective drainage methods to prevent the ingress of water into excavations and to keep them dry. The drainage methods employed shall be such that fresh concrete or founding material will not be carried away with the water.

All work in or near water courses and standing water shall be undertaken in accordance with the Environmental Management Plan.

SECTION 8

CULVERT AND DRAINAGE WORKS

CONTENTS

TABLES

8. CULVERTS AND DRAINAGE WORKS

8.1. Scope

This section covers the following:

(a) The provision and installation of concrete pipe culverts, prefabricated concrete box culverts, nestable and multiplate corrugated metal pipe culverts, gullies and inlets, and arches of half round channels.

(b) The construction of cast in situ concrete U-drains and minor structures including culvert inlet and outlet structures, scour checks, catchpits, and cascades.

(c) The construction of drainage protection works including rip-rap, stone pitching and gabions.

(d) The excavation and/or fill and all work associated with the construction of:

trenches to receive culverts (other than cast in situ concrete box culverts covered in Section 7.3.2)
inlet drains
outfall drains
mitre (turnout) drains
cut-off drains
subsoil drains
catchwater drains
minor structures
scour checks
erosion protection works
guiding dams

8.2. Materials

8.2.1 Pipes and Fittings

(a) Concrete pipes shall comply with the requirements of BS 5911-1.

(b) Concrete for concrete pipes shall have a minimum cement content of 300 kg/m^3, and comply with Section 18 of this Specification.

(c) The pipes shall have flexible joints in accordance with BS 5911-1 or ogee joints in accordance with BS 5911-110.

(d) Reinforcement may be inserted in the pipes to strengthen them for handling, but the size, spacing and placing of reinforcement shall be to the approval of the Engineer.

(e) All concrete shall be compacted either by spinning or vibrating.

(f) All concrete pipes shall be cured by keeping them saturated with water for at least seven days after casting and protected from the sun and drying winds for at least fourteen days after casting. No pipe shall be used in the work until it is twenty-one days old. The date of casting shall be painted on the outside of the barrel.

Pipes shall be cured in an approved manner. Water courses, rivers, dams, ponds and other natural water bodies shall not be used for curing of concrete pipes. Curing water shall be released into a suitable area in accordance with the Environmental Management Plan. No curing water shall be released in natural water bodies.

A minimum of 10% of the pipes shall be tested from initial batches prepared by the Contractor and thereafter the frequency of testing shall be decided by the Engineer.

All pipes shall, unless otherwise specified, be strength Class 120, with minimum crushing loads in accordance with Table 8 of BS5911-1 (Table 8.1). Strength class is defined in BS EN 1916 as the minimum crushing load in kilonewtons per metre, divided by one thousandth of either a unit's nominal size (DN) or nominal width (WN).

If required by the Engineer, a set of six concrete cubes shall be made for each day's manufacturing of concrete pipes. Where the 28 day crushing strength does not reach the C30/37 requirement, or if pipes appear sub-standard the Engineer may order the above load tests on a set of three pipes from the suspect batch. If the mean strength of the three tests is less than 100% of the required strength and the minimum value of any one test is less than 95%, the whole batch shall be rejected.

(g) Pipes for use in subsoil-drains shall be one of the following:

(i) porous concrete pipes to BS 5911-114;
(ii) concrete pipes to BS 5911-1 and BS 5911-3 with a maximum length of 1.5 m laid with open joints.
(iii) 100 mm diameter PVC pipes complying with BS 3506 Class 3: The pipes shall be perforated or slotted, the diameter of the perforation or width of the slot being 3 ± 1.0 mm and the total area of the holes or slots being 0.5 to 1.0% of the surface area of the pipe.

(h) The Engineer shall reject any cracked pipes, which will be destroyed or removed from site.

Table 8.1: Minimum crushing loads for strength class 120 units with a circular bore for use in a trench (table 8 of BS 5911-1

Nominal size (DN)	Minimum crushing load, F_n (kN/m)
225	27
300	36
375	45
400	48
450	54
500	60
525	63
600	72
675	81
700	84
750	90
800	96
825	99
900	108
1000	120
1050	126
1200	144
1350	162
1400	168
1500	180
1600	192
1800	216
2000	240
2100	252
2200	264
2400	288
2500	300
2800	336
3000	360

8.2.2 Metal Pipes and Arches

(a) Corrugated metal pipe culverts shall be in accordance with AASHTO M 36.

(b) Structural plate for pipe, pipe arches and arches shall be in accordance with AASHTO M 167.

(c) Unless otherwise directed, all pipes shall be painted prior to assembly both inside and out with one coat of purpose made bituminous paint, approved by the Engineer. During assembly both areas of pipe sections in contact shall be painted with a second coat of purpose made bituminous paint immediately prior to fixing.

After assembly all pipes shall be painted over the exposed area outside with a further coat of purpose made bituminous paint, and all pipes of 1.2 m diameter and over shall also be painted internally.

(d) All corrugated metal pipe culverts shall be surrounded with concrete.

8.2.3 Concrete

All concrete work shall be carried out in accordance with the relevant requirements of Sections 18 and 19 of the Specification.

8.3. Order of Works

(a) The Drawings give a guide only to the location and size of each culvert. Precise details of length, skew and invert levels will be issued to the Contractor by the Engineer from time to time as construction proceeds. The Contractor should allow in his programme a period of 30 days between submission of cross-sections in accordance with Section 3 of the Specification and the issue of precise culvert details.

(b) Where the Contractor considers that drainage conditions are such that it is not necessary to construct a pipe culvert ahead of the embankment, the Engineer may consent to its installation after construction of the embankment on the following conditions:

   (i) that the Contractor shall be responsible for any damage or delays to the culvert or to the embankment earthworks; and
   (ii) that the construction of the culvert shall follow immediately upon the substantial completion of the embankment earthworks;
   (iii) any additional costs due to additional excavation and backfilling works shall be at the Contractor's expense.

(c) Where culverts are to be constructed under a road formation in cutting, excavation and backfill shall be carried out after the bulk earthworks are complete but before the processing of the 300 mm layer below formation level in cuttings unless otherwise approved.

(d) The drainage works shall, in all cases, be completed before the commencement of pavement construction.

8.4. Final Location of Box and Pipe Culverts

Notwithstanding the information contained in the Drawings, the final locations and invert levels of box and pipe culverts shall be subject to confirmation or adjustment by the Engineer as he deems appropriate, prior to commencement of construction.

8.5. Excavation for Culverts

8.5.1 Classification of excavated materials

All excavated material for culverts and drainage works shall be classified as in Clause 7.2 of the Specification.

8.5.2 General

The depth of excavation for culverts shall be sufficient to accommodate the required bedding as detailed on the Drawings or instructed by the Engineer.

Should excavations be effected to a greater depth or width than is necessary, the Contractor shall, at his own cost, backfill the excess excavation with approved materials, compacted to the density of the adjacent ground, to the correct levels and dimensions, to the satisfaction of the Engineer.

The Contractor shall carefully set aside the various suitable materials encountered so that they may be reused for backfilling. If excavated materials are unsuitable the Contractor shall dispose of them in spoil areas.

Where, in the opinion of the Engineer, the surface of the excavation has become soft or unsuitable due to the Contractor's method of working, the Contractor shall at his own expense remove and replace the unsuitable material with non-structural concrete as specified in Clause 18.2 of the Specification or other material acceptable to the Engineer.

The Engineer's approval of the final excavated surface shall be obtained prior to the installation of culverts or the construction of structures.

8.5.3 Excavation in soft material

The final excavated surface in soft material on which culverts or structures are to be constructed shall be compacted to a dry density of at least 93% MDD (GHA S1) to a depth of 150 mm. Where corrugated metal pipes are to be placed, the material immediately below shall not contain any protruding sharp stones.

For culverts which are to be constructed approximately on the existing ground after the removal of topsoil, the Contractor shall level the existing ground by excavating and/or filling in layers. He shall then compact the ground for 150 mm below invert or underside of bedding material to a dry density of 93% MDD (GHA S1) such that the foundation for the culvert or bedding is true to grade and of uniform density over the whole length of the culvert.

The sides of pits, trenches and other excavations shall, where required, be adequately supported with timber or any other material approved by the Engineer.

Where instructed by the Engineer, shoring shall be left in trenches or other excavations.

Where ground conditions are such that a satisfactory foundation cannot be achieved the Contractor shall remove the unsuitable material either until a suitable material is encountered or to the depth and width approved by the Engineer. The Contractor shall backfill the resultant excavation with approved material to a dry density of at least 93% MDD (GHA S1). Approved material may include rock fill as specified in Clause 5.7 of the Specification and/or selected backfill material in accordance with Clause 8.8 of the Specification.

8.5.4 Excavation in Hard Material

(a) For concrete pipe culverts

(i) Where hard material is encountered in trenches for concrete pipe culverts, it shall be excavated so that no hard material protrudes within 50 mm of the underside of the pipe barrel.

(ii) Where shown on the Drawings or instructed by the Engineer, the excavation shall be deepened by 50mm to accommodate a concrete blinding layer, whose top surface shall be a minimum of 150mm below the underside of the barrel to accommodate the base slab.

(iii) Where both soft and hard material are encountered in the trench either the soft material shall be removed to a depth of 300 mm or to such depth as agreed by the Engineer, and replaced with non-structural concrete Class NS 10 or, if directed by the Engineer the hard material shall be removed to a depth of 300 mm and backfilled with similar material to that in the remainder of the trench invert compacted to at least 93% MDD (GHA S1) or as instructed by the Engineer.

(b) For metal pipe culverts

(i) Where hard material is encountered in trenches for corrugated metal pipe culverts, it shall be excavated to a depth of 150 mm below the invert level of the culvert and replaced with 150 mm of sand or other approved material to provide a firm but flexible bed for the culvert.

(ii) Where both soft and hard material are encountered in the trench the hard material shall be removed to a depth of 300 mm and backfilled to 93% MDD (GHA S1) with similar material to that in the remainder of the trench invert, or as directed and agreed by the Engineer.

(c) For minor structures

In accordance with the relevant sections of Clause 7.3 of the Specification.

8.6. Bedding and Laying of Pipe Culverts

Pipe culverts shall normally be bedded directly on in-situ soft material. Where the in-situ material is unsuitable the invert shall be excavated and backfilled as specified in Clauses 8.5.3 and 8.5.4 of the Specification.

(a) Bedding and laying of concrete pipe culverts on in-situ or imported material.

After compaction in accordance with Clause 8.5.3, the bottom of the excavation or the finished level of the ground for bedding of the culverts shall be shaped to the lower part of the pipe such that the barrel of the culvert rests on it over a width of at least one third of its diameter, and throughout the length of barrel.

Voids shall be formed under the joints and sockets so that adequate space is provided under the pipe to form the joint. When the joint has been formed the void shall be packed hard with bedding material. The underside of the barrel shall be packed hard with selected fill material with a maximum particle size of 20 mm, at a suitable moisture content, and rammed solid.

(b) Bedding and laying of concrete pipes in hard material or on a concrete bed

Where pipes are laid in hard material, they shall be bedded on 1:3 cement: sand mortar at least 50 mm thick, 150 mm wide and extending the full length of the barrel.

After the joints have been formed, concrete Class NS15 shall be packed hard under the barrel and sockets of the culvert extending upwards on each side of the pipe to the height shown on the Drawings.

(c) Bedding and laying of metal culverts

All pipes shall be laid, bedded and jointed in accordance with the manufacturer's recommendations.

Where shown on the Drawings the excavation shall be trimmed to the contour of the base of the culvert and a bed of fine granular material not less than 75 mm thick shall be placed, compacted and shaped to enable the culvert to be bedded.

During assembly both contact areas of the pipe sections shall be painted with a second coat of bituminous paint as specified in Subclause 8.2.2 (c) immediately prior to fixing.

Pipe laying shall be started at the outlet end with the separate sections firmly jointed together and with outside laps of circumferential joints pointing upstream. With the permission of the Engineer pipes may be assembled out of the trench and lowered in, in which case particular care shall be taken to ensure the barrels are properly bedded along the whole length. Outside legs of longitudinal joints shall point downwards.

Multiple installations shall be laid with centrelines parallel. Unless otherwise instructed or shown on the Drawings, the clear distance between barrels of adjacent pipes shall be at least equal to one half the diameter of the pipes.

(d) Concrete Beds, Surrounds and Haunches

The floor of the trench shall be thoroughly cleaned trimmed and compacted before any bed, surround or haunch is placed and shall be subject to approval by the Engineer before concreting is commenced.

Unless otherwise specified, all concrete for beds, surrounds and haunches shall be Class NS15 formed to the dimensions shown on the Drawings or as instructed by the Engineer. The concrete shall be well compacted beneath the pipe but care should be taken to ensure that the pipes are not damaged or displaced during placing of the surround.

Unless otherwise instructed by the Engineer, 150 mm of concrete surround shall be provided to concrete pipes in the following circumstances:

(i) concrete pipes up to and including 600 mm diameter with less than 600 mm cover or more than 3.0 m of cover;

(ii) concrete pipes over 600 mm diameter and not exceeding 900 mm diameter with less than 1.0 m of cover or more than 3.0 m of cover; and

(iii) concrete pipes over 900 mm diameter, at any depth.

All pipes shall be laid true to line and level supported on hardwood or concrete wedges. The joints shall be properly seated and filled flush inside and outside with 1: 3 cement mortar. No part of the surround shall be placed until the Engineer has approved the laying and jointing of the pipes.

(e) Wingwalls, Headwalls and Aprons

Concrete for wingwalls, headwalls and aprons shall be Class C20/25.

8.7. Joints in Concrete Pipes and Pipe Ends

(a) Flexible joints between prefabricated pipe sections

Flexible joints between concrete pipes having integral sockets may be formed by a shaped rubber gasket fitted within the socket or by a rubber ring of circular cross section (O-ring) placed on the pipe spigot. The type of flexible joint to be used shall be subject to the approval of the Engineer.

Before any joint is made all parts of the joint shall be clean and free from mud, oil, grease or other deleterious matter.

Fixed gaskets shall be lubricated strictly in accordance with the manufacturer's recommendations. O-ring gaskets shall not be lubricated.

The spigot of the pipe to be laid shall be entered into the socket of the previous pipe with the two pipes in line, and a firm steady pressure exerted on the end of the pipe being laid. The spigot shall be pulled hard into the socket and then eased back the distance recommended by the manufacturer to provide flexibility in the joint.

After jointing, the position of O-rings shall be tested with a feeler to ensure that they are correctly positioned. If any ring shows a significant departure from a line following a pipe circumference, the joint shall be broken and remade using a new ring.

Where plain ended pipes are connected by a sleeve incorporating flexible joints, the joints shall be made as described for pipes with integral sockets. The joint between the first pipe and the sleeve shall be completed before the second pipe is inserted into the sleeve.

Where indicated on the Drawings or instructed by the Engineer, joints shall be sealed on the outside with two layers of bitumen-impregnated burlap of 340 g/m^2, or a similar approved material. The strip of burlap shall be at least 150 mm wide, and shall be placed symmetrically over the joint. The pipes shall first be treated with a primer of 60% bitumen emulsion, over the width of the strip of burlap.

(b) Joints in cast in-situ pipes

Joints in cast in-situ pipes shall be as detailed on the Drawings, specified in the Special Specification or as directed by the Engineer.

(c) Pipe ends

Unless otherwise specified pipe ends shall be left square.

8.8. Backfill

Backfill for concrete and metal pipe culverts shall be selected material obtained from the excavation. Where the excavated materials is unsuitable or there is insufficient suitable excavated material or where the culvert is laid close to or above existing ground then selected backfill shall be obtained from borrow pits. All backfill for such structures, whether from excavated material or borrow pits shall have a CBR of at least 10% measured after 4 day soak on laboratory specimens compacted to 95% MDD (GHA S1), a Plasticity Index of less than 25%, a maximum particle size of 20 mm and shall be compacted to a dry density of 93% MDD (GHA S1).

After pipe culverts have been firmly laid on the required bedding as described in Clause 8.6 and where no concrete haunch or surround is called for, selected fill material shall be placed in layers not exceeding 150 mm compacted thickness and thoroughly compacted along the remainder of the underside of the barrel of the pipe and in the joint holes. Similar selected material shall then be brought up uniformly on both sides of the pipe to the top of the trench, in layers compacted to 93% MDD (GHA S1) and not exceeding 150 mm compacted thickness. Compaction around the pipe shall be carefully done. No power rammers shall be used within 300 mm of the pipe.

Timbering and sheeting used for the purposes of supporting the excavation shall be eased up 150 mm at a time in step with the backfill layer and compaction of the backfill shall be achieved under and behind such timber and sheeting.

For pipe culverts that have been constructed close to, above or protruding above the existing ground level, the backfilling under the flanks and alongside and over the culverts shall be placed and compacted in layers not exceeding 150 mm after compaction to a density of at least the density required for the material in adjoining layers of embankment fill. The width of backfilling along the flanks of the culvert shall be at least (2 + 1.5h) m from each side of the culvert (where 'h' is the height from the underside of the layer being compacted to the crown of the pipe in metres).

The material used for filling alongside the culvert above existing ground shall be the same material as will be used for the adjacent embankment fill. Backfilling shall be carried out simultaneously and equally on both sides of the culvert to avoid unequal lateral forces.

In all cases there shall be cover of at least 600 mm over the crown of the culvert before construction equipment is driven over it unless other protective measures approved by the Engineer have been provided.

Where the acidity of the material used for backfilling needs to be neutralised, the Contractor shall add 5% of lime by mass, or such other quantity as the Engineer may instruct, to the fill material throughout the width and depth instructed by the Engineer. The lime shall be evenly spread over the surface of each layer of fill material and shall be mixed in with rakes and the moisture content adjusted as necessary before it is compacted.

8.9. Half Round Concrete Channels

600 mm diameter half round concrete channels shall comply with Clause 8.2.1 except that they will not be subject to a load test. Where a channel is cast in pipe moulds, every care shall be taken to see that the battens separating the two halves are rigidly secured to the mould, the edges of the channel are parallel to the axis of the barrel, and each channel is of identical shape.

The excavation to receive the half round concrete channels shall be compacted to 93% MDD (GHA S1) to a depth of 150 mm and shaped as shown on the Drawings before the channel is laid. The invert of the trench shall be accurately excavated to line and level and shaped so that the barrel of the channel rests on a width of one third of its diameter and throughout the length of the barrel.

After the channel is laid selected fill material shall be placed, watered if necessary, and compacted against the sides of the channel for the remainder of the height so that the channel is rigidly held in position before the next length is laid. Joints shall be made by placing a thick covering of 1:3 cement mortar on the joint face of the section already installed before driving the next channel section hard up against it. The excess mortar squeezed out of the joint shall be neatly trowelled off to a smooth invert.

All channel ends shall be soaked with water for one hour before jointing and all joints shall be protected from the wind, sun and rain by a covering acceptable to the Engineer and shall be kept constantly damp for a period of at least 3 days after forming.

8.10. Subsoil Drains

A subsoil drain includes any type of drain designed to collect groundwater whether this is rising from below or percolating from the surface and may or may not include a pipe. It may also include impermeable membranes above or below the pipe or permeable filter membranes all as detailed on the Drawings, or instructed by the Engineer during the course of the Works. Instructions for subsoil drains in cuttings will not generally be given until the bulk earthworks are complete within that particular cutting and subsoil drains that are instructed shall be completed before the work on the adjacent 300 mm layer below formation commences.

Trenches for subsoil drains shall be not less than 0.5 m wide or the outside diameter of the pipe plus 0.3 m whichever is the greater. Concrete pipes shall comply with sub-paragraph (g) of Clause 8.2.1 and shall be laid with joints open by 10 mm. Trenches for subsoil drains using PVC pipes shall be as shown on the Drawings.

The filling in subsoil drains shall be clean hard crushed rock or gravel, and, in soils where fines are not liable to migrate, the grading shall be in accordance with BS EN 12620 for 37.5 mm maximum size graded aggregate or as otherwise instructed by the Engineer.

Where permeable filter membranes are instructed they shall be of an approved geotextile. Transverse joints shall be lapped by at least 0.5 m with the upstream material laid on top. Longitudinal joints shall be stitched together. The geotextile shall not be left exposed to sunlight for more than 3 weeks, and shall be installed in accordance with the manufacturer's instructions or as detailed in the Drawings.

8.11. Cast In Situ Concrete U-Drains

Trenches for cast in situ U-drains shall be accurately excavated with vertical sides to the dimensions and gradients indicated on the Drawings, or specified by the Engineer. The width of the trench shall be equal to the required overall width of the drain structure, such that the structure can be cast against the sides of the trench. Overexcavation shall be made good in accordance with the Engineer’s instructions, prior to constructing the drain. Alternatively, the Engineer may require the outer sides of the drain walls to be formed, and the resulting void backfilled, all to the Contractor’s expense. The bottom of the excavation shall be compacted to 93% MDD (GHA S1) to a depth of 150 mm.

Internal formwork to the walls and invert shall be accurately positioned in the trench, to the correct dimensions and gradient, and adequately secured against flotation or other displacement during concreting.

Where cast in situ concrete U-drains are constructed partially or wholly above ground, external formwork for the entire outer surfaces complying with Section 19 shall be used.

Unless otherwise shown on the Drawings, concrete shall be Class NS 20 and the surface finish shall be Class UF2 for unformed surfaces (top of drain walls) and Class F2 for internal formed surfaces.

8.12. Minor Drainage Structures

Minor drainage structures shall include culvert inlet and outlet structures, catchpits, cascades, spillways and concrete ditches. They shall be constructed in accordance with the details shown on the Drawings, and /or issued by the Engineer from time to time.

Excavation and backfilling of minor drainage structures shall be in accordance with the relevant clauses of this section, applicable to culverts.

Unless otherwise shown on the Drawings, concrete shall be Class C20/25 and the surface finish shall be Class UF1 for unformed surfaces and Class Fl for formed surfaces.

The surface finish to in situ concrete drainage works shall be as specified hereunder:

Formed surfaces:

Exposed	Class F2 (except as separately provided for hereunder)
Non-exposed	Class F1

The faces of pipe culvert headwalls, wing walls and aprons, which form part of the conduit of the concrete channels shall be to Class F3 finish

Unformed surfaces:

The areas of concrete upon which precast concrete lids shall be seated shall be to Class UF3
Unless otherwise directed, all other unformed surfaces shall be to Class UF1 finish

8.13. Extension of Existing Culverts

8.13.1 Reinforced culverts

The preparation of joints is necessary in the case of extensions of existing concrete culverts. After chiselling the surfaces of the concrete, it, as well as any exposed reinforcement, shall be cleaned. New reinforcement shall be lapped to the existing reinforcement and the concrete faces shall be treated with an approved bonding agent.

8.13.2 Unreinforced culverts

The preparation of joints is necessary in the case of extensions of existing concrete culverts. After chiselling the surfaces of the concrete, it shall be cleaned. The concrete faces shall be treated with an approved bonding agent.

8.14. Protection Work

Where shown on the Drawings or instructed by the Engineer the Contractor shall provide and place protection works.

Protection works in connection with drainage channels, culvert inlets and outlets and river training will consist generally of stone pitching, rip-rap or gabions in accordance with Clauses 8.15, 8.16 and 8.17 of the Specification.

8.15. Stone Pitching

8.15.1 Plain stone pitching

Plain stone pitching shall be formed of hard stone, roughly dressed square. The least dimension of any stone shall not be less than 200 mm, and the volume not less than 0.01 m^3, unless otherwise approved by the Engineer. Where in the opinion of the Engineer, fused laterite stones are of sufficient hardness and durability, they may be used for stone pitching.

The area to be stone pitched, shall be prepared by excavating, shaping and trimming as necessary, and by thoroughly compacting by hand ramming to prevent subsequent settlement.

A trench shall be excavated, as directed by the Engineer, along the toe of slopes to be pitched, or along the unprotected edges in the beds of streams.

Pitching shall commence at the bottom of the trench. The stones shall be set on edge and securely bedded with the largest dimensions at right angles to the flow of water, fitted closely together so as to leave only a minimum of voids between the stones which shall be filled in with suitably shaped and tightly wedged spalls. The top of the pitching shall be finished flush with the adjacent material.

8.15.2 Grouted Stone Pitching

Grouted stone pitching shall be done in accordance with all the requirements specified for plain stone pitching, except that the stones shall be thoroughly cleaned of adhering dirt or clay, moistened and laid using one of the two methods described below. The method to be adopted shall be decided by the Engineer.

Grout and mortar for grouted stone pitching shall comply with the requirements of Clause 18.16, and shall be composed of one part cement to six parts sand.

Method 1

The stones shall be embedded in freshly laid cement mortar composed of one part of cement to six parts of sand and the spaces between the stone shall be filled with grout of the same composition as the mortar. The mortar and grout shall be placed in a continuous operation for any day's run at any one location. The grout shall be worked into the pitching so as to ensure that the voids between the stones are completely filled with grout to the full depth of the stone pitching, and smoothed off flush with the pitched face.

Method 2

The stones shall be embedded in freshly laid cement mortar, and individual stones shall be joined to the preceding ones with sufficient mortar to ensure full coverage of the joint to the full depth of the pitching when the stones are pressed together. Excess mortar shall be struck off flush with the pitched face. The mortar in the bedding and joints shall be composed of one part cement to six parts of sand.

Weepholes shall be provided through grouted pitching as instructed by the Engineer.

8.15.3 Precast blocks

Precast concrete or Sandcrete blocks shall be used for erosion protection works on abutment slopes where specified in the Special Specification. Precast concrete and sandcrete blocks shall comply with the requirements of Section 2.16 and shall be placed according to section 11.10.

8.16. Rip-rap

Rip-rap shall consist of one or more courses of large rock placed on bank slopes and toes in stream and river beds and other localities as required.

Stone for rip-rap shall consist of well shaped hard dense durable rock. At least 50% of the pieces shall have a volume greater than 0.03 m^3 and not more than 5% shall have a volume of less than 0.01 m^3.

The surfaces to receive rip-rap shall be neatly trimmed to line and level, and all loose material compacted. The perimeter of rip-rap areas shall be protected by means of rock filled trenches, walls or other structures as detailed on the Drawings, or directed by the Engineer. Rock fill for perimeter trenches shall be of the same quality and size as that used in the construction of the adjoining rip-rap, but voids shall be filled with smaller stone and the entire backfill compacted.

A filter bed consisting of one or more layers of permeable material shall be placed on the prepared surface to the specified thickness. Care shall be taken not to mix the various grades of filter material, nor to disturb material already placed. If required, a filter fabric of an approved quality and grade shall be placed on the prepared surface or over the filter bed, as specified.

Where instructed by the Engineer or shown on the Drawings the stones shall be laid with close joints from the bottom of the slope of embankment or existing ground upward, the larger of the stones being laid at the bottom. The surface shall be hand packed, carefully bedded and tightly wedged with suitable spalls to form an even surface. Alternatively the Engineer may direct that the stones are dumped from above and that the rip-rap is roughly dressed to the dimensions shown on the Drawings or instructed by the Engineer.

8.17. Gabions

Gabions shall be galvanized steel-wire-mesh cages, of acknowledged and approved make, packed with rock and used for the construction of retaining walls, channel linings, revetments and other anti-erosion structures. They shall comply with the standard sizes given in Table 8.2, and subdivided into cells by means of diaphragms.

Table 8.2: Standard Dimensions for Gabion Boxes and Mattresses

	Length (m)	**Width (m)**	**Depth (m)**	**Diaphragm Spacing (m)**	**Maximum Mesh Size (mm)**
Boxes	1.0, 2.0, 3.0 and 4.0	1.0	0.3, 0.5 and 1.0	1.0	100
Mattresses	6.0	2.0	0.2, 0.3, and 0.5	0.6 or 1.0 as specified	80

The cut edges of all mesh used in the construction of gabions shall be selvedged.

Wire used for gabions and for tying during construction shall be in accordance with BS 1052, shall have a tensile strength of at least 380 kN/m^2 and shall comply with Table 8.3. Galvanising shall be in accordance with BS EN 10244 and shall withstand 220 hours of exposure to salt spray test before failure by rusting.

Wire mesh shall comply with BS EN 10223 and the maximum mesh size, measured across the twisted wire flats shall be as indicated in Table 8.3

Gabions of PVC coated mesh and binding wire shall be of an acknowledged make, subject to approval by the Engineer.

Table 8.3: Wire for Gabion Construction

	Diameter (mm)	Galvanising (g/m^2)
Mesh Box	3.4	275
Mattress	2.7	260
Binder Box	2.2	240
Mattress	2.2	240
Selvedge Box	3.9	290
Mattress	3.4	275

Gabions shall be constructed to the shapes and dimensions indicated on the Drawings, Special Specification or as directed by the Engineer.

The surface upon which gabions are to be laid shall be trimmed to line and level and compacted to a minimum dry density of 93% MDD (GHA S1). Where required, a foundation trench shall be excavated along the toe of the revetment or wall, to the dimensions indicated on the Drawings or specified.

The assembly and installation of gabions shall be in accordance with the manufacturer's instructions, subject to the Engineer's approval. Joints shall be stitched together with 600 mm minimum lengths of binder wire, with at least one stitch per 50 mm, and each end of the wire shall be fixed with at least two turns upon itself. Adjacent gabions shall be stitched together with binder wire along all touching edges.

Sufficient connecting wires shall be tensioned between the vertical sides of all the outer visible cells, to prevent the deformation of cages as they are filled with stone. The corners of gabion cages shall be securely tied together to provide a uniform surface, and ensure that the structure does not resemble a series of blocks or panels.

Gabion boxes shall be laid with broken bond throughout to avoid continuous joints both horizontally and vertically.

The alignment of the gabion structure shall be correct to within a tolerance of 100 mm of the specified alignment and the level of any course of gabion shall be correct to within a tolerance of 50 mm of the specified level. In addition adjacent gabions shall not vary by more than 25 mm in line and/or level from each other.

Gabion structures, as constructed shall be within a tolerance of ± 5% on the specified height or width and ± 3% on the specified length.

Gabions shall be handpacked with clean, hard, durable, unweathered boulders or broken rock of 150 mm minimum dimensions and 300 mm maximum dimension. The sides shall be packed first in the form of a wall, using the largest pieces, with the majority placed as headers with broken joints to present a neat outside face. The interior of the gabion shall be hand packed with smaller pieces and the top layers shall be finished off with larger pieces. The whole interior and top layers shall be packed tight and hammered into place.

Where indicated on the Drawings or ordered by the Engineer, a geotextile of approved quality and grade shall be placed behind gabion faces in contact with existing or backfilled ground. The Contractor shall ensure that the geotextile is not damaged during the construction or backfilling around the gabion works and any damaged or torn material shall be replaced.

At the back face and ends of completed gabion work or where shown on the Drawings or instructed by the Engineer the existing soil shall be backfilled, thoroughly compacted against the sides of the gabions and finished flush with the top surface of the gabion.

8.18. Masonry for Structures

8.18.1 General

Except where otherwise indicated in the Contract, the length of any stone proposed for masonry shall not exceed three times its height. The breadth on the bed shall not be less than 150 mm nor greater than three quarters of the thickness of the wall.

All stratified stone possessing bedding planes shall be laid with its natural bedding plane as nearly as possible at right angles to the direction of load. In the case of arch rings, the natural bedding plane shall be radial.

Facework quoins shall be built to a height not exceeding 900 mm in advance of the main body of the work and adjacent walling stepped down on either side.

Masonry facework between the quoins shall then be built to a height not exceeding 450 mm above the backing, which shall then be brought up to level with the completed facework. At no time shall the backing be built higher than the facework.

8.18.2 Joints

Except for dry rubble walling, all joints shall be sufficiently thick to prevent stone-to-stone contact and shall be completely filled with mortar. Mortar shall be of the type described in the Contract and shall comply with the relevant requirements.

8.18.3 Protection of new work

Newly laid masonry shall be protected against the harmful effects of weather. All visible masonry and any surface below the masonry which will be visible on completion of the works shall be clean and free of damage.

8.18.4 Squared rubble-coursed or broken-coursed

All stones shall be truly squared and dressed on the beds and joints for a distance of at least 125 mm from the exposed face. Bond stones shall be provided at the rate of one to every 0.85 m^2 of exposed face, and shall measure not less than 150 by 150 mm on the face, and not less than 450 mm in length or the full thickness of the wall if the latter is less than 450 mm. Sneck stones shall not be less than 75 mm in any dimension. Vertical joints shall not include more than three stones, and the horizontal lapping of the stones shall not be less than 100 mm.

8.18.5 Backing to masonry facework

Backing to masonry facework shall be as specified. The facework shall not be displaced by the placing of backing.

8.18.6 Masonry facework fixed to concrete

Any loose material shall be removed from the concrete and its surface washed clean before any masonry is laid.

The variation in depth, front to back of stones for masonry facework, shall be specified in the Special Specification and the space between the facework and the backing shall be completely filled as the work proceeds, with fine concrete.

The portion of the fixing projecting from the concrete shall be completely embedded in the mortar of the facework and shall be kept back a minimum of 50 mm from the face of the masonry.

8.18.7 Special stonework including quoins, copings, plinths voussoirs, etc

Special stonework shall consist of selected and approved stones dressed to the shapes and dimensions and where required, their faces worked, all as described in the Special Specification.

8.18.8 Natural stone

Building stone shall be as described in the Special Specification, of good, hard and durable quality, uniform in texture and free from iron bands, sand holes, flaws, shakes and other imperfections. Samples of the stone intended for use in the works shall be submitted for the Engineer's approval.

8.19. Underground Side Drains and Gullies

Pipes shall be of concrete or PVC, laid, set and jointed in accordance with this Section. Gullies will be of cast iron construction. Gullies shall be installed before the pipes into which they lead and after the adjoining waterbound pavement layers have been constructed. Gullies will be set to the finished level of the road and will be laid so that they will allow a free flow of water from the completed pavement. The gully trap shall be constructed of Class NS 20 concrete. The trap shall be founded on Class NS 15 concrete.

8.20. Mitre Drains, Cut-off Drains, Catchwater Drains, Side Drains, Culvert Outfall Drains and Earth Dams

Mitre drains, cut-off drains, catchwater drains, culvert outfall drains and earth dams shall be formed at the locations and to the lines and levels shown on the Drawings or as instructed by the Engineer.

Where shown on the Drawings or instructed by the Engineer the Contractor shall construct earth dams in side drains, cut-off drains, catchwater drains, mitre and outfall drains to prevent the flow overshooting the drainage works or to direct flows into culvert inlets. Similar earth structures may also be used as erosion checks. Earth dams shall be formed in selected fill material compacted to a minimum dry density of 93% MDD (GHA S1).

Intercepting ditches shall be constructed as shown on the Drawings or as instructed by the Engineer to intercept surface flow at the top of cuttings or the foot of embankments. They should have a normal depth of 0.6 m below existing ground surface level and a minimum gradient of 1 in 100.

Where shown on the Drawings or directed by the Engineer, turn-outs shall be formed to disperse the water flows from the roadside ditches and intercepting ditches where the normal ground slopes away from the new road at the spacings shown in Table 8.4.

Table 8.4: Spacing of turn-outs

Longitudinal gradient of new road/ditches (%)	Distance between turn-outs (m) (where applicable)
0 – 2	200
2 – 4	150
> 4	100

8.21. Scour Checks

The Contractor shall excavate in the invert of the side drains, cut-off drains, catchwater drains, outfall drains and mitre drains for scour checks to be located as shown on the Drawings or directed by the Engineer.

Scour checks shall be constructed in concrete Class NS 20 or made from gabions or as otherwise approved by the Engineer. Formwork shall be provided and placed for all concrete required above the existing drain profile.

Where the overflow section of a scour check is above the invert level of the drain the void upstream of the scour check shall be backfilled to the level of the overflow section. The upper 50 mm of the backfill shall be topsoil and shall be planted with grass and such topsoiling and grassing shall comply with the requirements of Section 5 of the Specification.

8.22. Cleaning and Maintenance

The Contractor shall be responsible for maintaining all drainage structures, culverts, channels and drains free of silt and extraneous material until the end of the Contract, including the Defects Liability Period or its equivalent and shall repair any damage to the Works caused by his failure to maintain the drainage system.

When cleaning the drains, the Contractor shall ensure that the waste materials are deposited in an identified and approved spoil-deposit area.

SECTION 9

PASSAGE OF TRAFFIC

CONTENTS

9. PASSAGE OF TRAFFIC

9.1. Scope

This Section covers the provisions that the Contractor must make for the construction and maintenance of the necessary diversions and detours to facilitate the safe and convenient movement of pedestrians and public traffic through the Works during the construction and maintenance periods, as well as the obliteration of the diversions as they become redundant.

9.2. Summary of Provisions

(a) Where public traffic using an existing road is affected by construction of the new road, the Contractor shall be responsible for the safe and easy passage of such traffic and carry out one or more of the following:

(i) Effect improvements to and maintain existing roads.
(ii) Construct and maintain diversions.
(iii) Facilitate the flow and safe passage of traffic through or over the Works during day and night.

(b) The Contractor shall consult and liaise with officials of the local Police and other Government bodies in the area with regard to all matters of traffic management and provide all assistance necessary to ensure smooth traffic movements through the construction works.

(c) The Contractor shall develop and submit a Traffic Control Plan related to traffic accommodation to the Engineer, not less than 30 days before work commences. Such a plan shall show amongst other things the method of protection of the public and give details of the hours of operation, location, types and numbers of traffic safety devices, barricades, warning signs, flagmen and the like. The Contractors shall employ a trained traffic steward to facilitate the efficient and safe passage of traffic through the work site. Standard signs and barriers shall be used to secure work sites. The signs shall be reflectorised or adequately illuminated at night and correctly positioned in a manner approved by the Engineer and kept clean and legible at all times. The Contractor shall reposition, cover, or remove signs as required during the various stages of construction. The adequacy of these temporary signs and barriers shall be subject to the Engineer's approval.

(d) The Contractor shall provide and maintain temporary signs, barriers, lights etc. along diversions and existing roads adjacent to the Works in order to ensure the safe passage of traffic during the Contract in accordance with the Code of Practice for Signing at Roadworks.

(e) The Contractor shall provide adequate notice of the implementation of diversions etc. and shall ensure efficient and safe passage of traffic at all times.

(f) The Contractor shall be required to provide and maintain all access and haul roads to ensure access to all parts of the Site for his plant, labour and materials.

(g) The Contractor shall provide and grant access to persons whose properties fall within or adjoin the area over which he is working, and in this respect the Contractors attention is drawn to the Conditions of Contract.

(h) The Contractor shall protect adjacent public roads from the effects of his own construction traffic and shall repair all damage resulting from this traffic as directed by the Engineer. The Contractor shall take reasonable precautions to keep the approach roads to bridges and any of his haulage, delivery or return routes clear of material spills from his operations to the satisfaction of the Engineer. All spills shall be cleared by the Contractor without delay.

9.3. Improvements to Existing Roads

Where shown on the Drawings or instructed by the Engineer the Contractor shall carry out improvements to any existing roads adjacent to or affected by the Works including:

(a) Site clearance and removal of topsoil from the shoulders and verges.

(b) Scarifying, re-shaping, widening and watering and compacting the top 150 mm of the existing road to 95% MDD (GHA S1).

(c) Laying suitable gravel wearing course.

(d) Cutting, re-shaping and deepening where necessary, side drains and mitre drains, including clearing and maintaining existing protection works.

(e) Clearing and maintaining culverts and cutting or deepening outfall drains.

(f) Clearing and maintaining existing watercourses and protection works.

(g) Repair of potholes in bitumen roads.

(h) Re-sealing of bitumen roads.

(i) Providing, erecting and maintaining temporary traffic signs, barriers, lights, fences etc.

(j) Undertake any other works instructed by the Engineer.

The extent of improvements required will be detailed in the Special Specification.

9.4. Maintenance of Existing Roads

The Contractor shall maintain the existing roads scheduled in the Special Specification in a good, safe and trafficable condition from the commencement of the Contract until the adjacent section of new road, or diversion where applicable, is opened to public traffic.

The road shall be maintained to at least the same standard as existed at the commencement of the Contract or to the standard following improvement under Clause 9.3 of this Specification.

Maintenance shall include watering, full width grading and dragging as necessary to retain a smooth surface free from ruts, potholes and loose material, keeping clear watercourses and culverts, cutting grass, minor repairs to culverts and bridges and assistance to traffic and pedestrians. In the case of bitumen roads, potholes and edge failures shall be repaired with cold asphalt mixed and laid in accordance with Section 17.5 of this Specification.

Major repairs to culverts and bridges, flood damage, resealing and regravelling may be instructed in which case separate payment will be made.

9.5. Construction of Diversions

(a) General

It is the full responsibility of the Contractor to secure and provide safe detouring of traffic 24 hours a day, during the construction phase. The length of a deviation shall be the shortest practicable route taking into account gradients and obstructions. Detailed alignment shall be agreed between the Engineer and the Contractor. The decision to choose traffic deviation alongside the construction works or to use alternative routing is with the Contractor, subject to approval by the Engineer.

The Contractor shall give at least 30 days notice in writing of his intention to commence construction of any diversion. Such notice shall include details of cross-overs, one-way traffic operations, restricted widths, culverts, drainage, drifts, bridges, gradients in excess of 7%, earthworks, signs, barriers, lights, traffic lights, and methods of operation of the entire system. Upon approval of such notice in writing from the Engineer the Contractor shall become responsible for the passage of traffic including maintenance of the deviation and the project road in that section.

(b) Geometry

Diversions shall be constructed to the cross-section shown on the Drawings for a 50 km/h design speed with a width of 6 m and surfaced with 150 mm layer of gravel suitable as wearing course.

Single-lane traffic operation shall not be permitted unless in the opinion of the Engineer, it is impracticable to provide a two-lane diversion. A single-lane carriageway shall not be less than 4.0 m wide with traffic control and passing bays provided at approximately 250 m intervals. Safe passage for non-motorised traffic and pedestrians shall be ensured.

The gradient of any diversion shall not exceed 7%, except with the approval of the Engineer, and any change of gradient shall be formed to a smooth vertical curve with a length of not less than 10 m per 1% difference of gradient. Where gradients in excess of 7% are permitted by the Engineer on any diversion the Contractor may be required to seal the diversion with a double seal surface dressing or other approved seal and maintain such seal whilst the diversion is in use.

(c) Construction

Site clearance and earthworks shall be carried out in accordance with Sections 4 and 5 of this Specification.

Gravel wearing course shall be constructed in accordance with Section 10 of this Specification.

(d) Drainage and drifts

Drifts shall be constructed such that water is normally less than 150 mm deep, except when in flood.

The edge of a drift shall be defined with posts or other markers acceptable to the Engineer and a gauge installed to indicate the maximum depth of water over the road. The minimum width of drift shall be 3.5 m.

Temporary bridges shall be constructed by the Contractor if an existing bridge is inadequate and cannot be strengthened or if a drift would not be practicable.

(e) Services

The Contractor, in cooperation with the Engineer, shall make arrangements for all public services such as power and telephone lines, water mains, etc, to be moved where required for the construction of diversions and he shall be solely responsible for the safety of such services. No payment will be made for any additional expenses caused by delays in moving such services. Where the moving of services is not required, the Contractor shall clearly indicate where such services cross the deviation so that these points will be clearly visible to the operating staff.

(f) Reinstatement of diversion

Prior to the commencement of construction of any diversion or the use of land provided for the diversions the Contractor shall supply one print (125 mm by 175 mm colour print) or digital image of each of a series of photographs taken at a maximum of 500 m intervals along the line of the diversion and the Contractor shall not commence construction of any diversion until the prints have been accepted by the Engineer as being a true record of the condition of the land prior to construction including land usage, fences, existing roads and tracks, drainage and any other features.

The Contractor shall reinstate the diversion to a condition similar to the condition prevailing prior to the commencement of construction of the diversion in accordance with the Environmental Management Plan. The colour prints provided by the Contractor may be used by the Engineer to confirm that the reinstatement is satisfactory. Where the diversion is on private land the Contractor may obtain a written statement, signed by the landowners, requesting that the diversion be left unreinstated in lieu of reinstating the diversion. Where the diversion is within the road reserve or on other land owned by the Government the Contractor shall reinstate the diversion to a condition prevailing prior to the commencement of construction of the diversion, or such lesser reinstatement as may be approved by the Engineer.

9.6. Maintenance of Diversions

The Contractor shall maintain the diversions constructed under Clause 9.5 of this Specification to the standards defined by that Clause, until the adjacent section of new road is opened to public traffic. The diversions shall be maintained to a standard that generally allows a travelling speed of at least 30 km/h for all vehicle types.

Where required by the Engineer, regular water spraying or application of a chemical dust palliative to the road shall be employed in order to minimise dust for safety, health or social reasons.

9.7. Passage of Traffic Through the Works

Where shown on the Drawings or instructed by the Engineer that traffic is to be passed through or across the Works the Contractor shall so order his work in half widths or in short lengths, so as to pass traffic over or across his work.

At locations where replacement or strengthening of structures requires the regulation of traffic, the construction work should be carried out in stages in order to maintain public traffic either on part of the existing structure, or on the strengthened or replaced structure.

The frequency and duration of delays to traffic while being passed through or across the Works shall be kept to a minimum and shall not exceed 10 minutes without the prior approval of the Engineer and should normally be less than 5 minutes. Any method of working that requires a road closure in excess of 10 minutes shall require 48 hours prior notice, and the approval of the Engineer, who may refuse to allow such closure in default of due notice or may require rescheduling of the closure.

The Contractor shall ensure, when passing traffic through the Works that all excavations and other hazards are properly protected with barriers and are illuminated at night.

9.8. Signs, Barriers and Lights

The Contractor shall provide, erect and maintain temporary signs, barriers, lights, traffic lights, etc. along existing roads scheduled in the Special Specification and along diversions constructed in accordance with Clause 9.5 of this Specification.

The number, type and siting of these signs etc. shall be in accordance with the Drawings and this Specification, or as directed by the Engineer.

The construction of all informatory signs, warning signs, mandatory signs and priority signs used for temporary signing shall comply with the requirements of the current Manual of Road Signs and Markings.

Direction signs, advance direction signs and confirmatory signs may be manufactured as fixed short life signs.

Sign plates for fixed short life signs shall be manufactured from hardboard, plywood or chipboard or other material that is approved by the Engineer. The sign shall be constructed so as not to deteriorate during the estimated time the sign will be in use. The face of the sign shall be sealed with a wood filler, or otherwise treated to provide a satisfactory appearance. The sign shall be supported on one or more posts.

Where one-way traffic operation is necessary the Contractor shall provide, maintain and operate traffic lights. The use of "Stop" and "Go" boards provided, maintained and operated by the Contractor shall be permitted between 0630 hours and 1830 hours in lieu of traffic lights. Traffic lights shall be used at all other hours.

Should the Contractor appear to be neglectful or negligent in furnishing appropriate warning and protective measures, the Engineer may direct attention to the existence of the hazard, and the necessary warning and protective measures shall be furnished and installed at the Contractor's expense. Should the Engineer indicate the inadequacy of warning and protective measures, such action on the part of the Engineer shall not relieve the Contractor from responsibility for public safety or relieve him of his obligation to furnish and pay for these devices.

Special provision shall be made on certain projects for carrying out Works at night. The Contractor shall ensure that adequate warning lighting to ensure safe passage of traffic during such Works is provided, operating and maintained during the Works.

Where the distance between the edge of a road or diversion and the permanent Works is less than 10 m, continuous fences and barriers shall be erected. Such fences and barriers shall be painted with reflective red and white paint in alternate sections. Where pedestrians must use the line of the road or diversion for access, similar fences and barriers shall be provided to separate pedestrians and traffic.

Barriers, other hazards and entrances to detours and diversions and one-way operations shall be illuminated throughout the night by red lamps or amber flashing lights provided by the Contractor and supported at a height of between 0.7 m and 1.35 m above the road, and maintained burning bright.

9.9. Closure, Diversion or Re-opening of Existing Roads

Where as a result of the Works, an existing public or private road is to be permanently closed, or diverted, or temporarily diverted or re-opened to traffic, the Contractor shall give the Engineer at least 30 days notice of his requirements or intentions. Depending on the length of road and amount of work involved, the Engineer may negotiate with the appropriate Authority or owner regarding the method, order and times of carrying out the work and issue instructions to the Contractor accordingly. Where the amount of work involved is small, the Engineer may instruct the Contractor to make his own arrangements. In all cases, the Contractor shall obtain the Engineer's instructions and no road shall be interfered with in any way until the appropriate Authority's or owner's consent to the work has been obtained.

9.10. Assistance to Public

The Contractor shall render such assistance to the public as shall be necessary to allow safe and convenient passage of traffic at all times. This could include information signs, leaflets, brochures or radio reports as considered appropriate.

9.11. Access Roads

9.11.1 Public roads

Where the Contractor proposes to use an existing public road as an access to a borrow area, or as a haulage road for the construction of any work under the Contract, such as is likely to cause a subsequent claim for "extraordinary traffic", the Contractor shall give the Engineer at least 30 days notice of his intention to use such a road. The Engineer may call for a joint inspection of the road by the Local Road Authority, the Contractor and the Engineer, to agree upon a statement of the actual condition of the road, supported by photographs or digital images, prior to use by the Contractor and to determine the extent of any remedial work required.

The Contractor shall inform and consult the public and road users about the road works and about any access problems through meetings, road signs, the media, or other measures. The Contractor shall consult with the affected communities well in advance, and the Engineer may request a plan that specifies at least the following:

(a) the proposed route,
(b) the estimated number and types of vehicles per day, and
(c) measures for limiting vehicle speeds and dust nuisance in built-up areas.

Where, in the opinion of the Engineer, the existing road is inadequate to withstand the volume and weight of the Contractor's traffic, or the proposed routing will cause undue disturbances in the form of noise, safety hazards, dust or other disturbances to local communities, the Engineer may instruct the Contractor:

(a) to improve the road;

(b) to construct a temporary road in lieu; or

(c) to use an alternative route.

9.11.2 Private access roads

Where materials from a borrow pit are hauled on private access roads, such roads shall be maintained properly to the satisfaction of the Engineer during borrow operations at the borrow pit. No additional payment will be made for this work, and full compensation for maintaining private access roads used as haul roads will be regarded as being included in the rates tendered and paid for in the various items of work where the materials are used.

9.11.3 Access Roads to Borrow Pits etc

Access roads to stockpile and spoil areas, quarries and borrow pits shall be constructed on the line approved or instructed by the Engineer. The access road shall follow the shortest practicable route between the stockpile or spoil area, quarry or borrow pit and the nearest point to it on the new alignment such that both travel times and costs are minimised. The Contractor shall construct and surface appropriately such access roads as are required. The access road shall be drained with temporary ditches and culverts of adequate size and strength to ensure that the existing watercourses and drainage of the area are not restricted or polluted.

The siting of the junction of an access road with the existing road shall be to the satisfaction of the Engineer and the Contractor shall comply with the Engineer's instructions, particularly regarding clearance of obstructions to provide adequate sight lines, temporary drainage or culverts and the provision of signs and traffic control.

The Contractor shall apply water or a suitable dust palliative on sections of the access and haul routes that are located through villages to reduce the amount of dust generated. In areas of water scarcity, the Engineer may waive this requirement, but extra slow speeds shall then be imposed.

The Engineer reserves the right to disallow certain haul routes should these be likely to cause unreasonable nuisance or hazards to the public.

The provision of access roads shall not be measured for payment.

9.12. Use of New Road or Road under Construction by Contractor’s Construction Traffic

The Contractor shall not be permitted to use completed sections of the road or diversion or any completed pavement or surfacing layer for hauling earthworks, pavement or other materials with earthwork plant or vehicles having axle loads exceeding the legal limit. Furthermore, the use of completed sections of the road or completed pavement layers will be restricted if, in the opinion of the Engineer, damage to structures, subgrade, the formation, pavement or surfacing could ensue.

The Contractor shall allow the Engineer to carry out check axle weighings on his vehicles and shall observe any instructions given by the Engineer with regard to reduced loadings should this prove necessary.

9.13. Accommodation of Traffic where the Road is Constructed in Half Widths

Where by reason of difficult terrain or any other reason, the construction of diversions is not feasible, the Contractor shall, upon the written instruction of the Engineer, construct the road in half widths to allow traffic to use that half of the road not under construction. The length of the half-width construction shall be kept to a minimum, with provision for traffic travelling in opposite directions to pass at frequent intervals.

The Contractor shall arrange his work so as to allow traffic to have free one-way access to at least half the width of the roadway at all times during the construction period. He shall maintain that half of the road, which is being used for traffic for the time being, free from corrugations and other defects, to the satisfaction of the Engineer.

Wherever possible, the Contractor shall ensure that the entire road width shall be open at night and shall be left, at the end of each day’s work, in a good and safe trafficable condition to the satisfaction of the Engineer.

Should the road be not in a safe trafficable condition for two-way traffic over the entire width at the end of each day’s work, the Contractor shall provide adequate flagmen, signs, barricades, lights and the necessary staff at his own cost to ensure a reasonably free flow of traffic alternately in each direction throughout the entire period when the roadway is open to one-way traffic only.

SECTION 10

GRAVEL WEARING COURSE

CONTENTS

TABLES

10. GRAVEL WEARING COURSE

10.1. Scope

This Section covers the provision, laying and compacting of gravel as the wearing course on a road.

10.2. Definitions

The term "gravel" used throughout this Section means any material used as a wearing course on an unsealed road, and shall include lateritic gravel, quartzitic gravel, calcareous gravel, decomposed rock, soft stone, crushed rock, and any sands or non-plastic fines used to mechanically stabilize the wearing course.

A "gravel wearing course" means a top surfacing course constructed from one or a combination of these materials and may be a course placed on the formation of a new road where no pavement and final bituminous surface is included in the Contract, or placed on the formation of a service road, deviation or access road.

10.3. Sources of Material

Material for gravel wearing courses may be obtained from any of the following sources:-

(i) Borrow pits
(ii) Spoil areas
(iii) Excavation in cuttings, widened if necessary
(iv) Specific fines sources, as appropriate.
(v) Quarries

10.4. Material Properties

The grading and plasticity requirements of gravel and mechanically stabilized gravel after placing and compaction are summarised in Table 10.1. The grading shall be a smooth curve within and approximately parallel to the envelopes with a Grading Coefficient in the range specified.

Table 10.1: Grading of gravel wearing course materials

Sieve size (mm)	% by mass passing	
	Class l	**Class 2**
37.5		100
20	95- 100	85- 100
10	65- 100	55- 100
5	45 -85	35 -92
2	30 -68	23 -77
0.425	18 -44	14 -50
0.75	12 -32	10 - 40
Grading Coefficient (Gc)	16 – 34	16 – 34
Maximum oversize (% > 37.5 mm)	5	5
Shrinkage Product (Sp)	100 - 365	100 - 365

Gc - (Grading coefficient) = (P26.5 – P2) x P4.75/100 (percentage passing 26.5 mm sieve minus percentage passing 2.00 mm sieve multiplied by percentage passing 4.75 mm sieve)/100

Sp - Shrinkage Product = Product of linear shrinkage (GHA S6) and percentage passing 0.425 mm sieve

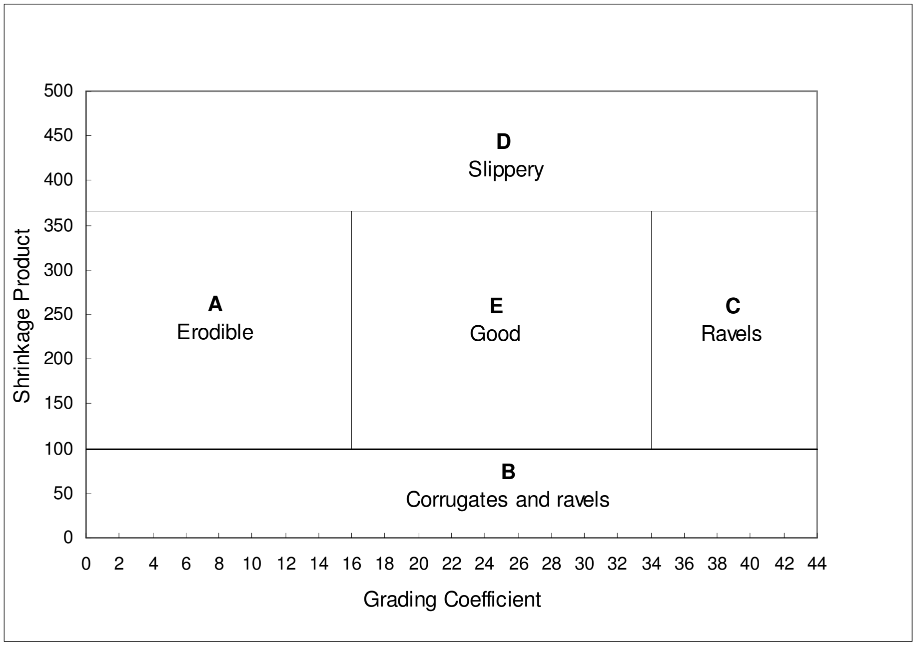
All particle size analyses used to determine these parameters must be normalised for 100% passing the 37.5 mm sieve.

The material shall have a minimum CBR of 20 at 95% MDD (GHA S1) after 4 days soaking.

The material after placing shall have Shrinkage Product (Sp) (weighted linear shrinkage) and Grading Coefficient (Gc) properties that plot within the "Good" Zone (Zone E) of Figure 10.1, unless approved otherwise by the Engineer.

The use of material class (1 or 2 which relate to the maximum particle size) will be specified in the Special Specification.

Figure 10.1: Gravel Wearing Course Material Classification



10.5. Order of Work

Unless otherwise instructed by the Engineer, the Contractor shall commence laying wearing course starting as close as possible to the source and shall work away from it so that the maximum amount of compaction is given to the completed wearing course by the Contractor's vehicles. The Contractor shall route his vehicles to give even wear and compaction over the whole width of the wearing course.

Where sections of road overlie black cotton soils, or other highly-swelling materials, the Contractor shall place wearing course material over an imported selected layer.

10.6. Preparation of Formation

The formation shall be cleaned of all foreign matter, and any potholes, loose material, ruts, corrugations, depressions and other defects that have appeared due to improper drainage or through trafficking shall be corrected. If considered necessary by the Engineer, the Contractor shall scarify, water, grade and recompact the formation to line and level. The formation shall be proof rolled by a loaded truck, scraper or other approved means prior to dumping of the wearing course material.

10.7. Laying and Compaction

The gravel wearing course material shall be deposited in such quantity and spread in a uniform layer across the full width required, so that the final compacted thickness is nowhere less than as shown on the Drawings or instructed by the Engineer. Every reasonable effort shall be made to prevent segregation during the loading, hauling, dumping, spreading, mixing, trimming and compaction operations.

The compacted thickness of any layer laid, processed and compacted at one time shall not exceed 200 mm. Where a greater compacted thickness is required, the material shall be laid and processed in two or more layers. The minimum layer thickness shall be 100 mm. The material shall be broken down in the pavement by grid, sheepsfoot or other suitable rollers to the grading specified in Clause 10.4. Any oversize material that cannot be broken down to the required size shall be removed and disposed of by the Contractor.

The material shall be scarified and the moisture content adjusted by either uniformly mixing in water or drying out the material such that the moisture content during compaction is between 80% and 105% of the Optimum Moisture Content (GHA S1). It shall be graded and trimmed to final line and level. Light compaction may be applied before the final trim is carried out but once 25% of the compactive effort has been applied no further trimming or correction of surface irregularities will be allowed.

The final trim shall be in cut and the Contractor shall ensure that material from the trim is neither deposited in low areas nor spread across the section but graded clear of the works.

Following the final trim the material shall be compacted to a dry density of at least 95% MDD (GHA S1). During the grading, trimming and compaction of the material the Contractor shall ensure that the material does not dry out by applying sprays of water or other means sufficient to maintain the material within the specified limits of moisture content.

10.8. Mechanical Stabilization

Where instructed by the Engineer, the gravel wearing course shall be mechanically stabilized by the addition of non-plastic fines on site. The gravel and non-plastic fines shall be deposited one above the other with the largest proportion being dumped and spread first, along the road in such proportions as are directed for stabilization and shall be mixed and windrowed together so that, upon spreading, the materials become thoroughly mixed, and do not segregate.

10.9. Testing

The Contractor shall proof roll the completed layers in accordance with Clause 12.6 of the Specification.

10.10. Maintenance

The wearing surface shall be maintained by the Contractor in its finished condition and shall be watered, graded, dragged, reshaped, or recompacted as necessary, until the Certificate of Completion is issued, or until the Engineer instructs that the road shall be opened to public traffic, whichever is the sooner.

10.11. Construction Tolerances

The completed layer shall comply with the construction tolerances given in Clause 3.3 or those given below when a statistical quality control scheme (Clause 2.21) is being utilised:

(a) Level

The level tolerances referred to in Clause 2.21.4 shall be as follows:

	H_{90}	H_{max}
Gravel wearing course......................	-	25 mm

(b) Layer thicknesses

The thickness tolerances referred to in Clause 2.21.4 shall be as follows:

	D_{90}	D_{max}	$D_{average}$
Gravel wearing course......................	-	30 mm	0 mm

SECTION 11

SHOULDERS, FOOTPATHS, BICYCLE LANES AND BLOCK PAVING

CONTENTS

TABLES

11. SHOULDERS, FOOTPATHS, BICYCLE LANES AND BLOCK PAVING

11.1. Scope

This Section covers the construction of shoulders, footpaths, bicycle lanes and limited areas of block paving, eg at intersections.

11.2. Material for Construction of Shoulders

Material for construction of shoulders shall be as shown on the Drawings or instructed by the Engineer. It may consist of:

(a) Gravel wearing course or natural material in accordance with Sections 10 and 12 of the Specification.
(b) Graded crushed stone in accordance with Section 13 of the Specification.
(c) Cement or lime treated material or lean concrete in accordance with Section 14 and 15 of the Specification.
(d) A bituminous mix in accordance with Section 16 or 17 of the Specification.
(e) A combination of (a) to (d) above.

11.3. Material for Construction of Footpaths and Bicycle Lanes

Material for construction of footpaths shall be as shown on the Drawings or instructed by the Engineer. It may consist of:

(a) Gravel wearing course or natural material in accordance with Sections 10 and 12 of the Specification.
(b) Graded crushed stone in accordance with Section 13 of the Specification.
(c) Cement or lime treated material or lean concrete in accordance with Section 14 and 15 of the Specification.
(d) A bituminous mix in accordance with Section 16 or 17 of the Specification.
(e) Precast concrete blocks in accordance with Section 2.16.
(f) Precast concrete flags in accordance with BS EN 1339.
(g) A combination of (a) to (f) above.

11.4. Construction of Shoulders

Where the shoulders and the base course are to be constructed from the same material, they shall be constructed simultaneously.

Where the shoulders are to be constructed from a different material to the basecourse, material for use in the shoulders shall comply with that specified for gravel wearing course in Section 10 of the Specifications, or as shown on the Drawings or directed by the Engineer when not a natural gravel.

Shoulders shall not be constructed ahead of adjacent pavement layers and the Contractor shall ensure that the method of construction is such that at no time is water prevented from draining off any of the pavement layers. The method of laying and compacting shoulder material and the compaction requirements shall be in accordance with the relevant sections of Clauses 12.5 and 12.6 of the Specification.

The Contractor shall not start constructing the final bituminous surfacing of any part of the road before he has completed the shoulders of such section to the satisfaction of the Engineer.

Shoulder material shall be spread, broken down as required, watered, mixed and compacted in accordance with the Specifications, and shall be compacted to a density of not less than 95% MDD (GHA S1) or as directed by the Engineer.

11.5. Surface Treatment of Shoulders

Bituminous surface treatments shall be in accordance with Section 16 or 17 of the Specification, as shown on the Drawings.

11.6. Construction of Footpaths and Bicycle Lanes

Footpaths and Bicycle Lanes shall consist of a base course on layers as shown on the Drawings. The base material shall conform to the Specification for Subbase in Section 12 and shall be compacted to not less than 95 %MDD (GHA S1) prior to placement of the wearing course shown on the Drawings.

11.7. Concrete Paving Flags on Footpaths and Bicycle Lanes

Paved footpaths and bicycle lanes using precast concrete flags shall be laid to lines and levels as shown on the Drawings or as instructed by the Engineer. The flags shall be of precast concrete in accordance with the Drawings and Class 1 or 2 of BS EN 1339 and in conformity with Section 18 of the Specification. The bending strength requirements determined in accordance with Annex F of BS EN 1339 shall be as shown in Table 11.1.

Table 11.1: Bending strength classes

Class	Characteristic bending Strength (N/mm^2)	Minimum Bending Strength (N/mm^2)
1	3.5	2.8
2	4.0	3.2

The base layer upon which the slabs are to be laid shall be compacted to 95% MDD (GHA S1), and the layer shall conform to the Specification for subbase in Section 12. The base shall be blinded with sand and/or quarry dust to a depth of not less than 10 mm and not more than 40 mm, and the paving flags shall be laid and tamped firmly to level and position into the blinding ensuring the required cross-falls are maintained. Joints shall be at right angles to the footpath or bicycle lane and, where specified, shall be plastered with mortar in accordance with Section 18 of the Specification.

11.8. Paving Blocks for Footpaths and Bicycle Lanes

Footpaths and bicycle lanes paved with concrete blocks shall be laid to lines and levels as shown on the Drawings or as instructed by the Engineer. The blocks shall be of precast concrete in accordance with the Drawings and BS EN 1338 or SABS 1058 and in conformity with Section 18 of the Specification.

Paving block thickness in footpaths and bicycle lanes shall be 60 mm but at sections where there are vehicular accesses, the block thicknesses shall be 80 mm. Blocks for footpaths and bicycle lanes shall have a minimum strength of 30 N/mm^2 and for limited vehicular access, of 35 N/mm^2.

The base layer upon which the blocks are to be laid shall be compacted to 95% MDD (GHA S1), and the layer shall conform to the Specification for subbase in Section 12. The base shall be blinded with sand and/or quarry dust to a depth of 25 to 30 mm, and the paving blocks shall be laid and tamped firmly to level and position into the blinding.

11.9. Asphalt for Footpaths and Bicycle Lanes

Asphalt for footpaths and bicycle lanes shall comply with the relevant clauses of Section 17.

11.10. Block Paving for Limited Areas

11.10.1 Materials

(a) Bedding Sand

Bedding sand for concrete block paving shall not contain any clay, silt or deleterious impurities and shall comply with the following grading requirements (Table 11.2):

Table 11.2: Grading for bedding sand

Sieve size (mm)	Percentage passing
9.5	100
4.75	95 -100
2.36	80 - 100
1.18	50 - 85
0.60	25 - 60
0.30	10 - 30
0.15	5 - 15
0.075	0 - 10

(b) Jointing Sand

100% of the sand used to fill the joints between the concrete blocks shall pass through a 1.18 mm sieve and between 10% and 15% of it shall pass through a 0.075 mm sieve

(c) Concrete Paving Blocks

Concrete paving blocks shall comply with the requirements of SABS 1058. The block shall be of the class, type and thickness specified in the Special Specification. The surface texture and colour of all blocks shall be uniform.

(d) Concrete

Cast in situ concrete edge beams or intermediate beams shall be constructed in accordance with the provisions of Section 18. Prefabricated kerbing and channelling shall comply with the requirements of Section 8 and 23.

11.10.2 Construction

(a) Underlying Pavement Layers

The underlying pavement layers shall be constructed and prepared in accordance with the requirements for the relevant pavement layers in Sections 5 and 12, the Special Specification and the Drawings. Where specified or required by the Engineer the prepared surface shall be treated with approved herbicide and ant poison before the layer of sand for bedding is placed.

(b) Bedding Sand

A layer of bedding sand shall be placed on top of the prepared surface of the underlying pavement layer. It shall be accurately levelled to an uncompacted thickness of 25 mm (± 5 mm) or as specified so that the concrete paving blocks will have the correct level after compaction. The bedding sand shall be placed immediately before the concrete paving blocks are laid and shall not be compacted before the blocks have been laid.

(c) Concrete Paving Blocks

The blocks shall be laid in the pattern shown on the Drawings or as directed by the Engineer. Unbroken blocks shall be laid first and the filler pieces afterwards. Filler pieces shall be neatly sawn or hewn to fit exactly into the space to be filled. Any space of which the size is less than 25% of the size of an unbroken block, shall be filled with C35/45 concrete. The size of the joints between blocks shall be between 2 mm and 4 mm, and the top faces of the blocks shall be flush.

After the paving blocks have been laid, the pavement shall be compacted by two passes of a suitable vibrating-plate compactor operating at a frequency of 65 Hz to 100 Hz and a low amplitude. Its plate surface shall be 0.2 m^2 to 0.4 m^2 and it shall develop a centrifugal force of 7 to 16 kN.

After compaction of the pavement as described above, jointing sand shall be spread and brushed into the joints until the joints have been properly filled. Any surplus sand shall then be broomed off and the pavement shall then be subjected to two further passes by the plate vibrator.

(d) Edge Beams and Intermediate Beams

Cast in situ or prefabricated concrete edge beams or intermediate beams shall be constructed on the underlying pavement layer in accordance with the details shown on the Drawings. No paving blocks shall be laid before the edge and intermediate beams have developed sufficient strength to withstand the construction forces.

11.11. Construction Tolerances

11.11.1 Shoulders, Footpaths and Bicycle Lanes

The completed layers shall comply with the construction tolerances given in Clause 3.3 or those given below when a statistical quality control scheme (Clause 2.21) is being utilised:

(a) Level

The level tolerances referred to in Clause 2.21.4 shall be as follows:

	H_{90}	H_{max}
Shoulders, footpaths and bicycle lanes..........	-	25 mm

(b) Layer thicknesses

The thickness tolerances referred to in Clause 2.21.4 shall be as follows:

	D_{90}	D_{max}	$D_{average}$
Shoulders, footpaths and bicycle lanes..........	-	30 mm	0 mm

(c) Width

The average width of the layer shall not be less than the specified width, and nowhere shall the outer edge deviate by more than the following from the edge lines shown on the Drawings:

Shoulders…………………. . . . . 75 mm

11.11.2 Block Paving

(a) Line of Pattern	
Maximum deviation from any 3 m straight line	10 mm
Maximum deviation from any 20 m straight line	20 mm
(b) Vertical deviation from a 3 m straight edge	
At the edge beams	+3 mm - 0 mm
Elsewhere	± 10 mm
(c) Maximum difference in surface levels of adjacent units	5 mm

SECTION 12

NATURAL MATERIAL SUBBASE AND BASE

CONTENTS

TABLES

12. NATURAL MATERIAL SUBBASE AND BASE

12.1. Scope

This Section covers the provision, laying and compacting of natural gravel material for subbase and base in the pavement.

12.2. Definitions

12.2.1 Natural Materials

The term "natural material" includes lateritic gravel, quartzitic gravel, calcareous gravel, soft stone, conglomerate, sand or clayey sand or a combination of any of these materials. A natural material that can be processed using bulldozers and shovels without the need for blasting or crushing plant is also referred to as "gravel".

Natural material shall be material that can be extracted from a borrow area or a road cutting by ripping to a depth of 300 mm with a single tine hydraulic ripper acceptable to the Engineer drawn by a track type crawler tractor in good order complete with all equipment and accessories as supplied and rated at 220 kW flywheel power and over with an operating mass of not less than 35 tonne and being operated in accordance with the manufacturer's recommendations.

The material may require the use of either a grid or sheepsfoot roller with more than 8 000 kg mass per metre width of roll to break it down and/or screening to achieve the specified grading.

12.2.2 Sources of Materials

Natural material for subbase and base may be obtained from any of the following sources:-

(i) Borrow pits
(ii) Spoil areas
(iii) Excavation in cuttings, widened if necessary.
(iv) Material broken up from an existing pavement layer

The Contractor shall comply with all the requirements of Section 6 of this Specification in regard to identification and operation of the above sources.

12.2.3 Approval by the Engineer

Before any gravel is used for subbase or base, prior written approval shall be obtained from the Engineer after he is satisfied as a result of such testing as he may order that the materials meet the specified requirements for the purpose.

12.3. Material Requirements

The materials types (G80, G60, G40 and G30) denote the minimum quality for a particular use in the Works, either specified in the Drawings or instructed by the Engineer. In the cases where a minimum quality of earthworks material is not specified, the following guidelines shall apply and the Engineer's instruction shall be the applied standard to which materials quality control is applied.

12.3.1 Material class and typical use

G80	Base course
G60	Base course for low traffic roads
G40	Base course for sealed rural access roads
	Subbase
G30	Subbase

Irrespective of the minimum required quality specified or the above guidelines, the highest quality of approved gravel for pavement layers available at economical haul distances, complying with the requirements of the Specifications and Drawings, shall be selected for use.

12.3.2 Material requirements for natural gravel base course (G80 and G60)

Materials for base course layers of Class G80 as specified on the Drawings shall comply with the requirements of Table 12.1. Where specified on the Drawings, the base course for low traffic roads shall comply with the requirements for Class G60 or G45 materials as specified in Table 12.1.

12.3.3 Material requirements for natural gravel subbase (G40 and G30)

Materials for subbase layers of Class G40 or Class G30 materials as specified on the Drawings shall comply with the requirements of Table 12.1.

Table 12.1: Requirements for natural gravel materials for base and subbase

Material properties	Material Class			
	G80	**G60**	**G40**	**G30**
CBR (%)	80	60	40	30
CBR Swell (%)	0.25	0.5	0.5	1.0
Grading				
% Passing Sieve Size (mm)				
75	100	100		
37.5	80 - 100	80 - 100		
20	60 - 85	75 - 100		
10	45 - 70	45 - 90		
5.0	30 - 55	30 - 75		
2.0	20 - 45	20 - 50		
0.425	8 - 26	8 - 33		
0.075	5 – 15	5 – 22		
Grading Modulus (min)	2.15	1.95	1.5	1.25
Maximum size (mm)	53.0	63.0	75.0	2/3rd layer thickness
Atterberg Limits				
Liquid Limit (%) (max)	25	30	30	35
Plasticity Index (%) (max)	10	12	14	16
Linear Shrinkage (%) (max)	5	6	7	8
Plasticity modulus (max)	200	250	250	250
Other properties				
10%Fines (kN) (min)	80	50	-	-
Ratio dry/soaked 10%Fines (min)	0.6	0.6		

Notes:

All CBR's will be determined at the field density specified for the layer in which the material is used.

All Atterberg limits will be determined using GHA S6) (Section 2)

All grading specifications are applicable after placing and compaction. Grading curves shall be smooth curves within the specified envelopes and approximately parallel to the envelopes.

Grading Modulus (GM) = 300 – (percentage passing 2.0 + 0.425 + 0.075 mm sieves) x 100

Plasticity modulus = Plasticity Index x percentage passing 0.425 mm sieve

12.4. Compaction Requirements

12.4.1 General requirements

The minimum required compacted density for pavement layers made of natural gravel shall be as given in Table 12.2.

Table 12.2: Compaction requirements for pavement layers of natural gravel

Layer and typical material class specified	Average dry density (% MDD) (GHA S1)	Minimum dry density (%MDD) (GHA S1)
Base course (G80, G60 or G40)	98	97
Subbase (G40 or G30)	95	94
Note: Compaction to refusal measured by Compaction Meters fitted to the compaction plant should be carried out where possible. However, refusal density shall always exceed the density specified above.		

The maximum thickness of any layer compacted in one lift shall not exceed 200 mm after compaction.

12.4.2 Compaction method specification

The Engineer may allow compaction to be carried out in accordance with a method specification instead of density control in cases where material characteristics or site conditions, in his opinion, make compaction density control inappropriate. Trials shall be undertaken to the full satisfaction of the Engineer in order to establish the appropriate type of equipment, processing method and required number of roller passes. The outcome of the trials shall be satisfactory to the Engineer for a method specification to be employed. All costs for undertaking such trials shall be borne by the Contractor.

The use of a compaction method specification may at the Engineer's discretion be implemented or discontinued any time he finds it appropriate or necessary for whatever reason.

12.5. Laying and Compacting

Gravel pavement material shall be laid, graded and compacted to the specified thicknesses, levels and tolerances.

The material shall be broken down to comply with the grading requirements specified. Any oversize material that cannot be broken down to the required size shall be removed and disposed of.

The material shall be deposited in the necessary quantity and spread in a uniform layer across the full width required, so that the final compacted thickness is nowhere less than shown on the Drawings. Every reasonable effort shall be made to prevent segregation during the dumping, spreading, mixing, trimming and compacting operations.

The compacted thickness of any layer laid, processed and compacted at one time shall not exceed 200 mm and where a greater compacted thickness is required, the material shall be laid and processed in two or more layers. The minimum layer thickness shall be 100 mm.

If material is laid in wet weather, precautions shall be taken to limit the ingress of water. Material shall not be left unshaped and uncompacted. Laying shall not proceed uphill in such a manner that rainfall runoff is trapped in the material.

The material shall be scarified and the moisture content adjusted such that during compaction it shall be between 80% and 105% of the Optimum Moisture Content (GHA S1). It shall be graded and trimmed to final line and level. Light compaction may be applied before the final trim is carried out but once 25% of the number of passes has been applied, no further trimming or correction of surface irregularities will be allowed.

The final trim shall be in cut and the Contractor shall ensure that material from the trim is neither deposited in low areas nor spread across the section but graded clear of the Works. Following the final trim, the material shall be compacted to a dry density of at least 95% MDD (GHA S1) in subbase and 98% in base. During the grading, trimming and compaction of the material, the Contractor shall ensure that the material does not dry out by applying light sprays of water or other approved means sufficient to maintain the material within the specified limits of moisture content.

On completion of compaction, the surface shall be well closed, free from movement under compaction plant and free from compaction planes, ridges, cracks, loose or segregated material. If the surface fails to meet the requirements of the Specification, the Contractor shall remove the full depth of the material from the pavement and replace new material to specification, or at the Engineer's discretion, rework the material in place by ripping, adjusting the moisture content where necessary and recompacting. The area treated shall be at least 30 m long and 3 m wide or such area to be determined by the Engineer as necessary to obtain compliance with the Specification.

No subsequent layer shall be laid over any gravel layer prior to the Engineers written approval of the layer.

12.6. Proof Rolling and Trafficking

Unless otherwise directed by the Engineer, the Contractor shall proof roll the completed layer with a dual-wheel, single axle load of not less than 13 tonnes and the layer shall be free from visible movement under the proof roller. Following proof rolling, completed subbases shall be opened to traffic for a maximum period of two weeks, or such lesser period as may be directed by the Engineer. Any reinstatement required due to the effects of such exposure shall be carried out prior to the construction of the base layer. Approval of the layer will only be given after the satisfactory completion of proof rolling and trafficking. Completed base courses shall not be opened to traffic.

12.7. Mechanical Stabilization

Mechanical stabilization of natural gravel subbase and base material, if required by the Special Specification or at the request of the Engineer, shall be defined as the admixture of stabilizing fines or aggregates so as to modify the grading characteristics of the material in accordance with Table 12.1. It can also be carried out by screening into two or more fractions, and recombining. It shall be carried out at the quarry or other site before placing and spreading the materials on the road. Mixing shall be carried out using a mixing plant with measuring hoppers so that a homogeneous mix in the proportions required can be obtained. If necessary, the moisture content of the materials to be mixed shall be adjusted before mixing so that the specified grading can be achieved.

The Contractor shall be deemed to have been aware at the time of preparing his Tender that blending of some naturally occurring gravels with sand and/or crusher aggregate/fines may be necessary in order to modify their plasticity characteristics or to comply with the grading specification. It shall be deemed that the costs of such blending by mechanical means off the site have been included in the Contractor's rates and prices for subbase or base items in the Bill of Quantities. The Contractor's method of carrying out such blending shall be subject to the approval of the Engineer who will require that the resulting material shall be a uniform mixture, homogeneous in texture and consistent throughout the depth of the layer.

12.8. Construction Tolerances

The completed pavement layers shall comply with the construction tolerances given in Clause 3.3 or those given below when a statistical quality control scheme (Clause 2.21) is being utilised:

(a) Level

The level tolerances referred to in Clause 2.21.4 shall be as follows:

	H_{90}	H_{max}
Subbase..	20 mm	25 mm
Base..	15 mm	20 mm

(b) Layer thicknesses

The thickness tolerances referred to in Clause 2.21.4 shall be as follows:

	D_{90}	D_{max}	$D_{average}$
Subbase..	21 mm	27 mm	5 mm
Base..	21 mm	27 mm	5 mm

(c) Grade

Deviations from the specified longitudinal grade shall not exceed those listed in Table 12.3 in respect of the specified grades on the completed base.

Table 12.3: Deviations from specified longitudinal grade

Length (L) of section under review (m)	Maximum deviation (g) of specified slope (%)
2	0.354
5	0.224
10	0.158
20	0.112
30	0.091
Note: Use the following formula for other lengths $g(\%) = 0.5/\sqrt{L}$	

(d) Width

The average width of the layer shall not be less than the specified width, and nowhere shall the outer edge deviate by more than the following from the edge lines shown on the Drawings:

Subbase . .. . 75 mm
Base . . . . 50 mm

(e) Cross-section

When tested with a 3 m straight-edge laid at right angles to the road centre line, the surface shall not deviate from the bottom of the straight-edge by more than 6 mm.

At any cross-section the difference in level between any two points shall not vary from their difference in level computed from the cross-sections shown on the Drawings by more than 15 mm.

(f) Surface regularity

When testing the base with a rolling straight-edge, the number of surface irregularities shall not exceed those given below:

(i) Average number of irregularities per 100 m equal to or exceeding 6 mm when taken over 300 m - 600 m lengths . ……………………………………………………4

(ii) Number of irregularities equal to or exceeding 6 mm when taken over 100 m sections. ……………………………………………………………………6

The maximum value of any individual irregularity measured with the rolling straight-edge or a 3 m straight-edge laid parallel to the road centre line shall not exceed 10 mm.

(g) Construction tolerances for rehabilitation work

The construction tolerances of Clause 12.8 shall be applicable to rehabilitation work, except where a gravel layer is placed on top of an existing layer without it being required that the existing layer be trimmed first to prescribed levels, the thickness tolerances of Subclause 12.8(b) shall not apply.

12.9. Routine Inspection and Tests

The Engineer will do routine inspections and conduct routine tests to determine whether the quality of material and workmanship provided comply with the requirements of this Section.

The test results and measurements will be assessed in accordance with the provisions of Section 2.21.

SECTION 13

GRADED CRUSHED STONE SUBBASE AND BASE

CONTENTS

TABLES

1. GRADED CRUSHED STONE SUBBASE AND BASE

1.1. Scope

This Section covers the procuring, furnishing and placing of approved graded crushed stone on top of a completed selected layer or subbase and constructing a crushed stone subbase or base, as the case may be, in accordance with the requirements of these Specifications.

1.2. Definitions

"Graded crushed stone" shall mean crushed stone with a smooth grading curve, which is within a specified envelope. The stone class and nominal size selected shall be specified in the Special Specification. The range of nominal sizes and gradings of crushed stone are defined in Clause 1.3 (c) below for Stone Classes A, B, C and D. The aggregate shall be produced entirely by the crushing of rock. Single stage crushing shall not be allowed and the crusher installation shall be capable of producing material complying with the specified requirements.

Graded crushed stone shall be obtained from quarries in accordance with the provisions of Section **Error! Reference source not found.** of the Specification.

1.3. Material Requirements

The material shall comply with the following requirements:-

(a) It shall consist of crushed stone, free from clay, organic or other deleterious matter, derived from hard, sound, durable and unweathered parent rock.

(b) It shall comply with the physical characteristics given below (Table 13.1). Material failing to satisfy the requirements of stone class D shall be rejected.

(i) Stone Classes A, B and C

Table 13.1 - Physical Characteristics of Crushed Stone (Classes A, B and C)

	Base			Subbase		
Stone Class	A	B	C	.A	B	C
LAA (%) (max).	30	40	45	40	45	50
Water absorption (%) (max)	1.5	2.0	2.0	2.0	2.5	2.5
FI (%) (max). (-28+20 & -20+14 mm)	25	30	30	35	35	35
10% Fines (kN) (min)	110 (dry)	110 (dry)	110 (dry)	50 (wet)	50 (wet)	50 (wet)
Wet/Dry % (min)	75	75	75	60	60	60

(ii) Stone Class D

Base

CBR at 98% MDD (GHA S1) and 4 days soak	min 80%
Los Angeles Abrasion	max 50%
Plasticity Index	max 6%
10% Fines Dry	min 100 kN
Wet/dry	min 75%

Subbase

The plasticity of the material shall be specified in the Special Specification.

CBR at 95% MDD (GHA S1) and 4 days soak	min 40%
10% Fines Wet	min 50 kN

(c) It shall comply with the following gradings:

(i) Stone Classes A, B and C

The grading of the material, after processing, placing and compaction in the pavement shall be a smooth curve without any marked gaps within, and approximately parallel to one of the following envelopes (Table 13.2). The class and nominal size shall be specified in the Special Specification.

Table 13.2 - Grading of Crushed Stone (Classes A, B and C)

Sieve Size (mm)	Percentage by mass passing			
	Base		Subbase	
	0/30	0/40	0/40	0/60
75				100
37.5	100	90- 100	90- 100	75 -95
20	65-95	60 -90	60 -90	50 -80
10	40-70	40 -75	35 -75	30 -67
5	26-50	26 -52	22 -59	20 -54
2	20-40	20 -45	15 -45	13 -40
0.425	10-24	15 -31	4 -23	4 -20
0.075	4 - 10	5 - 15	4 - 12	4 - 10

Cleanliness and plasticity: Material passing the 0.425 mm sieve shall have a Plasticity Index not exceeding 6%. The arithmetic mean of the PIs for a lot (minimum 6 tests) shall not exceed 4.5%.

(ii) Stone Class D

Base

Table 13.3 - Grading of Crushed Stone (Class D) for Base

Sieve (mm)	% by mass passing
50	100
37.5	90 - 100
20	60 - 100
10	35 - 90
5	20 - 75
2	12 - 50
0.425	7 - 33
0.075	4 - 20

`

Subbase

Maximum particle size	2/3 layer thickness or 80 mm whichever is the lesser.
Uniformity Coefficient	minimum of 5

(d) The grading and physical requirements of the material for use in treated material in accordance with Section **Error! Reference source not found.** of the Specification shall be specified in the Special Specification.

1.4. Laying and Compacting Graded Crushed Stone Subbase and Base

Before any crushed stone layer is placed, the underlying layer shall comply with the requirements of the layer concerned. No crushed stone layer shall be rolled if the underlying layer, either on account of rain or by any other cause is so wet as to constitute a danger of the underlying layers being damaged.

Graded crushed stone shall be laid with a paving machine capable of distributing the material in a loose layer of uniform thickness and without segregation, such that after compaction, the layer shall have a thickness as shown on the Drawings. Laying shall proceed from the centre to the sides of a pavement of cambered section, from the high side to the low side of a pavement with a single crossfall and downhill only so that runoff is not trapped.

Crushed stone shall be laid in individual layers not exceeding 150 mm thick unless otherwise approved by the Engineer and if the Contractor can demonstrate definitively in Trial Sections that the material supplied can be compacted satisfactorily with the equipment available on site to a single layer thickness in excess of 150 mm. The compacted thickness of any layer shall not be less than 100 mm.

The operations of transporting, laying and compacting the crushed stone layer shall be carried out in a manner such as to avoid disturbing the underlying pavement layer. Should such disturbance occur, the Contractor shall remove the disturbed material to the satisfaction of the Engineer at his own expense.

No material shall be hauled over uncompacted crushed stone material.

1.4.1 Compaction

As soon as possible after laying, compaction shall be carried out. The moisture content shall be adjusted as necessary and during compaction care shall be taken to maintain the moisture content evenly at the required value. Unless otherwise instructed by the Engineer, the moisture content at the time of compaction shall be between 80 and 105% of the Optimum Moisture Content as determined by the vibrating hammer method (GHA S4).

Graded crushed stone shall be compacted by means of vibrating, smooth-wheeled and/or pneumatic tyred rollers.

During compaction the rollers shall follow a regular route such that each track slightly overlaps the adjacent previous track and the entire area is covered uniformly. Compaction shall proceed from the sides to the centre or from one side towards previously compacted material. On superelevated curves, rolling shall progress from the lower to the higher edge. Compaction shall continue until the material shows no tendency to creep or settle in front of the rollers.

In areas where compaction plant used generally for compaction cannot operate efficiently or may cause damage to adjacent work, the Contractor shall compact the crushed stone layer with hand-operated vibrators and mechanical tampers of types approved by the Engineer, until the dry density at every level in the crushed stone layer in such places is at least equal to that of the compacted crushed stone layer in the general vicinity.

The dry densities to be achieved as a percentage of the Maximum Dry Density (MDD) determined by the vibrating hammer method (GHA S4) shall be as follows, unless a statistical quality control plan is in place, in which case Table 2.12 shall apply:

(i) Base: average dry density not less than 98% MDD with no result less than 97% MDD.

(ii) Subbase: average dry density not less than 95% MDD with no result less than 94% MDD.

Where the results of the construction control tests for any of the base or subbase materials are less than that specified, the full depth of the layer shall be removed and replaced to specification or, with the approval of the Engineer, reworked. The area treated shall be the whole section submitted for approval or, following a retest, a length of at least 50 m both sides of each test and retest failure or such area to be determined by the Engineer as necessary to obtain compliance with the Specification.

In addition to the above (and taking precedence when ordered by the Engineer), the dry densities to be achieved as a percentage of the particle density of the stone determined using GHA S3 shall be:

(iii) Base: average dry density not less than 88% of the particle density with no result less than 85% of the particle density (oven - dry value).

(iv) Subbase: average dry density not less than 86% of the particle density with no result less than 84% of the particle density (oven - dry value).

On completion of compaction, the surface shall be well closed, mechanically stable and free from compaction planes, ridges, cracks, loose or segregated material.

If the surface fails to meet the requirements of this Specification, it shall be corrected by being scarified, reshaped and recompacted with the addition of further fines or the replacement of crushed stone containing excessive fine material as may be necessary, this being done in such a way that no segregation of material occurs. The Engineer may instruct other forms of corrective action, at his discretion. The cost of any corrective actions requested shall be deemed to be included in the rate for providing and compacting the crushed stone layer.

The Contractor shall obtain the Engineer's approval of the compacted crushed stone layer before placing the base or priming. Traffic shall not be permitted to travel on the crushed stone base without the permission of the Engineer.

1.5. Testing of Crushed Stone Subbase and Base

During the construction of crushed stone layers, the Contractor shall take samples and carry out tests under supervision of the Engineer as specified in Section **Error! Reference source not found.**. As frequently as the Engineer shall request, but at least once for every 500 m^2 of crushed stone material laid the Contractor shall determine the particle size distribution and Plasticity Index of the compacted material. The Contractor shall also carry out any other tests as and when requested by the Engineer in order to confirm compliance of the stone material with the requirements in Clause 1.3 of the Specification.

1.6. Trial Sections

Prior to the commencement of construction of a crushed stone layer, the Contractor shall construct areas of trial layer at sites agreed with the Engineer. The area of the trial shall be not less than 500 m^2 in extent. The trial shall be supplemented by such testing in the field and laboratory as the Engineer directs.

Prior to commencement of construction of the Trial sections, the Contractor shall submit in writing to the Engineer his proposals for placing, spreading, grading and compacting the materials comprising the layer. If in the opinion of the Engineer, the results of the trial section and the Contractor's proposed plant and method to spread, grade and compact the crushed stone materials are adequate and in accordance with the Specifications, the Engineer shall give his approval. If otherwise, the Contractor shall submit in writing proposals for modifying the plant or methods and shall, if the Engineer so requires, construct further trials until the Engineer approves the Contractor's proposals.

None of the foregoing provisions shall prevent the Engineer from requiring the Contractor to vary his plant or methods at any time during the execution of the Works, should this be considered essential for successful completion of the Contract. The Contractor shall not vary plant or methods, which have been approved by the Engineer without the Engineer's approval of such variation.

Notwithstanding the Engineer's approval of the Contractor's plant and methods, the Contractor shall at all times be solely responsible for constructing the crushed stone layer in accordance with the Specification and Drawings.

The Contractor shall not commence placing of the crushed stone material until he has obtained the Engineer's approval in writing, of the plant and methods that he proposes for spreading, grading and compacting the material.

1.7. Finishing of the Layer

The Contractor shall ensure that the passage of any vehicle or plant over the partially or fully completed layer does not cause any rutting or other damage or disturbance to the layer, and should such rutting or damage or disturbance occur, the Contractor shall repair it as directed by the Engineer, all at the Contractor's own expense.

Immediately before laying surfacing on a completed crushed stone base, the upper surface shall be tested for smoothness and accuracy as specified.

In particular, care shall be taken to ensure that the bituminous prime coat is applied on the upper surface as soon as possible after the Engineer's approval on the smoothness and accuracy of the base is obtained.

1.8. Protection and Maintenance

The Contractor shall protect and maintain the completed crushed-stone layer at his own expense until the next layer or the seal or surfacing is applied. Maintenance shall include the immediate repair of any damage to or defects in the layer and shall be repeated as often as is necessary. Repairs shall be so made as to ensure an even and uniform surface to be restored after completion of the repair work.

Traffic shall not be allowed on any unprimed crushed stone layer unless so authorised or directed by the Engineer.

The crushed-stone base shall be primed as soon as possible and, where so ordered by the Engineer, traffic may have to be routed across completed and primed layers as specified in Section **Error! Reference source not found.**.

1.9. Tolerances

The completed pavement layers shall comply with the construction tolerances given below:

(a) Level

The level tolerances referred to in Clause **Error! Reference source not found.** shall be as follows:

	H_{90}	H_{max}
Subbase..	20 mm	25 mm
Base..	15 mm	20 mm

(b) Layer thicknesses

The thickness tolerances referred to in Clause **Error! Reference source not found.** shall be as follows:

	D_{90}	D_{max}	$D_{average}$
Subbase..	21 mm	27 mm	5 mm
Base..	21 mm	27 mm	5 mm

(c) Grade

Deviations from the specified longitudinal grade shall not exceed that listed in Table 13.4 in respect of the specified grades on the completed base.

Table 13.4: Deviations from specified longitudinal grade

Length (L) of section under review (m)	Maximum deviation (g) of specified slope (%)
2	0.354
5	0.224
10	0.158
20	0.112
30	0.091
Note: Use the following formula for other lengths $g(\%) = 0.5/\sqrt{L}$	

(d) Width

The average width of the layer shall not be less than the specified width, and nowhere shall the outer edge deviate by more than the following from the edge lines shown on the Drawings:

Subbase . .. . 75 mm
Base . . . . 50 mm

(e) Cross-section

When tested with a 3 m straight-edge laid at right angles to the road centre line, the surface shall not deviate from the bottom of the straight-edge by more than 6 mm.

At any cross-section the difference in level between any two points shall not vary from their difference in level computed from the cross-sections shown on the Drawings by more than 15 mm.

(f) Surface regularity

When testing the base with a rolling straight-edge, the number of surface irregularities shall not exceed those given below:

(i) Average number of irregularities per 100 m equal to or exceeding 6 mm
when taken over 300 m - 600 m lengths . ……………………………………….……..4

(ii) Number of irregularities equal to or exceeding 6 mm when taken
over 100 m sections ………………………………………………………………6

The maximum value of any individual irregularity measured with the rolling straight-edge or a 3 m straight-edge laid parallel to the road centre line shall not exceed 10 mm.

(g) Construction tolerances for rehabilitation work

The construction tolerances of Clause **Error! Reference source not found.** shall be applicable to rehabilitation work. Where a gravel layer is placed on top of an existing layer that has not required to be trimmed first to prescribed levels, the thickness tolerances of Clause **Error! Reference source not found.** shall not apply.

1.10. Routine Inspection and Tests

The Engineer will do routine inspections and conduct routine tests to determine whether the quality of material and workmanship provided comply with the requirements of this Section.

The test results and measurements will be assessed in accordance with the provisions of Section **Error! Reference source not found.** when so instructed by the Engineer.

SECTION 14

CEMENTITIOUS AND BITUMINOUS TREATED MATERIALS

CONTENTS

TABLES

14. CEMENTITIOUS AND BITUMINOUS TREATED MATERIALS

14.1. Scope

This section deals with the addition of cement, lime, bitumen or any other approved additive as a stabilizer to improve soils in the upper layers of earthworks, natural gravels and/or crushed materials. Following the addition and mixing in of the stabilizer, the material is referred to as "treated material".

14.2. Sources of Material

Upper layers of earthworks as described in Section 5.

Quarries and borrow pits as described in Section 6.

14.3. Material Requirements

14.3.1 Soils

Natural materials as described in Sections 5 and 12. Soils with a sulfate content ($S0_3$) greater than 0.5%, by mass, shall not be used for cement or lime stabilization.

(a) Natural material for treated upper surface of formation

The materials to be treated shall conform to the following requirements:

Sands, silty and clayey sands:

maximum size (mm)	10
% passing 0.075 mm sieve	max 50

All materials:

Plasticity Index for lime stabilization (%)	max 30
Plasticity Index for cement stabilization (%)	max 20
Plasticity Modulus	max 2500
Organic matter (%)	max 3

Additional requirements for lime treated materials:

% passing 0.425 mm sieve	min 15
Plasticity Index (%)	min 10

After treatment the material shall have a CBR of at least 15% measured after 7 days curing and 4 days soaking on the site mix compacted to 95% MDD (GHA S1) and the treated material shall have a Plasticity Index not exceeding 15% and a Plasticity Modulus less than 250.

(b) Natural material for cement or lime treated subbase

The materials to be treated shall conform to the following requirements:

Gravels:

maximum size (mm)	50
% passing 0.075 mm sieve	max 40

Sands, silty and clayey sands:

maximum size (mm)	10
% passing 0.075 mm sieve	max 50

All materials:

Plasticity Index for lime stabilization (%)	max 30
Plasticity Index for cement stabilization (%)	max 20
Plasticity Modulus	max 2500
Organic matter (%)	max 2
Methylene Blue Value	min 2

Additional requirements for lime treated materials:

% passing 0.425 mm sieve	min 15
Plasticity Index (%)	min 10

After treatment the material shall have a CBR of at least 60% measured after a 7 day curing and 4 day soaking period on the site mix compacted to 95% MDD (GHA S1) and the treated material shall have a Plasticity Index not exceeding 10% and a Plasticity Modulus less than 250.

Material for a stabilized subbase in an inverted pavement structure shall have a UCS of between 3 and 6 N/mm^2.

(c) Natural materials for cement stabilized base

The materials to be treated shall conform to the following requirements:

Gravels and coarse clayey sands:

maximum size (mm)	40
% passing 0.075 mm sieve	max 35
Uniformity Coefficient	min 10
Plasticity Index (%)	max 20
Plasticity Modulus	
mix-in-place method	max 1500
stationary plant method	max 700
CBR at 95% MDD (GHA S1) and 4 day soak	min 30%

After treatment the material shall have a UCS of between 1.5 and 3.0 N/mm^2 measured after 7 days curing and 4 days soaking on the site mix compacted at 97% MDD (GHA S1) and the treated material shall have a Plasticity Index of less than 6 and a Plasticity Modulus of less than 250.

(d) Natural materials for bitumen stabilized base

The materials to be treated shall conform to the following requirements:

maximum size (mm)	50
% passing 0.075 mm sieve	2 - 20
Plasticity Index (%)	max 7*
Sand equivalent	min 30
CBR at 95% MDD (GHA S1) and 4 day soak	min 30%

* If PI > 7% it can be reduced by the addition of an appropriate quantity of lime

After treatment the material should have the following properties:

Table 14.1: Requirements for Bitumen Treated Material

Parameter		Minimum Strength (N/mm^2)
Unconfined Compressive Strength (UCS), in accordance with B.S. 1881, part 116. 7-day strength, moist curing @ 25°C, height/width 1:1	Minimum 97% of GHA S1 density*	0.7
Indirect tensile strength (ITS) on 100 mm diameter briquette cured at 40ºC for 72 hours, in accordance with AASHTO T 198	Marshall compaction (75 blows per side)	0.2
Indirect tensile test (ITS) on cured briquettes, soaked for 24 hours as above	Marshall compaction (75 blows per side)	0.15
Maximum added cement content by weight		2%

14.3.2 Crushed materials

Crushed stone materials will typically only be treated (modified) with lime or cement to reduce their plasticity to the required limits (Clause 13.3) in exceptional cases. Treatment with bitumen will be to improve their strength and durability and to waterproof the layer. Details will be provided in the Special Specification.

14.3.3 Stabilizers

(a) Cement

Unless otherwise specified cement shall be a Portland cement (CEM I) or an extended Portland cement (CEM II) complying with the requirements of GS 22 and GS 766 respectively or BS EN 197. The maximum strength Class shall be 42.5 and rapid hardening cement shall not be used.

(b) Lime

Lime shall be Hydrated Calcium Lime and shall comply with the requirements of BS EN 459-1 and Clause 2.8 of Section 2 or as specified in the Special Specification.

(c) Bitumen

Bitumen shall be bitumen emulsion complying with ASTM D 977 or, when foamed, AC-10 viscosity graded bitumen as specified in Table 16.1.

14.3.4 Other stabilizers

Other stabilization agents such as proprietary chemical soil stabilizers, fly ash and ground slags may be used subject to approval by the Engineer, following laboratory and field investigations (where necessary) to confirm that the agents are suitable and to provide a satisfactory stabilization mix design.

14.4. Storage and Handling

The requirements of Section 18 of the Specification shall apply to cement used for stabilization.

All lime shall be kept under cover and protected from moisture. Consignments shall be used in the same sequence as they are delivered. Stocks that become damaged or which are stored on the Site for more than 3 months shall not be used unless testing immediately prior to use confirms that they comply with the requirements of Clause 2.8. Operators and labour shall be provided with protective clothing, masks and goggles during lime stabilization operations.

14.5. Amount of Stabilizer to be Added

The amount of cement, lime or bitumen to be added shall be agreed with the Engineer following laboratory and site trials carried out by the Contractor in accordance with Section 2 of the Specification.

In order to ensure adequate durability of lime or cement stabilized material, the stabilizer content should exceed the Initial Consumption of Lime (Clause 2.9.3) by at least 1%.

14.6. Mix-In-Place Method of Construction

The mix-in-place method may be used for the addition and mixing in of stabilizer.

14.6.1 Mixing equipment

The equipment for pulverizing the material and mixing in the stabilizer shall be purpose-built equipment, either single or multipass machines, capable of pulverizing the materials and mixing in the stabilizer to the full depth of loose layer necessary to give the specified thickness of compacted material.

If single-pass equipment is used for plastic soils, the degree of pulverization as determined in accordance with BS 1924-2 (Clause 1.5) shall not be less than 80%.

The mixers shall be equipped with a device for controlling the depth of processing and mixing blades shall be maintained or reset periodically so that the correct depth of mixing is obtained at all times.

Mixing by grader alone will not be permitted, unless approved by the Engineer.

14.6.2 Preparation of the layer

Before the stabilizer is applied, the material to be treated shall be spread and broken down and oversize material removed so that the maximum size of the particles is not more than that specified. If multi-pass processing is employed, the material shall first be pulverized to the required tilth by successive passes. The material shall then be shaped true to line, grade and cross-section and, if required, lightly compacted. The loose thickness shall be controlled so as to give the specified thickness after compaction has been completed.

The moisture content of the layer before the addition of the stabilizer shall be adjusted to within the range of 70 to 85% of the Optimum Moisture Content (GHA S1).

14.6.3 Spreading the stabilizer

After the layer to be treated has been prepared, the stabilizer shall be spread uniformly over the full area to be worked at the specified rate by means of an approved type of mechanical spreader in a continuous process, recycling equipment, or it may be spread by hand when approved by the Engineer. If a spreader is used ahead of the mixer, it shall be fitted with a device to ensure a uniform and controllable rate of spread both transversely and longitudinally.

When spreading is done by hand, pockets or bags of stabilizing agent shall be accurately spaced at equal intervals along the section to be stabilized so that the specified rate of application can be achieved. The stabilizing agent shall be spread as evenly as possible, and shall then be uniformly distributed over the entire surface to be treated by levelling off the stabilizing agent by means of hand rakes and/or screeds.

Only sufficient stabilizer for immediate use shall be spread ahead of the mixing operation.

Only equipment actually used in the spreading or mixing operation shall be allowed to pass over the stabilizer, when so spread, before it has been mixed into the material to be treated.

Stabilizer should not be spread on windy days, and care shall be taken to ensure that stabilizer does not get deposited beyond the outer limits of the road during application and mixing.

14.6.4 Mixing and watering

Immediately after the stabilizer has been spread, it shall be thoroughly mixed into the material for the full depth of the layer. Mixing shall continue until the resulting mixture forms a fine and homogeneous tilth over the full area and width to be treated. The mixing machine shall be set so that it cuts at least 100 mm into the edge of any adjoining lane processed previously so as to ensure that all of the material forming the layer has been properly processed.

Care shall be taken both during this and during subsequent watering operations that the underlying layer is not disturbed and that no material from the underlying or adjacent layers is mixed with that being processed.

Immediately after the stabilization agent has been properly mixed with the soil or gravel, the moisture content should be assessed and if additional watering is necessary to bring the mixture to the required moisture content, then this shall be added. Water shall be added in a uniform and controllable manner and, where necessary, in successive increments. Each increment shall be mixed in a separate mixing operation. Care shall be taken to avoid a concentration of water at any point or a flow of water over the surface. The water supply and watering equipment shall be adequate to ensure that all water required will be added and mixed with the material being treated within a short enough period to enable compaction and finishing to be completed within the period specified in Subclause 14.8.

Any part of the mixture that becomes too wet after the stabilizer has been added and before the mixture is compacted will be rejected and any such part shall be allowed to dry out until its moisture content is satisfactory and shall be scarified, restabilized, with fresh stabilizer, compacted and finished off in accordance with this Clause, all at the expense of the Contractor.

Throughout the process of mixing in the stabilizer and water, a uniform thickness of the mixture shall be maintained and, if necessary, the mixture shall be graded to maintain the correct uncompacted thickness and shape. Any part of the mixture that becomes segregated shall be removed and replaced.

14.7. Stationary Plant Method of Construction

14.7.1 Mixing Equipment

Stationary mixing plant shall be of the power driven paddle or pan type and may be of the batch or continuous type.

If batch mixers are used, the appropriate measured amounts of material and stabilizer shall first be placed in the mixer, water being then added as necessary to bring the moisture content of the resulting mixture within the range suitable for compaction determined in the laboratory and site trials. Special care shall be taken with batch type paddle mixers to ensure that the stabilizer is spread uniformly in the loading skip so that it is fed evenly along the mixing trough and that with both paddle and pan mixers the stabilizer is proportioned accurately by a separate weighing or proportioning device from that used for the material being stabilized. Mixing shall be continued until the mixture has the required uniformity and for not less than 1 minute unless a shorter minimum period is permitted by the Engineer after satisfactory trials.

If continuous mixing is used, the paddles, baffles and rate of feed of materials shall be adjusted to give uniformly mixed material.

If a spray is used for distributing water into the mixer, it shall be adjusted to give uniformity in moisture content throughout the mix.

14.7.2 Transporting

Mixed material shall be transported to the road in suitable vehicles that are equipped with protective covers to avoid moisture losses during transport. To prevent excessive haul time, not more than one hour should elapse between the start of moist mixing of cement treated materials and the start of compaction. The haul time of cement treated materials should not exceed 30 minutes. Material that becomes segregated or affected by weather (wetting or drying out) shall be removed from the Works and replaced.

14.7.3 Laying

The mixed material shall be spread by means of a mechanical paver to the required width and such thickness that the tolerance requirements as specified in Section 3 of this Specification are obtained after final compaction. Segregation shall be avoided and the layer shall be free from pockets of coarse or fine material.

14.8. Compaction and Finishing

For cement treated materials, final compaction and finishing shall be completed within 2 hours after the cement comes into contact with the material to be treated, unless otherwise approved by the Engineer following site trials.

For lime treated materials, final compaction and finishing shall be completed within 4 hours after the lime comes into contact with the material to be treated, unless otherwise approved by the Engineer following site trials.

14.8.1 Thickness limitations

The compacted thickness of any treated layer laid, processed and compacted at one time shall not exceed 180 mm. Where a greater thickness is required, the material shall be laid in two or more layers.

The compacted thickness of any treated base layer shall not be less than 3 times the maximum particle size of the material and the compacted thickness of any treated subbase layer shall not be less than twice the maximum particle size of the material.

14.8.2 Compaction requirements

The minimum density for all lime and cement treated bases and subbases shall be 97% and 95% MDD (GHA S1) respectively. The moisture content at the time of compaction shall be between 90% and 105% of Optimum Moisture Content (GHA S1) but shall not exceed 80% of the saturation moisture content of the material.

During compaction the layer shall be continuously bladed by motor grader, and loss of moisture by evaporation shall be corrected by further light applications of water.

During compaction of the stabilized layers, the Contractor shall lightly harrow or scarify the crust before final rolling, if so required by the Engineer, in order to prevent the formation of laminations near the surface of the layer. Final rolling shall be done with equipment that will give a smooth surface finish which conforms to the surface tolerances specified. Low patches on the surface may not be filled after compaction.

A sufficient number of compacting units shall be employed on the work to ensure that, from the time the stabilizing agent is first applied to the layer, the mixing process, watering, compacting, shaping and final finishing will be completed within the periods specified in Clause 14.8.

14.8.3 Finishing

The surfacing finish after compaction of any treated layer shall be free from ridges, compaction planes, laminations, loose and segregated material and other surface irregularities.

14.9. Joint Between New and Existing Work

The forming of construction joints and the protection of previously treated or other work shall be carried out so as to produce a uniformly compacted and homogeneous layer free from ridges or other irregularities.

Full width working, without longitudinal joints, will generally be required. Half-width working may be acceptable to the Engineer to pass traffic. When forming longitudinal joints with the mix-in-place method, at least 100 mm of the first laid half-width layer shall be retreated and mixed in with the second half-width layer.

When forming transverse joints, with the mix-in-place method, at least 1.0 m length of the previously laid treated work shall be incorporated into the new treated layer and the Engineer may instruct that the percentage of stabilizer be increased at these places.

When forming longitudinal or transverse joints with the stationary plant method of construction, previous work shall be cut back to expose fully treated and compacted material.

Any finished portion of the stabilized layer adjacent to new work, which is used as a turn-round area by equipment in constructing the adjoining section, shall be provided with a protective cover of soil or gravel of at least 100 mm thick over a sufficient length to prevent damage to work already completed. When the adjoining section is being finally finished, such cover shall be removed to permit the making of a smooth vertical joint at the junction of the different sections. Material in the vicinity of the joint which cannot be processed satisfactorily with normal construction equipment shall be mixed and compacted by hand or with suitable hand-operated machines.

14.10. Protection and Curing

Cement and lime stabilized layers shall be protected against rapid drying out for at least seven days following completion of the layer.

Treated layers shall be kept continuously damp by lightly spraying with water for up to a maximum period of 24 hours from completion of compaction, but one of Methods (a), (b), or (c) shall be applied as soon as the moisture content of the stabilized layer so permits.

(a) Completely covering the layer with clear or light coloured approved polythene sheeting of minimum thickness 0.1 mm. The sheeting shall be laid to cover the whole of the surface of the layer and shall be securely held in contact with the layer. At joints the sheeting shall be lapped by at least 500 mm and any damaged sheeting shall be replaced.

(b) Completely covering the treated material with a layer of damp uncompacted gravel or soil material of minimum thickness 100 mm. This material, which may be that used for the next layer, shall be kept continuously damp.

(c) Spraying the layer with a suitable spray-grade bitumen emulsion at a rate instructed by the Engineer. This method shall not be permitted where the following layer is to be bituminous mix in accordance with Section 17 of this Specification.

Plant used for dumping and spreading material, and the application of water or emulsion shall have individual axle loads not exceeding 6 tonnes.

Immediately prior to placing protective methods (a) or (b) the surface of the treated layer shall be made thoroughly damp by lightly spraying with water.

The curing system shall be kept in place and intact for a minimum of 7 days after completion of compaction although small areas may be temporarily removed for the purposes of carrying out control testing but only for the minimum amount of time required for the testing. No traffic shall be allowed on any treated layer for 72 hours after compaction.

No additional payment will be made for curing as described above, except that the application of a curing membrane when ordered by the Engineer shall be paid for separately and the application of a prime coat shall be paid for under Section 16.

A curing period of 48 hours during which time no traffic will be allowed on the layer shall be provided for foamed and emulsified bitumen treated layers. No specific treatment of the layer is necessary during this period.

14.11. Traffic

Traffic or equipment, other than that actually engaged in the various treatment or protection processes, shall not run over the layer being processed or compacted.

On completion of curing no traffic or equipment shall be allowed on the treated layer with the exception of that required for proof rolling, priming or construction of the subsequent layer.

14.12. Tolerances

14.12.1 Geometric tolerances

The treated upper earthworks, subbase and base shall be constructed within the tolerances specified in Section 3 of the Specification.

14.12.2 Amount of stabilizer

(a) Mix-in-place method of construction

The average amount of stabilizer, measured before mixing, over a length of 100 m shall not be less than the amount ordered.

The average amount of stabilizer in the treated material measured at five points over a length of 100 m shall not be less than the amount ordered.

The amount of stabilizer, measured after mixing, shall at no point be less than 70% or more than 130% of the amount ordered.

(b) Stationary plant method of construction

The average amount of stabilizer in the treated material measured at five points over a length of 100 m shall not be less than the amount ordered.

The amount of stabilizer measured after mixing shall at no point be less than 90% or more than 110% of the amount ordered.

(c) Determination of stabilizer content

The cement content in mixed materials shall be determined according to BS 1924-2 Clause 5.1 or to AASHTO T 211.

The lime content in mixed materials shall be determined according to BS1924-2 Clause 5.2 or to AASHTO T 232.

14.13. Rectification

Any cement or lime treated layer that is outside the above tolerance or fails to meet the density requirement in Clause 14.8.2 shall be removed to its full depth and replaced to specification. The area treated shall be at least 5 m long and full width of the paving laid in one operation. If areas are corrected within 7 days of laying, no construction traffic or compaction plant shall use the surrounding satisfactory areas.

SECTION 15

LEAN CONCRETE

CONTENTS

TABLES

15. LEAN CONCRETE

15.1. Scope

This section deals with the addition and mixing in of cement to graded aggregate, and the transporting, laying and compaction of the mix, hereinafter referred as "lean concrete" for base, subbase or pipe bedding.

15.2. Source of Materials

Material shall be obtained from quarries in accordance with Section 6 of the Specification.

15.3. Materials Requirements

15.3.1 Aggregates

(a) Grading shall be in accordance with Table 15.1

Table 15.1: Grading of Aggregate for Lean Concrete

Sieve Size (mm)	% Passing (by mass)
37.5	100
20	65 – 95
10	40 – 70
5	30 – 55
2	18 – 40
0.425	10 – 24
0.075	0 - 3

(b) Combined aggregate

Fines (passing 0.425 mm)	shall be non-plastic
Sand-equivalent	Min 30%
Organic matter	Max 0.3% (by mass)

(c) Coarse aggregate (retained on a 6.3 mm sieve)

FI	Max 25%
LAA	Max 35%
10% Fines Dry	Min 110 kN
Wet/Dry	75%

15.3.2 Cement

Unless otherwise specified cement shall be Portland cement (CEM I) complying with the requirements of GS 22 or BS EN 197.

15.3.3 Storage and handling of cement

The requirements of Section 18 of this Specification shall apply to the storage and handling of cement.

15.3.4 Water

Water shall comply with the requirements of BS EN 1008.

15.4. Mix Requirements

15.4.1 Proportions

The amount of cement to be added shall be agreed with the Engineer following laboratory trials, and site trials carried out by the Contractor in accordance with Section 2 of the Specification.

15.4.2 Crushing strength

The essential strength requirement for the material is that the average 28-day strengths of groups of three cubes shall be such that not more than one such average strength in any consecutive five such averages is less than 10 N/mm^2. If, however, the overall average of any consecutive five groups of three cubes (i.e. fifteen cube strengths) falls below 12 N/mm^2 at 28 days, or if the average range of five consecutive groups exceeds 20 N/mm^2 the Engineer may require the use of different materials, mix proportions, plant or methods notwithstanding any approval that may have been previously given to such materials, mix proportions, plant or methods.

The initial rate of testing shall comply with the requirements of Sections 2 and 18 of the Specification until the Engineer is satisfied that the specified material is being consistently produced.

Further, in order to ensure a high probability that at an early stage the above requirements will be met, the average 7-day strengths of groups of three cubes shall not be less than 7 N/mm^2 and if more than one of the 7-day average strengths of groups of three cubes in any consecutive five such averages falls below 9 N/mm^2 the cement content shall be increased to such a value as may be approved by the Engineer and the making of cubes shall be continued at the same rate as at the start of the work until the results show that a satisfactory material is being consistently produced.

15.5. Method of Construction

15.5.1 Site trials

The Contractor shall carry out site trials in accordance with Section 2 of the Specification at least one month before he intends commencing full scale construction of any lean concrete layer. Should the trial show that the specified strength and compaction requirements cannot be achieved the Contractor shall amend the mix proportions or the laying and compaction techniques in order to achieve the required result.

15.5.2 Mixing, transporting and laying

Lean concrete shall be mixed, transported and laid in accordance with Section 14.7 of the Specification (stationary plant method of construction).

15.5.3 Compaction

Immediately after laying, the mix shall be compacted by vibratory and smooth wheel rollers to 96% of the target dry density as defined hereunder. Compaction shall be completed within 2 hours of the cement being added to the aggregates at the batching plant.

The target dry density shall be determined daily as follows:-

> From three separate batches of the mix, two 150 mm test cubes shall be prepared in accordance with BS EN 12390-3 except that the cubes shall be compacted to refusal in three layers using a vibrating hammer as described in GHA S4, but with a square flatplate head with an area of between 10,000 and 15,000 mm^2. As soon as the cubes can be handled without damage, their density and moisture content shall be determined in accordance with BS EN 12390-7. The average dry density of the six cubes shall be the target dry density.
>
> The density of the compacted base shall be determined for each 500 m^2 laid. The Contractor shall provide a portable coring rig capable of cutting acceptable cores of minimum diameter 150 mm and to a depth of at least 250 mm. The density and moisture content of each core shall be measured in accordance with BS EN 12390-7.
>
> Following the determination of the density each core shall be crushed and the minimum equivalent cube strength shall be 7 N/mm^2 at 7 days calculated in accordance with BS EN 12504-1.
>
> The compacted thickness shall not exceed 250 mm.

15.5.4 Finishing and Tolerance

The surface finish after compaction shall be free from ridges, compaction planes, laminations, loose and segregated material and other surface irregularities and shall be to line and level and within the tolerances specified in Section 3 of this Specification.

15.5.5 Joints

At the end of each day's work the lean concrete shall be compacted against a securely fixed vertical temporary stop-end and if compaction is being done with a vibratory roller this shall be used transversely close to the stop-end. In addition, the material in the corners adjacent to the stop-end shall be compacted by means of a small power-operated compactor. When the stop-end is removed any poorly compacted material adjacent to it shall be removed and a 1 : 1 cement:sand grout shall be applied to the exposed face to a thickness of 5 – 10 mm before proceeding with the laying of further adjoining lean concrete. Such fresh lean concrete shall be thoroughly compacted against the joint and where a vibratory roller is employed this shall be used transversely close to the joint again using the small power-operated compactor in the comers of the new work. None of the compacting equipment shall be allowed to bear directly on the hardened or partially hardened lean concrete previously laid.

Where the full width of the layer cannot be placed by one pass of the paver, work shall be arranged so that at longitudinal joints a free edge of spread material is not exposed for more than one hour after mixing before placing the adjacent layer. Where a free edge is exposed for more than one hour after mixing, it shall be cut back to expose fully compacted material before laying the adjacent layer.

15.5.6 Curing

Curing and the period of curing shall be in accordance with the Special Specification.

15.6. Rectification

Any layer of lean concrete that fails to meet the above finish criteria or is outside the above tolerances and compaction requirements shall be removed from the pavement and replaced to specification. The area treated shall be at least 5 m long and the full width of the paving laid in one operation. If areas are corrected within 7 days of laying, no construction traffic or compaction plant shall use the surrounding satisfactory areas.

15.7. Traffic

Traffic or equipment, other than that actually engaged in the various treatment processes, shall not run over the layer being processed or compacted.

No traffic or equipment will be allowed on a treated layer earlier than that period specified in the Special Specification after completion of compaction, and subsequently only that traffic necessary for construction of the next layer will be permitted on the treated layer.

SECTION 16

BITUMINOUS SURFACE TREATMENTS AND SURFACE DRESSINGS

CONTENTS

TABLES

16. BITUMINOUS SURFACE TREATMENTS

16.1. Scope

This section comprises all of the general requirements for bituminous binders and aggregate for bituminous surface treatments. The design and construction of surface treatments shall comply with the current version of the Ministry of Transportation Surface Dressing Manual.

16.2. General

16.2.1 Equipment

The Contractor shall submit to the Engineer full details of the plant that he proposes to use and the procedures he proposes to adopt for carrying out the construction of surface treatments.

All construction plant shall be so designed and operated as to produce surface treatments complying with the requirements of this Specification. The plant and equipment used shall be of adequate rated capacity, in good working order and subject to the approval of the Engineer. Obsolete or worn out plant will not be allowed on site. All plant and equipment operated on the road during sealing shall be free from any binder, fuel or oil leaks and no refuelling or servicing of any equipment shall be allowed to take place while such equipment is on the road.

Prior to the start of the work the Contractor shall supply the Engineer with copies of the manufacturer's handbooks and check lists pertaining to the equipment, containing details of the correct settings and adjustments of the equipment.

The Engineer shall have access at all times to the equipment for the purposes of inspection. The Contractor shall carry out regular calibration checks in the presence of the Engineer and shall immediately correct any faults that are found.

Any alteration that has been or is being effected to any construction plant, and which does not comply with the specifications of the manufacturer, shall be brought to the attention of the Engineer.

The Contractor shall not commence work on the surfacing until he has obtained the Engineer's approval of the plant and methods that he proposes using.

16.2.2 Bituminous Materials

Bituminous binders shall comply with the following:

(a) General

Before any bituminous binder is delivered to the site, the Contractor shall provide the Engineer with certification from the manufacturer that the material to be supplied complies in all respects with the relevant specification.

(b) Straight-run bitumen

Straight-run bitumens shall comply with all of the requirements given in Table 16.1.

Table 16.1: Properties of bitumen viscosity graded at 60°C (ASTM D 3381)

Test	AC-10	AC-20
Viscosity 60°C (Poise)	1 000 ± 200	2 000 ± 400
Viscosity, 135°C (min, cSt)	150	210
Penetration, 25°C, 100g 5 s, min	70	40
Flash point Cleveland open cup, (min °C)	219	232
Solubility in Trichloroethylene (min %)	99.0	99.0
Tests on residue from thin film oven test		
Viscosity, 60°C, max, P	5 000	10 000
Ductility, 25°C, 5 cm/min, cm	50	20

(c) Cutback bitumen

Rapid-curing cutbacks shall comply with all of the requirements of AASHTO M 81 (ASTM D 2028).

Medium-curing cutbacks shall comply with all of the requirements of AASHTO M 82 (ASTM D 2027).

Slow curing cutbacks shall comply with all of the requirements of ASTM D 2026.

Cutback bitumens shall be graded either by viscosity or penetration, the approximate equivalents and typical applications being summarised in Table 16.2.

Table 16.2: Grades of cutback bitumen

Application	Classification grade	ASTM/AASHTO grade	Viscosity (cSt)	% cutter (kerosene) by volume
Priming	AMC00	-	8-20	56
	AMC0	MC30	30-60	44
	AMC1	MC70	70-140	34
Primerseal	AMC2	MC250	250-500	27
	AMC3	MC800	500-1 500	21
	AMC4		1 500-5 000	16
Seal	AMC5	MC3000	5 000-12 000	11
	AMC6		12 000-32 000	7
	AMC7			3

(d) Bitumen emulsion

Bitumen emulsions shall comply with all of the requirements of ASTM D 977 (anionic) and D2397 (cationic).

(e) Non-homogeneous (heterogeneous) modified binders
Bitumen-rubber binder shall comply with the following requirements:

(i) Base bitumen
The bituminous binder used in the production of the bitumen-rubber shall be an AC-10 or AC-20 grade bitumen that complies with the requirements of ASTM D 3381 or equivalent, or a blend of the two grades to provide a product with the viscosity properties specified in the Special Specification.

(ii) Rubber
The rubber shall be crumbs obtained by processing and recycling pneumatic tyres. It shall be pulverized with a maximum size of 1.18 mm and not more than 5% finer than 0.075 mm, free from fabric, steel cord and other contaminants. A maximum of 4% by mass of fine particle size calcium carbonate, or talc, may be added to the rubber crumbs to prevent the rubber particles from sticking together.

(iii) Extender oils
The extender oil shall be a petroleum-derived material of high aromaticity and shall comply with the requirements of Table 16.3.

Table 16.3: Requirements of extender oils

Property	Requirements
Flash point	180 °C (min)
% by mass of saturated hydrocarbons	25% (max)
% by mass of aromatic unsaturated hydrocarbons	50% (min)

(iv) Diluent
The diluent shall be a distillate of hydrocarbon.

(v) Bitumen-rubber blend
The bitumen-rubber blend, including extender oil and/or diluent, if necessary, shall comply with the requirements of Table 16.4.

Table 16.4: Bitumen-rubber blend

Property	Requirements
% rubber by mass of total blend	20% - 24%
% extender oil by mass of total blend	6% (max)
% of diluent by mass of total blend	7% (max)
Blending/Reaction temperature	170°C - 210°C
Reaction time	0.5 - 2 hours

Prior to commencement of the work, the supplier shall state in writing the percentage of rubber and the blending/reaction temperature he intends to use for his specific product. The actual percentage of rubber shall not deviate by more than 1.0% from the stated value and the actual reaction temperature shall not deviate by more than 10% from the stated value.

A continuous record of both percentage rubber added and reaction temperatures shall be kept on site by the Contractor.

The bitumen-rubber binder shall comply with the requirements of the Special Specification.

The Contractor shall provide the Engineer with time-temperature ratios in regard to the properties of his specific product before work may start in order to determine the final process and the acceptance limits.

(f) Homogeneous cold applied modified binders

If any polymer other than the elastomer polymers styrenebutadiene rubber (SBR) or styrene-butadiene-styrene (SBS) is required for the manufacture of cationic modified bitumen emulsions it shall comply with the requirements in the Special Specification.

Where applicable the following details will be indicated in the Special Specification:

(i) Type elastomer polymer
SBR or SBS. Unless otherwise specified SBR shall be used for tender purposes.

(ii) Grade base bitumen
AC-10 viscosity graded bitumen. Unless otherwise specified AC-10 grade shall be used for tender purposes.

(iii) Modified binder content
65% or 70%. Unless otherwise specified 65% shall be used for tender purposes.

The aforementioned components together with polymer content will dictate the attributes attainable.

A volatile solvent flux content of up to 3% mass by mass of the bitumen may be added to enhance emulsion performance with regard to prevailing climatic conditions. Any expected change to specified values shall first be discussed with the Engineer prior to the addition of any such enhancer.

16.2.3 Testing of Bituminous Materials

All bituminous materials shall be tested in accordance with the requirements of Section 2.13 of the Specification.

The minimum pumping temperatures, the range of spraying temperatures and the maximum heating temperatures of cutbacks, viscosity graded bitumens AC-10 and AC-20 and emulsions are given in Table 16.5.

Table 16.5 - Binder Temperatures

Binder			Temperatures (degrees C)*			
			Minimum pumping	Spraying		Maximum heating
				Slot-jets	Atomizing jets	
Cutback		RC30	10	35 -45		50
Cutback		RC70	25	55-65	-	70
Cutback		RC250	45	80-90	-	90
Cutback		RC800	60	100- 115	-	120
Cutback		RC3000	80	125 - 135	-	135
Cutback	AMC0	MC30	10	35-45	50-60	55
Cutback	AMC1	MC70	25	55-65	70-85	80
Cutback	AMC2	MC250	45	80-90	90- 110	100
Cutback	AMC3	MC800	60	100- 115	120 - 135	115
Cutback	AMC5	MC3000	80	125 - 135	135 - 150	150
Bitumen		AC-10	105	155 - 165	160 - 170	190
Bitumen		AC-20	108	160 - 170	165 - 175	190
Emulsion**						

* These spraying temperatures are for guidance only, since the optimum spraying temperature depends on the temperature/viscosity relationship for bitumen.

** The minimum pumping and spraying temperatures for emulsions shall be in accordance with the manufacturer's recommendations

For slot-jets the viscosity for spraying shall be 70 to 100 centistokes and for atomizing jets 35 to 60 centistokes.

16.2.4 Bituminous Binder Storage and Handling

When carried in bulk containers, records of binder temperature and time shall be kept in a manner acceptable to the Engineer.

The bitumen storage area and heating station shall be kept neat and tidy. The storage area shall be cleared of vegetation and the drums stacked on their sides and only in small quantities with gaps between each stack to reduce fire risk. The storage area shall be compacted and surrounded by a retention wall in accordance with the Environmental Management Plan to prevent contamination of surrounding areas in the event of leakage or spillage.

All boilers, pre-heating pits, distributors, tools, and plant shall be kept scrupulously clean. When changing the grade of bitumen and at the end of each day's work, all boilers and distributors shall be thoroughly cleaned out with a solvent. The flushings from boilers and distributors shall not be poured over the area indiscriminately, but shall be led by drainage channels to lined disposal pits, care being taken that flushings do not find their way into stormwater ditches, streams or uncompacted areas outside the retention area. During heating, pumping, and spraying, the Contractor shall minimize spills and wastage. All spills and waste material shall be cleaned up immediately..

When filling the bitumen distributor from the boilers or bulk containers, the bitumen shall be passed through a filter of fine wire gauze.

Discarded bitumen drums shall be stored in a designated location and stacked in neat piles. Care shall be taken to ensure that any bitumen remaining in the drums does not leak out.

On completion of the Works, waste material shall be disposed of in an approved manner, and the disposal pits and drainage channels shall be filled in, topsoiled and the site left clean and tidy, all in accordance with the Environmental Management Plan.

16.2.5 Heating of Bituminous Binder

During storage, the temperature of the bituminous binder shall be kept as low as possible, consistent with reasonable pumpability.

The bituminous binder shall be heated in boilers or bulk storage containers, equipped with adequate pumps and accurate thermometers. Thermometers shall normally remain in the temperature wells of the bitumen containers and shall only be removed for checking or replacement. Binder shall not be heated when the level is below that recommended by the container manufacturer. Thermometers shall be checked against a suitable standard reference before initial use, at monthly intervals and at any time when their accuracy is suspect. No bitumen shall be heated in a boiler when the thermometer is broken or inaccurate.

In heating the binder to pumping temperature, the Contractor shall ensure that only appropriate heating equipment such as kerosene or diesel-fired heating unit is used. Under no circumstances shall the Contractor use wood or rubber tires as a source of fuel for bitumen heating.

No penetration grade bitumen, cutback bitumen, or emulsion shall be heated above the maximum temperature given above and any that is overheated shall be removed from the Site and disposed of by the Contractor in accordance with the requirements of the Environmental Management Plan. Cutback bitumen shall only be heated in distributors, while being circulated. Circulation shall continue for at least 20 minutes after the burners have been turned off.

The rates of application of binder specified or instructed by the Engineer refer to volumes of binder corrected to 15.6°C using the Standard Petroleum Measurement Table (ASTM D 1250).

16.2.6 Adhesion Agent

Where required, the adhesion agent shall be of an approved type and shall be used in accordance with the manufacturer's instructions. It shall be added to the bitumen in the sprayer and the mixture circulated at a rate of at least 700 ℓ/min for 20 minutes before spraying.

16.2.7 Construction Limitations

No bituminous construction work will be permitted in adverse weather conditions (rain, wind, etc.). Bitumen shall not be sprayed when the road surface temperature is below 15°C.

Bituminous material, except for bitumen emulsions and prime coats, shall not be applied on a damp surface.

16.2.8 Safety Precautions

The Contractor shall take every precaution to avoid fire or health hazards. He shall always ensure that:

(a) bitumen is heated only to the temperature required for the particular application;

(b) hot bitumen never comes into contact with water;

(c) suitable protective clothing and gloves are used when handling hot bitumen and working around hot bitumen;

(d) dust is reduced to a minimum;

(e) barrier boards and cones are provided to control traffic;

(f) pilot vehicles are used to control traffic speed;

(g) adequate advance warning signs are in place, and

(h) trained traffic controllers with Stop/Slow bats to control traffic are used.

16.3. Prime Coat and Tack Coat

16.3.1 Scope

This section covers the use of low viscosity bituminous binders as prime coats to absorbent non-bituminous surfaces and the light application of bituminous binders as tack coats to bituminous or concrete surfaces.

16.3.2 Materials for Prime Coat and Tack Coat

For prime coat, the binder shall be specified in the Special Specification and will generally be a medium-curing cutback AMC0 (MC30), AMC1 (MC70) or a slow setting cationic emulsion (CSS-1).

For tack coat, the binder shall be a penetration grade bitumen applied hot immediately prior to laying the bituminous mixture layer or where approved or specified by the Engineer, a rapid curing cutback or medium curing cutback applied at sufficient time before laying the bituminous mixture to allow the evaporation of the cutter (solvent); or a quick-breaking emulsion or slow-setting emulsion, applied a sufficient time before laying the bituminous mixture to allow the emulsion to break and the water to evaporate or run off.

Blinding material, if required, will be specified in the Special Specification and shall consist of fine aggregate, or sand, or crusher dust and shall contain not more than 15% retained on a 6.3 mm sieve.

16.3.3 Preparation of Surface

The surface to be sprayed shall be thoroughly cleaned by sweeping with mechanical and/or hand brooms and all soil and loose or foreign material on the surface shall be removed to produce a hard, dense and uniform textured surface to which the prime or tack coat will be applied.

The surface to be sprayed shall be checked for compliance with surface tolerances, camber and level and any portions that do not meet these requirements shall either be corrected or removed and reconstructed before any bituminous spray is applied. The Engineer's approval of the surface shall be obtained immediately prior to spraying.

Unless otherwise directed by the Engineer, immediately prior to the application of prime coat, the surface of the layer shall be lightly sprayed with water to give complete coverage of the layer, but in no case saturated.

16.3.4 Spraying of Prime Coat and Tack Coat

The quantity of binder used shall give complete coverage of the surface and shall be shown in the Special Specification or provided by the Engineer. Should the specified rate of spray appear to be incorrect, the Contractor shall immediately stop spraying, inform the Engineer and amend the spray rate as instructed.

Bitumen shall be sprayed from a pressure distributor conforming to the Specification (Subclause 16.4.6) and no handspraying shall be permitted except in small areas, or to make good a defective area caused by a blocked nozzle.

The nozzles shall be arranged to give a uniform spray and shall be tested prior to spraying by discharging on to suitable material (such as building paper, metal sheets, etc.,) or into purpose made troughs. Testing shall not take place on the road, and any bitumen spilt on the ground shall be cleaned off.

If during spraying a nozzle becomes blocked or develops a defect, the spraying shall be immediately stopped, any area incompletely sprayed shall be made good with a handspray, and the machine repaired before further spraying is commenced.

During spraying all kerbs, road furniture, culvert headwalls and tree boles that are liable to be disfigured by splashing of bitumen shall be protected.

16.3.5 Curing and Blinding of Prime Coat

If, after the application of the prime coat, the bitumen fails to penetrate within the time specified or if the road must be used by traffic, blinding material shall be spread in the amount required to absorb any excess bitumen and to protect the primed surface.

Blinding material shall be spread from trucks in such a manner that no wheel will travel on uncovered bituminous material. Unless the Engineer permits otherwise, all loose material on the sprayed surface, including any blinding material shall be removed before any further layer of the pavement is laid.

Traffic shall not be allowed on the prime coat before blinding is complete.

16.3.6 Tolerances

The rate of application of bituminous binder across the width of each spray run shall not vary by more than ± 5% of the rate approved. The average rate of binder for each single run of the spray truck shall be at least equal to the target application rate. Dips shall be taken before and after each run and the actual spray rate calculated and recorded. Tray tests should be taken at least once a day or every 3 000 m^2 during priming operations to check the calculations based on dipping of the spray trucks.

The edges of the sprayed surface shall be true to line with a maximum deviation of 25 mm from the specified edge line.

16.4. Surface Dressings

16.4.1 Scope

This section covers the application of bituminous binders and uniform sized chippings as primerseals and single or multiple surface dressings to newly constructed or existing road surfaces as described in the current version of the Ministry of Transportation Surface Dressing Manual. It also includes Emulsion slurry seals and graded Otta seals.

16.4.2 Materials for Surface Dressings

(a) Binder

The type of binder will be specified in the Special Specification and will generally be an AC-10, a suitable cationic rapid-curing emulsion such as CRS-1, CRS-2, a medium-curing cutback AMC5 (MC3000) or a penetration/cutback mixture blended to the approval of the Engineer. For primerseals, the binder shall be an AC-10 viscosity graded bitumen cut back with 16% kerosene cutter by volume.

(b) Chippings

(i) Hardness, soundness, shape and cleanliness

The chippings shall consist of crushed rock, cubical in shape and free from visible stone dust and harmful material such as clay, salt, organic matter or other deleterious substances. They shall be essentially single-sized and have the appropriate Average Least Dimension (ALD) and a good affinity for bitumen. The percentage passing the 0.075 sieve shall not exceed 0.5% by mass.

The chippings shall comply with the requirements given in Table 16.6, for the appropriate class as specified in the Special Specification. Material failing to comply with chipping class 4 shall be rejected.

Table 16.6: Characteristics of Aggregate for Chippings

Chipping Class	1	2	3	4
Heavy vehicles per day in one direction	300-750	150-300	25-150	0-25
LAA (%) max SSS (%) max FI max 10% Fines Min (dry) kN Wet/Dry % Stripping Test (ASTM D 4867) (%) max	25 12 25 210 75 5	27 12 25 210 75 5	30 12 25 210 75 5	35 12 25 210 75 5

(ii) Grading shall be as in Table 16.7.

Table 16.7: Grading of Aggregate for Chippings

Sieve Size (mm)	Percentage by mass passing				
	Nominal Sizes (mm)				
	20	14	10	7	5
26.5	100				
19.0	85 - 100	100			
13.2	0 - 30	95 - 100	100		
9.5	0 – 5	0 – 20	85 - 100	100	
6.7		0 -5	0 - 30	85 - 100	100
4.75		-	0 -5	0 - 30	85 - 100
2.36		-	-	0 - 10	0 - 30
1.18		0 -0.5	0 -0.5	0 -0.5	0 - 5

10 mm nominal size chippings will usually be specified for primerseals.

16.4.3 Rate of Application of Binder and Chippings

Nominal rates of spray of binder and spread of chippings shall be as set out in the Special Specification. Adjustments to these nominal rates may be made by the Engineer who will instruct the actual rates to be used. Table 16.8 provides a guide to typical rates.

Table 16.8: Spray and Spread Rates for Binder and Chippings

Stone Size (mm)	Binder (ℓ/m^2)	Chippings[a] m^2/m^3
5	0.6 - 1.1	200 – 250
7	0.7 – 1.2	160 – 180
10	0.8 - 1.4	120 - 140
14	0.9 - 1.6	90 - 110
20	1.1 - 1.9	70 - 85

a - The chipping spread rate depends on a number of factors, primarily the nominal size of the chippings, the average least dimension (ALD) of the stone and whether the seal is single or double. Typical spread rates would be between 800/ALD and 900/ALD.

Tray tests shall be carried out at least once per day or every 3 000 m^2 during surface dressing operations to check spray and spread rates calculated from spray truck dippings and chip-spreader coverage, and more frequently when a number of short lengths are being surface dressed. Spray truck dippings shall be taken before and after each spray run and chip-spreader coverage shall be checked each day chipping operations are in progress.

16.4.4 Crushing, Screening, Washing and Stockpiling Chippings

The construction plant provided and the methods of operating it shall be such as will produce chippings that meet the specified requirements of Clause 16.4.2(b). This may require washing the chippings to meet the cleanliness requirements.

The Contractor shall comply with Section 6 of this Specification when stockpiling chippings. If required, the stockpile area shall be surfaced with 100 mm thickness of gravel or other material, acceptable to the Engineer. Contaminated chippings shall not be used in the Works.

16.4.5 Precoated chippings

Where hydrophilic or other aggregates that may cause adhesion problems are used for sealing, precoating may be specified in the Special Specification or instructed by the Engineer. All aggregate shall be precoated for resealing works.

The amount and type of bituminous binder used to precoat chippings shall be specified in the Special Specification or shall be as instructed by the Engineer and will generally be a medium curing cutback AMC1 (MC30), a semi-stable or stable emulsion such as anionic MS-2 or SS-1 or cationic CMS-2 or CSS-1 or a mixture of diesel and AC-10 grade bitumen as directed by the Engineer.

Where practicable, precoating should be done by the quarry supplying the aggregate for the seal. The quarry would be required to apply the recommended precoat agent at the recommended application rate directly to the aggregate as it comes off the conveyor belts into certified stockpiles or into trucks for direct delivery to the Works. The spray nozzles shall be capable of uniformly coating the aggregate.

If this is not practicable, precoating shall be done on site. A suitable area shall be designated and compacted for precoating, and berms shall be constructed around the site to ensure precoating agent does not contaminate the environment. Precoating shall be carried out utilising a mixing machine approved by the Engineer, or else a payloader and bitumen distributor. The aggregate must be clean and dry with minimal dust. The aggregate shall be loaded into the bucket (of known volume) of the payloader and the precoating agent applied at the manufacturers recommended rate (usually 12 ℓ/m^3). The measured volume of precoating fluid shall then be sprayed evenly over the aggregate. A stockpile of the partially precoated aggregate shall be constructed and then turned over with the payloader until all aggregate is uniformly coated.

Precoating of chippings shall not be carried out when rain is imminent. If chippings have been precoated and rain appears imminent, the chippings shall be adequately covered to prevent the precoating material being washed from the chippings in the stockpile.

All access to the stockpile sites should be clean, hard and dry, with the capability to shed water away from the windrowed stockpiles.

The precoated chippings shall not be tacky and liable to agglomerate. The chippings precoated with cutback or emulsion shall be stockpiled for the time required for the solvents or water to evaporate.

The precoated chippings shall be kept free of contamination by dust or other deleterious matter. Stockpiles of precoated aggregate shall be covered until used for the seal. All precoated chippings shall be stockpiled for a minimum of 7 days before use.

16.4.6 Construction Plant for Surface Dressing

(a) Bitumen distributors

Bitumen distributors shall conform to ASTM D 5360 or BS 1707. They shall be truck mounted and shall have sufficient power to maintain uniform speeds for the accurate application of the binder. The truck shall be equipped with an accurate speedometer showing the drive and the speed in m/min.

The truck shall be fitted with a gauge bar and chain or any other acceptable device clearly visible to the driver to enable him to follow the required edge. The distributor tank shall have a capacity of at least 4 000 ℓ and shall be fitted with a dipstick and rear mounted float needle or device for indicating the quantity of bitumen in the tank at any time. It shall be equipped with heaters capable of maintaining temperatures up to 220°C and be fitted with an accurate calibrated thermometer.

The circulation system shall permit pumping around the tank and around the spray bar without actually spraying at a rate of at least 700 ℓ/min. Spray bars shall be available for spraying width varying as a minimum from 0.6 to 4.0 m and up to 9 m and shall be adjustable transversely so that the operator can follow the required edge independently. The pressure in the spray bar shall be sufficient to give a consistent and uniform distribution of binder.

Distributors shall be capable of applying bituminous binder within the limits of ±5% of the specified rate of application over any portion of the surface.

Distributors shall be checked and calibrated before starting any work or when required by the Engineer. This shall include the calibration of all the metering devices and checking the uniformity of the transverse distribution of spray.

All distributors shall carry in the cabin a “rate of spray/machine speed” chart calibrated within the last 12 months.

(b) Chip-spreaders

Mechanical chip-spreaders shall be self-propelled or attached to the back of tipper trucks operated by experienced drivers. They shall be capable of spreading the chippings uniformly over variable widths, from 0.5 to 3.5 m, at the rates specified. Spreading of chippings directly from tipper trucks shall not be permitted.

The number and output of chip-spreaders shall be sufficient to ensure that chippings are spread immediately after the bituminous binder has been applied.

Chip-spreaders shall be checked and calibrated before starting any work or when required by the Engineer.

(c) Rollers

The main rolling shall be carried out with self-propelled pneumatic tyred rollers, having an unballasted mass of about 7 tonnes and minimum tyre inflation pressures of 600 kPa. The tyres shall be smooth, of uniform size and diameter and individual tyres inflation pressures shall not differ by more than 35 kPa from one another.

Steel-wheeled rollers shall not be used without the approval of the Engineer.

The number and output of rollers shall be sufficient to ensure that rolling does not lag behind spreading. Two pneumatic tyred rollers shall be on site to allow for mechanical breakdown and to assist with backrolling. At least one roller is required for every 1500 m^2 of road sprayed.

(d) Miscellaneous equipment

Sufficient trucks and loading machinery shall be employed to ensure an adequate, prompt and continuous supply of chippings.

Rubber tyred mechanical rotary brooms towed by or mounted on rubber tyred vehicles shall be provided.

All labour working with or bitumen or on bitumen application equipment shall be provided with protective clothing and footwear.

16.4.7 Preparation of Surface

Immediately before spraying, all loose material and foreign matter shall be removed by thorough brushing with mechanical brooms and/or washing or other acceptable methods. All hardened mud or other foreign matter shall be loosened by scraping before sweeping. The debris shall be deposited well away from the surface to be sprayed.

Any defect of the surface shall be made good and no binder shall be sprayed until the surface has been approved by the Engineer. The Engineer's approval of the surface shall be obtained immediately prior to the start of spraying. Adequate advance notice shall be given to the Engineer before any seal work is commenced.

16.4.8 Application of Surface Dressing

Spraying of the binder shall normally cover one lane width so that construction traffic may run over the other lane.

Immediately after the binder at the required temperature has been sprayed, clean dry chippings shall be uniformly applied at the specified rate with as many mechanical chip-spreaders as necessary to match the rate of spraying. The chip-spreader shall be operated such that the tack coat will be covered with aggregate before the wheel of the chip-spreader or truck pass over the tack coat and aggregate. The elapsed time between the spraying of binder and the spreading of chippings shall in no case exceed one minute.

Should it become apparent that the supply of chippings is about to fail, the binder spraying shall be immediately stopped and shall not resume until an adequate supply of chippings is assured.

The correct rate of spread is generally assessed visually as providing complete coverage, with a film of binder still visible between the chippings. Should the coverage appear to be incorrect, the Contractor shall immediately inform the Engineer, who will amend the rate of spread accordingly. Any excess of chippings shall be removed by hand and any insufficiently chipped area shall be chipped over by hand, so that adequate coverage is obtained. Brooming of the material to effect redistribution of chippings will not be permitted.

Rolling shall begin immediately after the chippings have been spread and, in no case, later than two minutes after the application of binder. Rolling shall proceed from the shoulder inwards towards the centreline until the entire surface has been covered with one roller pass. Thereafter, rolling should continue by overlapping each preceding pass by about one third of the effective roller width ensuring that all sections are covered at least three times by the wheel of the roller.

After the bituminous binder has set up sufficiently to prevent any aggregate from being dislodged, the surface shall be slowly dragged with a broom drag to ensure even distribution of the aggregate. Areas deficient in aggregate shall be back-chipped by hand and any excessive aggregate shall be removed by hand so as to leave a uniform single layer of aggregate lying shoulder to shoulder. Rolling shall continue until all chippings are firmly embedded into the binder. The number of passes shall be agreed with the Engineer. Usually, each point shall receive at least 6 passes of the pneumatic tyred roller. Excessive rolling, resulting in the crushing of chippings, shall be avoided.

The roller speed shall not exceed 15 km/h.

Additional rolling on a previously completed section shall be given later in the heat of the day by pneumatic tyred rollers in tandem with steel wheeled rollers unless otherwise instructed by the Engineer.

The final surface shall be well knit and have a uniform appearance free of roller-tyre marks and loose aggregate: all aggregate contaminated by fuel, oil or grease shall be removed and replaced with clean aggregate.

16.4.9 Transverse joints

To prevent overlapping at joints of separate binder applications, the previous work shall be covered with a sufficient distance of protective covering to prevent binder application on the previous treated section. Operators shall ensure that the sprayer is operating at the required rate before the untreated surface is reached and the initial spray starts on the covering. The same method shall be used to ensure a neat joint at the end of each spray run.

16.4.10 Longitudinal joints

The spraying of adjacent runs shall overlap by 150 mm. Aggregate shall not be placed on the 150 mm overlaps before the adjacent strip has been sprayed. The adjacent strip shall not be sprayed before the preceding strip, excluding the 150 mm overlap has been covered satisfactorily with aggregate in accordance with the Specification. As far as is practicable, the

Contractor shall so place the strips that the joint between adjacent aggregate applications shall fall on the centreline or lane line of the road.

16.4.11 Aftercare and Control of Traffic

The road shall not be opened to traffic until the binder has attained sufficient viscosity to prevent the stones being whipped off. In all cases the Contractor shall seek approval from the Engineer when any seal layer is opened to public traffic.

The Contractor shall not allow any construction equipment likely to cause damage to use the completed seal.

The Contractor shall erect temporary restriction signs, barriers and removable bumps or any other device, as agreed with the Engineer, to discourage vehicles from travelling too fast over the newly laid surface dressing. Measures to limit vehicle speeds to a maximum of 30 km/h, shall be continued until there is sufficient adhesion to ensure that the chippings will not be dislodged by faster vehicles.

After traffic has been permitted to run on the surface dressing for a period of 24 hours and when instructed by the Engineer, all loose chippings shall be swept removed to a stockpile for reuse or spoil in accordance with the Environmental Management Plan. Windrows of loose chippings shall not be allowed to accumulate at the sides of the road.

16.4.12 Tolerances

The completed seal shall be free from any corrugations or any other wavy effects where depressions are preceded and followed by humps or ridges, no matter how small the distance between the top of the hump and the bottom of the preceding or following depression. No ridge shall be present along longitudinal joints as a result of the double application of binder and aggregate.

The final average overall width of the surface dressing measured at six equidistant points over a length of 100 m shall be at least equal to the width specified or instructed. At no point shall the distance between the centreline of the road and the edge of the surface dressing be narrower than that instructed by more than 13 mm and the maximum allowable deviation from the specified edge line shall not exceed 15 mm.

The rate of application of binder across the lane width shall not vary by more than ± 5% of the target rate and for each length of lane sprayed in a single pass the average rate of binder application shall be not less than 95% nor more than 105% of the rate ordered. Rates sprayed outside the allowable range are subject to rejection. At the discretion of the Engineer and under certain circumstances, nonconforming work may be accepted subject to reductions in the pay rate being applied.

The average rate of application of chippings along and across the lane width for each single pass of the chip-spreader shall not vary by more than ± 5% of the rate ordered.

16.4.13 Multiple Surface Dressing

Where further seals are to be applied, second and subsequent seals shall be applied immediately after the first seal. The nominal size of chippings in the first seal shall be provided in the Special Specification (usually either 20 or 14 mm) and the size of chippings in the second seal shall be half the size of those in the first seal, unless otherwise ordered by the Engineer. The general rate of application of chippings and binder shall be as ordered by the Engineer according to conditions on site.

Work shall be carried out in the following sequence:

i. Preparation by sweeping to ensure that pavement is clean and free from foreign bodies (Clause 16.4.7).
ii. Application of first layer of binder (Clause 16.4.8).
iii. Spreading of chippings at controlled rate, followed by compaction to refusal by rubber tyred rollers. Moderate use of smooth wheeled steel rollers may be permitted. (Clause 16.4.8).
iv. Immediately after full compaction, brushing off loose chippings. Brushing shall continue until all chippings in excess of one chip thickness are removed.
v. Application of second layer of binder (Clause 16.4.8).
vi. Spreading of second layer of chippings followed by compaction with rubber tyred rollers (Clause 16.4.8). Smooth wheeled steel rollers should not be used on second and subsequent dressings.
vii. Check tolerances in accordance with Clause 16.4.12.
viii. Open to traffic and control speed in accordance with Clause 16.4.11.
ix. Brush off loose chippings.

All new Primary, Major Secondary and Urban roads and existing bituminous roads to be resurfaced shall have a minimum of two coats of surface dressing.

16.5. Sand Seal

16.5.1 Scope

This section covers an application of bituminous binder covered with sand to form a seal.

16.5.2 Material for Sand Seal

(a) Binder

The binder shall be specified in the Special Specification or shall be as instructed by the Engineer and will generally be a medium-curing cutback AMC3 (MC800) or AMC5 (MC3000) or CRS-1 cationic emulsion.

(b) Aggregate

The aggregate shall consist of sand or fine screenings, free from organic matter, clay and other deleterious material. The fines (passing a 0.425 mm sieve) shall be non-plastic. The Sand Equivalent shall exceed 40.

The grading shall be as in Table 16.9.

Table 16.9: Grading of Sand for Sand Seals

Sieve size (mm)	% by mass passing
6.3	100
5	95 - 100
4	90 - 100
2	50 - 95
1	20 - 80
0.6	10 - 50
0.425	3 - 25
0.3	0 - 15
0.150	0 - 8
0.075	0 - 5

16.5.3 Rate of Application of Binder and Fine Aggregate

The rate of spray of binder and the rate of spread of the aggregate shall be as specified in the Special Specification or as instructed by the Engineer.

During the sand sealing operation tray tests to determine spray and spread rate shall be carried out at least once per day or every 3 000 m^2.

16.5.4 Construction

The surface to be covered shall be prepared in accordance with Clause 16.4.7.

The binder shall be uniformly sprayed at the specified rate. Clean dry fine aggregate shall be uniformly spread and rolled, all in accordance with Clause 16.4.8, except that the fine aggregate shall be spread in excess of that required to cover the binder. Only rubber tyred rollers shall be employed.

16.5.5 Aftercare and Control of Traffic

The road shall not be opened to traffic until the binder has attained sufficient viscosity to prevent dislodgement of the aggregate. When opened, measures to limit traffic speed shall be taken as per Clause 16.4.11 for as long as the Engineer may require.

Any whipped-off aggregate shall be broomed back onto the road, as many times as are necessary for it to adhere fully to the binder and to ensure that no areas show excessive bleeding.

If a second sand seal is prescribed, work should not commence until the road has been trafficked for eight weeks. All loose sand on the existing surface shall be removed and the application of binder and sand and after-care treatment repeated as described above.

16.5.6 Tolerances

Sand seal shall be constructed within the same width tolerance as given in Clause 16.4.12 for surface dressing.

The rate of application of binder and aggregate across the lane width shall not vary by more than ± 10% of the rate ordered. The average rate of application of binder for a single pass of the spray truck shall be not less than nor more than 20% of the rate ordered. The average rate of application of sand for a single pass of the spreader shall not vary by more than ± 10% of the rate ordered.

16.6. Otta Seal

16.6.1 Scope

This section covers the supply and application of Otta Seal surface treatment for maintenance or new construction using a crushed or natural material, and cover seals made of sand or crusher dust. This section also covers the application of a double Otta Seal.

16.6.2 Materials

(a) Binders

AC-5 viscosity graded bitumen or AMC5 (MC3000) cutback grade bitumen or AC-10 grade bitumen cut back on site as ordered by the Engineer, shall be used.

(b) Kerosene for cutting back bitumen

Kerosene shall be used as the cutter where correction of viscosity is required or cutback bitumen is made on site from penetration grade bitumen. Allowance shall be made for quantities between 0 – 25% by volume of the total quantity hot sprayed bitumen, as directed by the Engineer.

(c) Anti-stripping agent

When anti-stripping agent is required it shall be added to the bitumen immediately before the start of spraying operations and shall be circulated for a minimum period of 30 minutes prior to spraying. Anti-stripping agent that has been kept hot in the bitumen distributor for more than 5 hours shall be considered stale, and a further dosage amounting to half of the originally specified shall be added.

(d) Aggregate for Otta Seals

(i) Grading

The grading curve for the Otta Seal shall fall smoothly within the envelope detailed in Table 16.10. The upper nominal size shall not be larger than 16 mm, unless ordered by the Engineer to be 20 mm nominal size.

Table 16.10: Grading of Aggregates for Otta seal

Sieve size (mm)	Percentage by mass passing through sieve (%)
20	100
14	60-80
10	36-98
5	10-70
2	0-44
1.18	0-38
0.425	0-25
0.075	0-10

(ii) Aggregate strength

The minimum 10%Fines value of aggregate shall be 110 kN and the value after soaking for 24 hours shall not be less than 75% of the dry value. These values may be reduced to 90 kN and 60% respectively for use on roads with AADT less than 100, when approved by the Engineer.

(iii) Flakiness Index

If crushed material is used the Flakiness Index should not exceed 30.

(e) Sand for cover seals

The materials used can be crusher dust, river sand or other natural sand and shall be non-plastic, free from organic matter and lumps of clay. All the material shall pass the 6.3 mm sieve, unless otherwise approved by the Engineer.

16.6.3 Construction and aftercare

(a) General

This clause contains the procedures for the construction of Otta Seals and sand cover seals. The operations listed below are part of normal construction procedures for the seals and no additional payment will be made for any other operations.

(i) Granular base courses do not normally require a prime, unless otherwise specified in the Special Specification or directed by the Engineer. Porous base courses shall always be primed.

(ii) The sealed surface shall receive not less than 15 passes of a pneumatic tyred roller on the day of sealing. On the same day, the Engineer may direct one pass with a 10 – 12 ton tandem steel roller. During the following 2 days, the entire sealed area, including the shoulders, shall receive a further minimum of 15 passes daily, unless otherwise approved by the Engineer. A minimum of two pneumatic tyred rollers with a minimum mass of 12 tonnes shall be used for the rolling operations.

(iii) The Engineer may direct uniform trafficking of the surfaced area. Channelling of the traffic may be required for certain periods and traffic cones or similar may be necessary to enforce this.

(iv) The road should be opened to traffic immediately after the sealing operations are completed, but a maximum speed limit of 50 km/h shall be enforced during the initial 2 to 3 weeks after construction.

(v) Aggregate that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2 - 3 weeks, as directed by the Engineer.

(vi) After 2 - 3 weeks of trafficking the excess aggregate shall be swept off the road surface and the speed limitations can be lifted, unless otherwise directed by the Engineer.

If natural gravel is used with a fairly high content of fines, the period may be extended to 6 weeks or as directed by the Engineer.

(vii) A team shall be retained on site to deal with areas of bleeding if required. The team will be required during the normal construction period as well as during the first hot season following the completion of sealing operations. The Contractor's attention is drawn to the fact that any cost of mobilising and operating this team shall be included in the tendered rates.

(viii) A minimum period of 8 - 12 weeks should elapse between construction of the subsequent layers of the surfacing, and during that period the road should receive as much heavy trafficking as possible, unless otherwise directed by the Engineer.

(ix) Prior to applying subsequent seals, the surfaced area shall be broomed free of dust and loose stones or other foreign matter.

(x) The sand cover seal shall on the day of surfacing receive not less than 15 passes of a pneumatic tyred roller with a minimum mass of 12 tonnes.

(xi) Aggregate that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2 - 3 weeks as directed by the Engineer.

(b) Equipment
Plant and equipment required for the construction of Otta Seals, as specified above shall be readily available on site.

(c) Preparation of the surface
The requirements of Clause 16.4.7 shall apply.

(d) Application of surfacing
The binders of the type and grade required, and the aggregates of the size specified in the Special Specification or ordered by the Engineer, shall be applied in accordance with the provisions of Clause 16.2.2 and Section 2.

(e) Rates of application of material

(i) Binder for Otta Seal
All spray rates shall refer to hot spray rates of binder including any cutters and shall fall within the range 1.5 and 2.0 ℓ/m^2 per layer of Otta seal. For tender purposes a nominal rate of 1.7 ℓ/m^2 should be used, however, the actual spray rate shall be established on site for approval by the Engineer.

Absorbent aggregates with a water absorption of more than 2% shall require an additional 0.3 to 0.5 ℓ/m^2 (in total) for both layers, as directed by the Engineer.

(ii) Binder for sand cover seal
All spray rates refer to hot spray rates of binder including any cutters and shall fall within the range 0.6 and 0.9 ℓ/m^2 for sand cover seals. For tender purposes a nominal rate of 0.8 ℓ/m^2 should be used, however the actual spray rate shall be established on site for approval by the Engineer.

(iii) Anti-stripping agent
When required, the anti-stripping agent shall be mixed with the hot bitumen at 0.5% to 1.0% by mass of bitumen as directed by the Engineer.

(iv) Aggregate for Otta Seals
The aggregate application rates for Otta Seals shall be in the range 50 to 75 m^2/m^3 per layer. For tender purposes a nominal spread rate of 65 m^2/m^3 per layer should be used, however the actual spray rate shall be established on site for the approval of the Engineer.

(v) Aggregate for sand cover seals
The application rates of crusher dust or sand shall fall within the range 83 and 100 m^2/m^3 for sand cover seals. For tender purposes a nominal spread rate of 90 m^2/m^3 should be used, however the actual spray rate shall be established on site for the approval of the Engineer.

16.7. Emulsion Slurries

16.7.1 Scope

This section covers the application of a mixture of bitumen emulsion, fine aggregate, cement or lime and water prepared in a mixer and then spread on the road surface in the form of a slurry.

16.7.2 Materials for Slurries

(a) Emulsion

The emulsion shall be specified in the Special Specification or shall be as instructed by the Engineer and shall be either an anionic emulsion SS-1h or QS-1h (slow setting or rapid-setting, respectively) or a slow-acting cationic emulsion CSS-1h.

(b) Aggregate

The aggregate shall be free of organic matter, clay, silt or other deleterious matter. It shall have a Sand Equivalent of at least 40.

The grading curve shall be within one of the envelopes given in Table 16.11, as specified in the Special Specification:

Table 16.11: Grading of Aggregate for Emulsion Slurries

Sieve Size (mm)	Percentage by mass passing		
	Type I (Fine)	Type II (Normal)	Type III Coarse
10	-	-	100
6.3	-	100	80-95
5	-	90-100	70-90
2	100	60-87	40-65
1	60-85	40-67	25 - 45
0.425	30-48	22-38	15-28
0.3	25-42	18-30	12-25
0.150	15-30	10-20	7- 18
0.075	10-20	5- 15	5 - 15

(c) Cement/Lime

Cement and lime and the testing thereof shall comply with the requirements of Sections 2 and 14 of the Specification.

16.7.3 Preparation of the Slurry Mixture

The proportion by mass of dry aggregate emulsion and cement or lime shall be specified in the Special Specification. These shall be termed the nominal proportions of bitumen emulsion and cement or lime.

Water shall be added in sufficient quantity to obtain the correct slurry consistency acceptable to the Engineer.

A mixer of a type approved by the Engineer shall be provided in good working order capable of producing a uniform slurry of the constituent materials. It shall be either a batch or a continuous type mixer.

The mixing cycle shall be sufficient to produce a uniform coating of the aggregate and a uniform consistency of the slurry. It shall continue until the slurry mixture is discharged into the spreader box or onto the road surface. The entire batch shall be discarded if there is evidence that the emulsion has broken. The slurry, ready for application, shall be a smooth, free flowing mixture throughout.

16.7.4 Rate of Application of Slurry Mixture

The rate of application of the slurry mixture shall be as specified in the Special Specification or as instructed by the Engineer.

Tray tests shall be carried out at least once per day or every 3 000 m^2 during slurry seal operations.

16.7.5 Construction

Where a slurry seal is to be applied to a surface dressing the surface dressing shall be trafficked for a period of at least two weeks prior to application of the slurry.

The surface to be covered shall be prepared in accordance with Clause 16.4.7.

The slurry mixture shall be evenly spread at the specified rate by a slurry machine, except in restricted areas where hand spreading may be permitted.

The surface immediately ahead of the spreader shall be slightly dampened. Slurry seal shall be rolled with smooth tyred pneumatic rollers. Rolling shall commence as soon as the slurry has set sufficiently to ensure that no rutting or pick-up will occur. The number of passes shall be as agreed with the Engineer but usually each spot shall receive at least 6 passes of the pneumatic tyred roller.

The finished slurry shall be of uniform surface texture and colour throughout the work. The finished surface shall be free from blow-holes and irregularities.

Where a slurry seal is to be applied to a surface dressing, the slurry shall be struck off such that the tops of the stone chippings will be just visible after the emulsion has set and cured.

16.7.6 Curing and Control of Traffic

All traffic shall be kept off the slurry until it has cured to a firm condition that will prevent pick-up of the mixture. Where two applications of slurry are required, the initial treatment shall be cured thoroughly prior to placing the succeeding application.

16.7.7 Tolerances

Slurry shall be constructed within the same width tolerances given in Clause 16.4.12.

The rate of application of slurry across the width of a lane sealed in a single pass shall not vary by more than ± 10% of the rate ordered, and the average rate of application along the length of a single pass shall be not less than nor more than 15% of the rate ordered.

SECTION 17

BITUMINOUS MIX BASES, BINDER COURSES AND WEARING COURSES

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TABLES

17. BITUMINOUS MIX BASES, BINDER COURSES AND WEARING COURSES

17.1. Scope

This section covers different types of bituminous mixes for Base and Surfacing (Wearing and Binder Courses) and is divided into the following Sections.

Section 17.2	General
Section 17.3	Asphalt Concrete for Surfacing
Section 17.4	Dense Bitumen Macadam for Base
Section 17.5	Cold Asphalt for Surfacing, Base, Levelling Courses and Patching

17.2. General

17.2.1 Asphalt concrete mixtures

All asphalt concrete mixtures shall be designed according to either the Marshall or Super-Pave procedures as specified in the Special Specification.

17.2.2 Requirements from Other Sections

This Section shall be read in conjunction with:-

Section 2	Testing of Materials and Workmanship
Section 3	Setting Out and Geometric Tolerances
Section 6	Quarries, Borrow Pits, Stockpile and Spoil Areas
Section 16	Bituminous Surface Treatments and Surface Dressing

17.2.3 Equipment

(a) General

The Contractor shall submit to the Engineer full details of the construction plant that he proposes to use and the procedures he proposes to adopt for carrying out the manufacturing and laying of the asphalt.

All construction plant shall be so designed and operated as to produce asphalt complying with the requirements of this Specification. The plant and equipment used shall be of adequate rated capacity, in good working order and subject to the approval of the Engineer. Obsolete or worn out plant shall not be allowed on site. All plant and equipment operated on the road during sealing shall be free from any binder, fuel or oil leaks and no refuelling or servicing of any equipment shall be allowed to take place while such equipment is on the road.

Prior to the start of the work the Contractor shall supply the Engineer with copies of the manufacturer's handbooks and check lists pertaining to the mixing and paving plants, containing details of the correct settings and adjustments of the plant.

The Engineer shall have access at all times to construction plant for the purposes of inspection. The Contractor shall carry out regular calibration checks in the presence of the Engineer and shall correct forthwith any faults that are found.

Any alteration that has been or is being effected to any construction plant, and which does not comply with the specifications of the manufacturer, shall be brought to the attention of the Engineer.

The Contractor shall not commence work on the pavement or surfacing until he has obtained the Engineer's approval of the plant and method that he proposes for crushing, screening, mixing, transporting, paving and compaction as appropriate.

(b) Mixing plant

Bituminous materials shall be mixed in a plant complying with ASTM D 995 and shall be located on the Site unless otherwise approved by the Engineer. It shall be equipped with at least three bins for the storage of aggregates and a separate bin for Active Filler. All bins shall be covered to prevent the ingress of moisture.

The plant may be either the batch-mix type or the continuous-mix type and shall be capable of regulating the composition of the mixture to within the tolerances specified in Clause 17.2.15. The plant shall have a surge bin for storage.

In the case of a drum type mixer, the system shall control the cold feeding of each aggregate fraction and of the filler by mass, by means of a load cell or another device regulating the feed automatically, and by immediately correcting any variation in mass, which results from moisture or from any other cause. The cold feed shall be regulated automatically in regard to the binder feed so as to maintain the required mix proportions.

The bitumen tank shall be capable of maintaining its contents at the specified temperature within a tolerance of ±5°C and shall be equipped with a thermostat to prevent the temperature rising above 180°C and a fixed thermometer easily read from outside the tank. Any bitumen which has been heated above 180°C or has degraded from prolonged heating shall be removed from the plant and disposed of in accordance with the Environmental Management Plan.

(c) Laying plant

Bituminous materials shall be laid by a self propelled spreader and finisher equipped with a hopper, delivery augers and a heated adjustable vibrating screed. It shall be capable of laying bituminous materials with no segregation, dragging, or other defects and within the specified width, thickness, profile, camber and crossfall tolerances. Delivery augers shall terminate not more than 200 mm from the edge plates.

(d) Compaction plant

The Contractor shall provide sufficient rollers of adequate size and mass to achieve proper compaction in compliance with the Specification for surface finish and density. No leakages of any nature may occur in the rollers.

Prior to commencing the laying of bituminous mixes in the permanent Works the Contractor shall carry out site trials in accordance with Section 2 and Clause 17.2.5 of this Specification to demonstrate the adequacy of his plant and to determine the optimum method of use and sequence of operation of the rollers.

17.2.4 Design and Working Mixes

The Contractor shall design all of the bituminous mixes required for the base, binder courses and wearing courses so as to meet the strength and other requirements of the Specification. All ingredients used in the mixes shall comply with the Specification and shall have been approved by the Engineer.

At least two months prior to commencing construction, the Contractor shall demonstrate to the Engineer that he can meet the aggregate grading requirements of the Specification and submit samples of each aggregate fraction to the Engineer.

The Contractor shall then carry out laboratory tests in order to decide upon the proportions of each constituent of the initial design mix or mixes to be used for the site trials which shall be carried out in accordance with Clause 17.2.5 of the Specification.

The Contractor shall submit the proposed design mix at least 4 weeks prior to production to the Engineer for approval. Following the successful completion of the site trials, the Contractor shall submit the final mix design, referred to as the job mix formula, to the Engineer for approval and the Contractor shall maintain this composition within the tolerances given in Clause 17.2.15.

Should any changes occur in the nature or source of the constituent materials, the Contractor shall advise the Engineer immediately. The procedure set out above shall be followed in establishing the new mix design.

17.2.5 Site Trials

Full scale laying and compaction site trials shall be carried out by the Contractor on all asphalt pavement materials proposed for the Works using the construction plant and methods proposed by the Contractor. The trials shall be carried out with the approval and in the presence of the Engineer, at a location approved by the Engineer. The support conditions at the location where the trials will be carried out shall be made similar to the support conditions at the Works.

The trials shall be carried out to enable the Contractor to demonstrate the suitability of the mixing and compaction equipment to provide and compact the material to the specified voids content and to confirm that the other specified requirements of the completed asphalt pavement layer can be achieved.

For any specified compaction effort, each trial shall be at least 100 m long and to the full construction width and shall be laid to the depth specified for the material. It may form part of the Works provided it complies with the Specification.

The Contractor shall allow in his programme for conducting site trials and for carrying out the appropriate tests. The trial on any pavement layer shall be undertaken at least 21 days ahead of the Contractor proposing to commence full scale work on that layer.

The Contractor shall compact each section of trial over the range of compactive efforts the Contractor is proposing and the following data shall be recorded as a minimum for each level of compactive effort at each site trial:-

(i) The composition and grading of the material including the bitumen content and type and grade of bitumen used.

(ii) The temperature of the bitumen and aggregate immediately prior to entering the mixer, the temperature of the mix on discharge from the mixer and the temperature of the mix on commencement of laying, on commencement of compaction and on completion of compaction. The temperature of the mixture is to be measured in accordance with BS 598, Part 3, Appendix A.

(iii) The type, size, mass, width of roll, number of wheels, wheel load, tyre pressures, frequency of vibration and the number of passes of the compaction equipment, as appropriate for the type of roller.

(iv) The target voids and other target properties of the mix together with the results of the laboratory tests on the mix.

(v) The density and voids achieved.

(vi) The compacted thickness of the layer.

(vii) Any other relevant information as directed by the Engineer.

At least eight samples shall be tested jointly by the Contractor and the Engineer on each 100 m of trial for each level of compactive effort to verify the grading, binder content, density, volumetric properties and the compacted thickness of the layer (see Section 2.17.2), and provided each of the eight sets of results over the range of compactive effort proposed by the Contractor meets the specified requirements for the material then the site trial shall be deemed successful. The above data recorded in the trial shall become the agreed basis on which the particular material shall be provided and processed to achieve the specified requirements.

If, during the execution of the Works, the construction control tests indicate that the requirements for a material are not being consistently achieved, then work on that layer shall stop until the cause is investigated by the Contractor. Such investigation may include further laboratory tests and/or site trials on the material to determine a revised set of data as above which, when approved, shall be the basis on which all subsequent material will be provided and processed to achieve the specified requirements.

Approval by the Engineer of a set of data recorded in a site trial shall not relieve the Contractor of any responsibility to comply with the requirements of this Specification.

17.2.6 Weather conditions and moisture

Bituminous hot-mix may be mixed and placed only under favourable weather conditions and shall not be mixed or placed when rain is imminent or during misty or wet conditions.

The mixing and placing of bituminous hot-mix will not be allowed if free water is present on the working surface or if the moisture content of the underlying layer, in the opinion of the Engineer, is too high.

No bituminous hot-mix overlay shall be placed immediately after a rainy spell on an existing partly cracked and/or highly permeable surfacing resulting in the trapping of moisture in the pavement structure. A minimum delay of 24 hours or such extended periods as ordered by the Engineer shall apply.

17.2.7 Preparation of Surface

Immediately before placing the bituminous mix in the pavement, the existing surface shall be cleaned of all loose material and foreign matter with mechanical brooms or by other approved methods. The debris shall be deposited well clear of the surface to be covered.

Any defect of the surface shall be made good and no bituminous mix shall be laid until the surface has been approved by the Engineer.

Unless otherwise directed by the Engineer, a tack coat shall be applied to the surface prior to the application of the bituminous mix. The type of binder to be used for the tack coat and its rate of application will be as directed by the Engineer.

17.2.8 Mixing of Aggregates and Bitumen

The bitumen shall be heated so that it can be distributed uniformly and care shall be taken not to overheat it. The temperature shall never exceed 170°C for AC-20 viscosity graded bitumen.

The aggregates shall be dried and heated to the temperature determined in accordance with Clause 17.2.5 so that they are mixed at between 130 and 170℃ for AC-20 grade bitumen.

The dried aggregates shall be combined in the mixer in the amount of each fraction established from the laboratory tests and site trials and the bitumen shall then be introduced into the mixer. The materials shall then be mixed until a complete and uniform coating of the aggregate is obtained.

The mixing time shall be the shortest required to obtain a uniform mix and thorough coating. The wet mixing time (i.e. time required for mixing aggregates and bituminous binder) shall be determined by the Contractor and approved by the Engineer for each plant and for each type of aggregate used. It shall normally not exceed 60 seconds.

17.2.9 Transporting the Mixture

The bituminous mix shall be kept free of contamination and segregation during transportation. Each load shall be covered with canvas or similar covering to protect it from the weather and dust. On discharge into the spreader, the temperature of the mix shall be as determined under Clause 17.2.5.

17.2.10 Laying the Mixture

Immediately after the surface has been prepared and approved, the mixture shall be spread to line and level by the laying plant without segregation and dragging. Temperatures shall be in accordance with figures established under Clause 17.2.5.

The mixture shall be placed in widths of one traffic lane at a time, unless otherwise approved by the Engineer. The compacted thickness of any layer shall be at least 3 times the nominal maximum size of the aggregate for wearing course and at least 2.5 times for binder course. The minimum thickness shall be 25 mm.

Only on areas where irregularities or unavoidable obstacles make the use of mechanical laying impracticable, may the mixture be spread and compacted by hand.

17.2.11 Compaction

Immediately after the bituminous mixture has been spread, it shall be thoroughly and uniformly compacted by rolling, at the temperatures determined in accordance with Clause 17.2.5.

The layer shall be rolled when the mixture is in such a condition that rolling does not cause undue displacement or shoving.

The number, mass and type of rollers furnished shall be sufficient to obtain the required compaction while the mixture is in a workable condition. The sequence of rolling operations shall be as agreed with the Engineer during site trials.

Initial rolling with a steel tandem or three-wheeled roller shall follow the laying plant as closely as possible. The rollers shall be operated with the drive roll nearest the laying plant, at a slow and uniform speed (not exceeding 5 km/h).

Rolling shall normally commence from the outer edge and proceed longitudinally parallel to the centreline, each pass overlapping one half of the roller width. On superelevated curves, rolling shall begin at the low side and progress to the high side. Where laying is carried out in lanes care shall be taken to prevent water entrapment.

Intermediate rolling with a pneumatic tyred or vibratory roller shall follow immediately. Final rolling with a steel wheeled roller shall be used to eliminate marks from previous rolling.

The frequency as well as the amplitude of vibratory rollers shall be adjustable. Vibratory rollers shall be used only where there is no danger of damage being done to the asphalt, structures and other layers. The Engineer will decide whether vibratory compaction equipment may be used on bridge decks and what the constraining parameters will be.

To prevent adhesion of the mixture to the rollers, the wheels shall be kept lightly moistened with water.

In areas too small for the roller, a vibrating plate compactor or a hand tamper shall be used to achieve the specified compaction.

17.2.12 Finishing, Joints and Edges

Any mixture that becomes loose and broken, mixed with dirt or foreign matter or is in any way defective, shall be removed and replaced with fresh hot mixture, which shall be compacted to conform to the surrounding area.

Spreading of the mixture shall be as continuous as possible. Transverse joints shall be formed by cutting neatly in a straight line at right angles to the centreline across the previous run to expose the full depth of the course. The vertical face so formed shall be painted lightly with hot AC 10 or AC 20 viscosity graded bitumen just before the abutting layer is placed against it.

Longitudinal joints of the wearing course shall correspond with the lane markings, unless approved otherwise by the Engineer. Joints in lower layers shall be offset not less than 150 mm on either side of the edges of the traffic lanes. All longitudinal joints between adjacent sections of the Works shall be made by cutting back the layer against which the material of the adjacent layer is to be placed, unless instructed otherwise by the Engineer. A cutting wheel shall be used for cutting longitudinal joints.

Before a new layer is placed next to an existing layer, the cut edge of the existing layer shall be painted lightly with hot AC 10 or AC 20 viscosity graded bitumen or with a thin coat of bituminous emulsion of the same type used for the tack coat, if so directed by the Engineer. The mixture placed in the abutting lane shall then be tightly crowded against the face of the previously placed lane. The paver shall be positioned to spread material overlapping the joint face by 20 to 30 mm. Before rolling, the excess mixture shall be raked off and discarded. Waste material shall be disposed of in accordance with the Environmental Management Plan.

Any fresh mixture spread accidentally on the existing work at a joint shall be carefully removed by brooming it back onto the uncompacted work, so as to avoid formation of irregularities at the joint. The finish at joints shall comply with the surface requirements and shall present the same uniformity of finish, texture and density as other sections of the work.

The edges of the course shall be rolled concurrently with or immediately after the longitudinal joint. In rolling the edges, roller wheels shall extend 50 to 100 mm beyond the edge.

17.2.13 Sampling and Testing of Bituminous Mixtures

The sampling of bituminous mixtures shall be carried out in accordance with AASHTO T 168 (ASTM D 979) and tested against the approved test results of the site trials (Clause 17.2.5 of the Specification).

17.2.14 Quality Control Testing

During mixing and laying of bituminous mixtures, control tests on the constituents and on the mixed material shall be carried out in accordance with Clause 17.2.13 and Section 2 of the Specification.

If the results of any tests show that any of the constituent materials fail to comply with the Specification, the Contractor shall carry out whatever changes may be necessary to the materials or the source of supply to ensure compliance.

If the results of more than one test in ten on the mixed material show that the material fails to comply with the Specification, laying shall forthwith cease until the reason for the failure has been found and corrected. The Contractor shall remove any faulty material laid and replace it with material complying with the Specification. Faulty material shall be disposed of in accordance with the Environmental Management Plan.

To obtain cores, the Contractor shall supply, maintain and operate a diamond tipped core drill (with the diamonds surface set in the core bit) capable of cutting the cored samples with clean edges and without disturbing the rest of the layer. The cores shall be 100 mm in diameter for the wearing course and binder course, and 150 mm in diameter for dense bituminous macadam.

The Contractor shall supply cooling water for the core bit (preferably containing 0.5% of detergent to act as a parting fluid) and shall take care, when recovering the cores, to avoid distortion or disintegration of the samples.

Core holes shall be properly backfilled with bituminous mixture, after painting the sides of the core holes with cutback bitumen, and compacted in layers not exceeding 30 mm in thickness until the surface of the compacted layer in the core holes is slightly above the level of the surrounding area. Final compaction of the material in the core hole shall be by a steel wheel roller.

17.2.15 Tolerances

Surfacing courses and base layers shall be constructed within the geometric tolerances specified in Section 3 of this Specification.

The Contractor shall maintain the composition of the mixture as determined from the laboratory and site trials within the following tolerances, per lot consisting of a minimum of 4 tests for binder content and 6 tests for aggregate grading:

Bitumen Content:	± 0.3%	(by total mass of total mix)
Passing 10mm and larger sieves	± 5%	(by total mass of dry aggregate including mineral filler)
Passing sieves between 10 and 1.0 mm	± 4%	(by total mass of dry aggregate including mineral filler)
Passing sieves between 1.0 and 0.075 mm	± 3%	(by total mass of dry aggregate including mineral filler)
Passing 0.075mm sieve:	± 2%	(by total mass of dry aggregate including mineral filler)

The average amount of bitumen in any length of any layer, calculated as the product of the bitumen contents obtained from single tests and the mass of mixture represented by each test, shall not be less than the amount ordered.

The average amount of bitumen for each day's production calculated from the checked masses of mixes shall not be less than the amount ordered.

The final average overall width of the upper surface of a bituminous mix layer measured at six equidistant points over a length of 100 m shall be at least equal to the width specified. At no point shall the distance between the centreline of the road and the edge of the upper surface of a bituminous mix layer be narrower than that specified by more than 13 mm.

17.3. Asphalt Concrete for Surfacing

17.3.1 Scope

This section covers asphalt concrete, defined as a thoroughly controlled, hot plant-mixed, hot-laid, mixture of well-graded dried aggregate and viscosity grade bitumen, which, when compacted on the approved prepared foundation, base course or existing surface, forms a dense material. Asphalt concrete can be applied as surfacing (binder course and wearing course) on all Primary, Major Secondary and Urban roads receiving asphalt concrete surfacing.

A distinction is drawn between asphalt concrete Type 1 (High Stability) and asphalt concrete Type II (Flexible). The asphalt concrete type will be specified in the Special Specification.

17.3.2 Materials for Asphalt Concrete

(a) The bituminous binder shall be an AC-20 viscosity graded bitumen, or a modified binder as specified by the Engineer in the Special Specifications.

(b) Aggregate

Coarse aggregate (retained on a 4.75 mm sieve) shall consist of crushed stone free from clay, silt, organic matter and other deleterious substances. The aggregate class will be specified in the Special Specification and shall comply with the requirements given in Table 17.1. Material inferior to Class C shall be rejected.

Table 17.1 - Characteristics of Coarse Aggregate for Asphalt Concrete

Coarse Aggregate (retained on a 4.75 mm sieve)				
Aggregate Class		A	B	C
LAA	Max	30	35	40
FI	Max	20	20	25
10% Fines Dry (kN)	Min	160	160	160
Wet : Dry ratio %	Min	75	75	75
Water absorption (%) (coarse aggregate)	Max	1.0	1.0	1.0

For asphalt concrete Type I and Type II, the coarse aggregate shall be entirely crushed with at least 95% of all particles having at least three fractured faces, unless specified otherwise by the Engineer.

Fine aggregate (passing a 4.75 mm sieve) shall be free from clay, silt, organic and other deleterious matter and shall be non-plastic. Unless otherwise specified in the Special Specification it shall consist entirely of crushed rock produced from stone having a Los Angeles Abrasion of not more than 40%. The Sand Equivalent of the fine aggregate shall not be less than 40.

If approved by the Engineer and if the specified requirements are met, the aggregate component may contain natural sand not obtained from the parent rock being crushed, on condition that such added material does not exceed 10% by mass, unless otherwise specified in the Special Specifications. The added sand shall have a liquid limit not more than 25% and a PI not more than 6.

(c) Mineral Filler

If the grading of the combined aggregates for asphalt concrete mixes show a deficiency in fines, an appropriate filler may be used to improve the grading. Filler may consist of active filler as defined hereinafter or of inert material such as rock dust having the required grading necessary to improve the grading of the combined aggregates. In no instance shall more than 1% by mass of active filler be used in asphalt concrete, unless specified otherwise in the Special Specification. Inert filler such as rock dust used to improve grading shall not be subject to this limitation.

An active filler shall be used to improve the adhesion properties of the aggregate. Active filler shall consist of hydrated lime unless specified otherwise in the Special Specification. The active filler shall be thoroughly dry and free from lumps and at least 75% (by mass) shall pass a 0.075 mm sieve and 100% shall pass a 0.425 mm sieve. The active filler shall have a bulk density in toluene of between 0.5 and 0.9 g/mℓ. The voids in dry compacted filler shall be between 0.3% and 0.5%, when tested in accordance with BS 812-2.

(d) Superpave Aggregate Requirements

The Engineer may order in the Special Specification for the aggregates to comply with the Superpave aggregate requirements. Tentative Superpave requirements are given in Table 17.2. The Engineer shall ensure that the latest available and appropriate Superpave requirements are specified in the Special Specification.

Table 17.2 – Tentative Superpave mixture Aggregate Requirements

Aggregate Blend Property	20-year Design ESALs			
	<1 million	1 – 3 million	3 – 10 million	10 – 30 million
Coarse Aggregate Angularity (CAA), (ASTM D 5821) (min) (1 face / 2 face), % - wearing course (1 face / 2 face), % - non wearing course	55 / - 50 / -	75 / - 55 / -	85 / 80 60 / -	95 / 90 80 / 75
Fine Aggregate Angularity (FAA) (AASHTO T 304, Method A) min % - wearing course min % - non wearing course	40 40	42 40	44 40	45 40
Flat and Elongated Particles (ASTM D 4791) max % by weight	-	(5:1 ratio) 10	(5:1 ratio) 10	(5:1 ratio) 10
Sand Eqiovalent (AASHTO T 176) (min)	-	-	45	45

17.3.3 Grading Requirements

The coarse and fine aggregate shall be combined in such proportions to produce an asphalt concrete mixture meeting all the requirements defined in this Specification and shall be within and approximately parallel to one of the grading envelopes given in Table 17.3, as specified in the Special Specification. Alternatively, the Engineer may specify that the asphalt concrete mixture shall comply with the Superpave requirements, the broad-band aggregate gradings of which are given in Table 17.4.

Table 17.3 – Grading Requirements for Asphalt Concrete

Sieve Size (mm)	Percentage by Mass Passing							
	Type I						Type II	
	Wearing Course			Binder Course			Wearing Course	
	0/14	0/10	0/6	0/20	0/14	0/10	0/14	0/10
28	-	-	-	100	-	-	-	-
20	100	-	-	90 – 100	100	-	100	-
14	90 – 100	100	-	75 – 95	90 – 100	100	90 – 100	100
10	70 – 90	90 – 100	100	60 – 82	70 – 90	90 - 100	70 – 95	90 – 100
6.3	55 – 75	60 – 82	90 - 100	47 – 68	52 – 75	60 – 82	55 – 85	62 – 90
4	45 – 63	47 – 67	75 – 95	37 – 57	40 – 60	45 – 65	46 – 75	50 – 80
2	33 – 48	33 – 50	50 – 70	25 – 43	30 – 45	30 – 47	35 – 60	35 – 65
1	23 – 38	23 – 38	33 - 50	18 – 32	20 – 35	20 – 35	25 – 45	25 – 50
0.425	14 – 25	14 – 25	20 – 33	11 – 22	12 – 24	12 – 24	14 – 32	14 – 33
0.300	12 – 22	12 – 22	16 – 28	9 – 17	10 – 20	10 – 20	11 – 27	11 – 27
0.150	8 – 16	8 – 16	10 – 20	5 – 12	6 – 14	6 – 14	6 – 17	6 – 17
0.075	5 – 10	5 – 10	6 – 12	3 – 7	4 – 8	4 – 8	3 – 8	3 – 8

Table 17.4 – Aggregate Gradation Broad Bands for Asphalt Concrete (Superpave)

Sieve Size (mm)	Percentage by Mass Passing		
	Type A	Type B	Type C
25			100
19		100	90 – 100
12.5	100	90 – 100	– 90
9.5	90 – 100	– 90	–
4.75	– 90	–	–
2.36	32 – 67	28 – 58	23 – 49
0.075	2 – 10	2 – 10	2 – 8

17.3.4 Requirements for Asphalt Concrete

The Engineer shall decide whether the mixture shall be designed in accordance with the Marshall mixture design method or the Superpave gyratory method.

It is the Contractor's responsibility to design a Marshall mixture in accordance with the most current AASHTO T 245 and the Asphalt Institute's Mix Design Methods for Asphalt Concrete MS-2 such that it meets the requirements of Tables 17.5 and 17.6 as specified in the Special Specification.

It is the Contractor's responsibility to design a gyratory mixture in accordance with the most current AASHTO T 312 and the Asphalt Institute's Superpave Mix Design Manual SP-2 (2 - hour short term ageing period is used for volumetric) such that it meets the tentative gyratory mixture requirements of Table 17.7, as specified in the Special Specifications. The Engineer shall ensure that the latest available and appropriate gyratory mixture requirements are specified in the Special Specification.

The proportion, by mass of total mixture, of bitumen shall be stated in the Special Specification. This shall be termed the nominal binder content. The binder content of the working mix will be agreed with the Engineer following laboratory tests and site trials.

Table 17.5 - Test Requirements for Asphalt Concrete (Marshall Mixture Design Method)

Asphalt Concrete	Type I Wearing Course	Type I Binder Course	Type II Wearing Course
Marshal Stability (2 x 75 blow) (kN) Marshall Flow Value (mm) Voids in total mix (%)	9 - 18 2-4 3-5	8.2 - 18 2-4 3 -5	8.2 - 18 3-5 3-5
Voids filled with binder (%)	65-75	65-75	70-80

Table 17.6 - Minimum Percent Voids in Mineral Aggregate (VMA)

Nominal Max. Particle Size (mm)[1]	Minimum VMA for Design Air Voids[2]		
	3.0%	4.0%	5.0%
1.18	21.5	22.5	23.5
2.36	19.0	20.0	21.0
4.75	16.0	17.0	18.0
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0
50	9.5	10.5	11.5
63	9.0	10.0	11.0

1: The nominal maximum particle size is one size larger than the first sieve to retain more than 10%

2 : Interpolate minimum voids in the mineral aggregate (VMA) for design air void values between those listed

Table 17.7 – Mixture Requirements (Gyratory Mixture Design)

Gyratory Mixture Requirements	20-year Design ESALs			
	< 1 million	1 – 3 million	3 – 10 million	10 – 30 million
Gyrations for $N_{initial}$	6	7	8	8
Gyrations for N_{design}	50	75	90	100
Gyrations for $N_{maximum}$	75	115	140	160
%Air Voids at N_{design}				
- wearing course	4.0	4.0	4.0	4.0
- non wearing course	3.5	3.5	3.5	3.5
% G_{mm} at $N_{initial}$				
- wearing course	-	≤ 91.5	≤ 90.5	≤ 90.0
- non wearing course	-	≤ 92.5	≤ 91.5	≤ 91.0
% G_{mm} at $N_{maximum}$				
- wearing course	≤ 98.0	≤ 98.0	≤ 98.0	≤ 98.0
- non wearing course	≤ 98.0	≤ 98.0	≤ 98.0	≤ 98.0
Voids filled with binder (VFB), %				
- wearing course	65 – 78	65 – 78	65 – 75	65 – 75
- non wearing course	70 – 80	65 – 78	65 – 75	65 – 75
Filler-to-binder ratio	0.6 – 1.6	0.6 – 1.6	0.6 – 1.6	0.6 – 1.6

17.3.5 Mixing and Laying Asphalt Concrete

The temperature of AC-20 viscosity graded bitumen when mixed with the aggregate shall be between 150°C and 170°C.

The minimum temperature of the mixture at the commencement of compaction shall be 130°C when AC-20 viscosity graded bitumen is used. The minimum temperature at completion of compaction shall be 100°C when AC-20 viscosity graded bitumen is used.

17.3.6 Compaction

The completed layer shall have a density as measured on recovered cores equal to or greater than 93% of the maximum specific gravity (G_{mm}) based on the individual lot. The maximum specific gravity value used to calculate the percentage density for the lot shall be the average value obtained from the maximum specific gravity results from at least three production tests taken during that day's paving.

17.4. Dense Bitumen Macadam for Base

17.4.1 Scope

This section covers dense bitumen macadam, defined as hot-mixed, hot-laid plant mixture of well graded aggregate and viscosity grade bitumen.

17.4.2 Material Requirements

(a) Viscosity grade bitumen

Bitumen shall be either AC-20 viscosity graded bitumen, unless otherwise specified in the Special Specification or instructed by the Engineer.

(b) Aggregate

Coarse aggregate (retained on a 4.75 mm sieve) shall consist of crushed stone produced from rock or boulders, the minimum size of which is at least 4 times the maximum size of the final crushed stone. The coarse aggregate shall be free from clay, silt, organic matter and other deleterious substances and shall comply with the following requirements:-

LAA	Max 35%
FI	Max 25
10% Fines Dry (kN)	Min 160 kN
Wet/Dry %	Min 75

Fine aggregate (passing a 4.75 mm sieve) shall be free from clay, silt, organic and other deleterious matter. Unless otherwise specified in the Special Specification it shall consist of entirely crushed rock produced from stone having a Los Angeles Abrasion loss of not more than 40%. The Sand Equivalent of the fine aggregate shall be not less than 40.

(c) Mineral filler

An active filler shall be used to improve the adhesion properties of the aggregate. Active filler shall consist of hydrated lime, unless specified otherwise in the Special Specification. The active filler shall be thoroughly dry and free from lumps and at least 75% (by mass) shall pass a 0.075 mm sieve and 100% shall pass a 0.425 mm sieve. The active filler shall have a bulk density in toluene of between 0.5 and 0.9 g/mℓ. The voids in dry compacted filler shall be between 0.3% and 0.5%, when tested in accordance with BS 812-2.

17.4.3 Grading Requirements for Dense Bitumen Macadam

The grading of the mixture of coarse and fine aggregate shall be within and approximately parallel to one of the grading envelopes given in Table 17.8, as specified in the Special Specification:

Table 17.8: Aggregate Gradings for Dense Bitumen Macadam

Sieve Size (mm)	% by mass passing:	
	0/40	0/30
50	100	-
37.5	90 - 100	100
28	75 - 95	90 - 100
20	60 - 90	65 - 95
14	50 - 75	55 - 80
6.3	30 - 55	35 - 60
2	18 - 38	20 - 40
1	12 - 30	15 - 30
0.300	6 - 20	8 - 20
0.150	4 - 15	5 - 15
0.075	2 - 8	3 - 8

17.4.4 Requirements for Dense Bitumen Macadam

The mixture shall comply with the appropriate requirements given in Table 17.9 and as stated in the Special Specification.

The proportion, by mass of total mix, of bitumen shall be as stated in the Special Specification. This shall be termed the nominal binder content. The binder content of the working mix will be instructed by the Engineer following laboratory tests and site trials.

Table 17.9: Test Requirements for Dense Bitumen Macadam

Property	0/40	0/30
Marshal Stability (2 x 75 blows) kN	8.2 - 18	8.2 - 18
Marshall Flow Value (mm)	2-4	2-4
Voids in total mix (%)	4-8	4-8
Loss of Stability after soaking (ASTM D 1075) as % of unsoaked value (max)	35	35

The temperature of the freshly mixed dense bitumen macadam shall be between 150°C and 170°C when AC-20 bitumen is used. The minimum temperature at laying and commencement of compaction shall be 130°C when AC-20 bitumen is used.

The requirements regarding laying specified in Clause 17.2.10 shall be modified as follows:

Laying plant capable of spreading the mixture over the full carriageway width shall be used as much as possible, otherwise the longitudinal joint shall be compacted before the temperature of the existing lane has dropped to 90°C where AC-20 bitumen is used. This temperature limitation requires the use of at least two mechanical pavers working in echelon.

The minimum thickness of the compacted layer shall be 70 mm when 0/30 aggregate is used and 100 mm when 0/40 mm is used. No compacted layer shall exceed 150 mm thickness.

17.4.5 Compaction

Rolling shall be continued until the voids measured in the completed layer are within the appropriate specified voids range given in Table 17.9.

17.4.6 Sealing of Dense Bitumen Macadam Base

Bitumen macadam base course shall be sealed by applying the wearing course or surface dressing specified within two weeks of completing any section of base course.

17.5. Cold Asphalt for Surfacing, Base, Levelling and Patching

17.5.1 Scope

This section covers cold asphalt defined as a hot or cold-mixed, cold-laid plant mixture of graded aggregate and bituminous binder.

17.5.2 Materials for Cold Asphalt

(a) Bituminous binder

For cold asphalt to be used immediately, the bituminous binder shall be a medium-curing cutback AMC2 (MC 250), AMC3 (MC 800) or AMC5 (MC3000), or a cationic or anionic premix grade (medium-setting, CMS-2, MS-1 or MS-2) or stable grade (slow-setting, CSS-1 or SS-1) emulsion, as specified in the Special Specification or as instructed by the Engineer.

For cold asphalt to be stockpiled, the bituminous binder shall be a medium-curing cutback AMC2 (MC 250) or AMC3 (MC 800) or a slow-curing cutback SC 250 or SC 800 or a slow-setting cationic (CSS-1) or anionic (SS-1) emulsion, as specified in the Special Specification or as instructed by the Engineer.

(b) Aggregates

Coarse aggregate (retained on a 4.75 mm sieve) shall consist of crushed stone produced from rock or boulders the minimum size of which is at least 4 times the maximum size of the final crushed stone. The coarse aggregate shall be free from clay, silt, organic matter and other deleterious substances. The aggregate class will be specified in the Special Specification and shall comply with the requirements given in Table 17.10 as appropriate. Material failing to comply with requirements of Class C shall be rejected.

Table 17.10: Aggregate Characteristics for Cold Asphalt

Coarse Aggregate (greater than 4.75 mm)				
Aggregate Class		A	B	C
LAA	Max	30	35	40
FI	Max	20	25	30
10% Fines Dry (kN)	Min	160	160	160
Wet/Dry ratio	Min	75	75	75

The fine aggregate (passing a 4.75 mm sieve) shall be free from clay, silt, organic and other deleterious matter. Unless otherwise specified in the Special Specification it shall consist of entirely crushed rock produced from stone having a Los Angeles Abrasion of not more than 40%. The Sand Equivalent of the fine aggregate shall be not less than 40.

(c) Mineral filler

The mineral filler shall consist of finely ground particles of limestone, hydrated lime, Portland Cement or other non-plastic mineral matter. The types and quantities of the mineral filler shall be specified in the Special Specification. Active filler shall be thoroughly dry and free from lumps. At least 75% (by mass) shall pass a 0.075 mm sieve and 100% shall pass a 0.425 mm sieve. The active filler shall have a bulk density in toluene between 0.5 and 0.9 g/mℓ.

17.5.3 Grading Requirements for Cold Asphalt

The mixture of aggregates shall be within and approximately parallel to the grading envelope specified in the Special Specification or as instructed by the Engineer.

17.5.4 Requirements for Cold Asphalt

The density and stability of the cold asphalt shall be as specified in the Special Specification or as instructed by the Engineer.

The proportion, by mass of total mix, of bitumen shall be stated in the Special Specification. This shall be termed the nominal binder content. The binder content of the working mix will be instructed by the Engineer following laboratory tests and site trials.

17.5.5 Mixing and Laying Cold Asphalt

When bitumen emulsion is used as the binder, heating and drying of aggregates and heating of the binder are not required. The moisture content of the mixture shall be adjusted in the mixing plant to permit optimum compaction. The aggregate shall have a moisture content in the range 3% to 5% at the time the emulsion is added.

When cutback bitumen is used as the binder the requirements of Clause 17.2.8 shall apply but with the temperature limitations given in Table 17.11.

Table 17.11: Temperature Limitations for Binder

Cutback	Mixing	Heating (Max)
MC and SC 250	55 - 80°C	100°C
MC and SC 800	70 - 100°C	125°C
MC3000	90 - 120°C	140°C

The aggregates shall be dried and heated so that they are mixed at the following temperatures:

60 - 90°C when MC or SC250 is used
75 - 115°C when MC or SC800 is used
90 - 130°C when MC3000 is used.

Cold asphalt may be placed at ambient temperature and may be laid by grader, provided the Contractor can demonstrate in the site trials that he can achieve the geometric tolerances for the base with this method.

17.5.6 Compaction

The average density of the 100 mm diameter cores cut from the cold asphalt shall not be less than 98% of the average density obtained from Marshall specimens (2 x 50 blows) made during laboratory tests on the mixture used for site trials. No individual density shall be below 95% of the average of the laboratory specimens.

SECTION 18

CONCRETE WORKS

CONTENTS

TABLES

18. CONCRETE WORKS

18.1. Scope

This section covers the materials, design of mixes, mixing, transport, placing, compaction and curing of concrete and mortar required in the Permanent Works.

18.2. Definitions

Structural concrete is any class of concrete used in reinforced, prestressed or unreinforced concrete construction, which is subject to stress.

Non-structural concrete is composed of materials complying with the Specification but for which a low nominal strength requirement is specified and which is used only for filling voids, blinding foundations and similar purposes where it is not subjected to significant stress.

A formed surface or face is one that has been cast against formwork.

An unformed surface is a horizontal or nearly horizontal surface produced by screeding or trowelling to the level and finish required.

A pour refers to the operation of placing concrete into any mould, bay or formwork, etc, and also to the volume which has to be filled. Pours in vertical succession are referred to as lifts.

18.3. Materials for Concrete

18.3.1 General

The Contractor shall submit to the Engineer full details of all materials that he proposes to use for making concrete. No concrete shall be placed in the Works until the Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or substituted by other materials without the consent of the Engineer.

18.3.2 Cement

Cement shall be Portland or Rapid-hardening cement, and shall comply with the requirements of GS 22 and/or BS EN 197 cement standard. Cement shall be classified according to strength class and constituents and the cement classification shall be clearly indicated when delivered to site.

The following cement compositions can be used in structural concrete (all percentages are by mass):

Portland cement:
CEM I (contains more than 95% Portland cement clinker)

Portland composite-cement:

CEM II / A (contains between 6 and 20% cement extender and between 80 and 94% Portland cement clinker)

The following cement compositions can be used in mass concrete if required by the Engineer (all percentages are by mass):

Portland composite-cement:

CEM II / B (contains between 21 and 35% cement extender and between 65 and 79% Portland cement clinker).

Blastfurnace cement:

CEM III / A (contains between 36 and 65% Blastfurnace slag and between 35 and 64% Portland cement clinker.

Cement extenders (with the notation used in BS EN 197) that can be used in cement are:

Ground Granulated Blastfurnace Slag (S) conforming to BS 6699 or BS EN 15167
Siliceous Fly Ash (V) conforming to BS EN 450
Calcareous Fly Ash (W) conforming to BS EN 450
Limestone (L or LL) that meets the requirements of BS EN 197

Sulfate resistant cement shall only be used if specified by the Engineer and all details of the cement shall be submitted to the Engineer before use.

Where a CEM I cement is used, cement extenders can be added to the concrete mix on condition that the percentages added do not exceed the percentages indicated above. The extenders shall meet the requirements as set in the standards listed. Extenders used in a concrete mixture are taken into account as part of the cement content for calculating the minimum cement content or the water/cement ratio: the properties of this blended cement shall be established according to the requirements of EN196.

The strength class of all cement is determined according to BS EN 196-1. The standard strength of cement is the compressive strength at 28 days. The standard and early cement strength requirements of BS EN 197 are listed in Table 18.1. The early strength of cement is determined after either 2 days or 7 days and the early strength can be normal (indicated by N) or high (indicated by R).

Table 18.1: BS EN 197 Cement strength requirements

Strength Class	**Compressive strength requirement** (MPa)				**Initial setting time**	**Lower level limit values for single results**			
	Early strength		**Standard strength**			**Early strength**		**Standard strength**	**Initial setting time**
	2 days	**7 days**	**28 days**		(min)	**7 days**	**28 days**	(min)	
32.5 N		≥ 16.0	≥ 32.5	≤ 52.5	≥ 75		14.0	30.0	60
32.5 R	≥ 10.0					8.0		30.0	
42.5 N	≥ 10.0		≥ 42.5	≤ 62.5	≥ 60	8.0		40.0	50
42.5 R	≥ 20.0					18.0		40.0	
52.5 N	≥ 20.0		≥ 52.5	-	≥ 45	18.0		50.0	40
52.5 R	≥ 30.0					28.0		50.0	

Cement with strength classes lower than 32.5 shall not be used in concrete.

18.3.3 Aggregate

Both coarse aggregate (stone) and fine aggregate (sand) shall be clean, hard and durable and shall be natural sand, crushed gravel sand or crushed rock sand complying with BS EN 12620. The aggregate shall not contain iron pyrites or iron oxides. It shall not contain mica, shale, coal or other laminar, soft or porous materials or organic matter unless the Contractor can show by comparative tests, on finished concrete that the presence of such materials does not adversely affect the properties of the concrete.

Where there is a danger of a particular combination of aggregate (particularly those containing amorphous and fine grained silica such as opal, tridymite, cristobalite and volcanic glasses in some quartzites, strain quartz, granites and metasediments) and cement giving rise to a harmful alkali-aggregate reaction, the particular combination shall be tested. When tested for potential alkali-silica reactivity in accordance with ASTM C 1260, C 227, C 295 and C 289, the aggregate shall be non-reactive.

All the material used as fine aggregate shall pass through a 4 mm sieve. In order to achieve an acceptable grading, it may be necessary to blend materials from more than one source.

The grading used in the initial mix designs shall be submitted to the Engineer and the grading of the fine aggregate used subsequently shall not deviate by more than the percentages indicated in Table 18.2 from the grading submitted. If the grading of the fine aggregate changes significantly, new mixes will have to be tested and approved for all classes of concrete.

Table 18.2: Tolerances on declared typical grading for fine aggregate (BS EN 12620)

Sieve size (mm)	**Tolerance in percentage passing** (% by mass)
4	±5
2	-
1	±10
0.250	±10
0.063	±3

The fine aggregate content passing a 63 micron sieve shall not exceed 3% for natural or crushed gravel sand or 15% for crushed rock sand.

The fineness modulus (FM) of the fine aggregate can be calculated as the sum of the cumulative percentages (by mass) retained on the following sieves (mm), expressed as a percentage:

$$FM = \frac{\Sigma\{(>4)+(>2)+(>1)+(>0.5)+(>0.25)+(>0.125)\}}{100}$$

The FM of the fine aggregate shall not vary by more than ± 0.2 from the approved modulus.

Coarse aggregate shall be supplied in the nominal sizes called for in the Special Specification and shall be graded in accordance with BS EN 12620 for each nominal size.

The proportion of clay, silt and other impurities passing a 63 micron sieve shall be not more than 1.0% by mass.

The total shell content of coarse aggregate shall not be more than the following:

40 mm nominal size and above	2% of dry mass
20 mm nominal size	5% of dry mass
10 mm nominal size	15% of dry mass

Coarse aggregate shall have a 10% Fines test result of not less than 160 kN and the Wet/Dry ratio shall be at least 75%.

The Los Angeles Abrasion (LAA) value of the coarse aggregate shall not be more than 40%.

The Flakiness Index of the coarse aggregate when tested in accordance with EN 12620 shall be:

For natural aggregate not more than 40
For crushed aggregate not more than 35

If the Flakiness Index of the coarse aggregate varies by more than five units from the average value of the aggregate used in the approved trial mix, then a new set of trial mixes shall be carried out if the workability of the mixes has been adversely affected by such variation.

The drying shrinkage of coarse aggregate shall not be greater than 0.075% when tested to BS EN 1367–4.

The aggregate shall not have a water absorption of more than 2.5% when tested according to ASTM C 127.

18.3.4 Water for concrete and mortar

Mixing water shall be clean and free from harmful matter such as detrimental concentrations of acids, alkalis, salts, sugar and other organic or chemical substances that could impair the durability and strength of the concrete or the imbedded steel. Water shall conform to BS EN 1008. For reinforced and prestressed concrete the chloride content of the mixing water shall not exceed 500 mg/ℓ.

18.3.5 Admixtures

The use of the admixtures in concrete may be required under the Contract to promote special properties in the finished concrete or may be proposed by the Contractor to assist him in compliance with the Specification.

Admixtures shall not be used in concrete without the approval of the Engineer, who may require that the admixtures be tested to prove their suitability. Admixtures shall conform to BS EN 934-2 or ASTM C 494 and shall be of an approved brand and type.

Admixtures shall be used only in liquid form and shall be batched in solution in the mixing water by a mechanical batcher that is capable of dispensing the admixture in quantities accurate to within 5% of the required quantity.

Calcium chloride or admixtures based on chlorides shall not be used in concrete. The chloride ion content of any admixture shall not exceed 2% by mass of the admixture nor 0.03% by mass of the cement in the mix.

Accelerating and retarding admixtures shall be used only where an accelerated or retarded set has been specified.

The total amount of admixtures, if any, shall not exceed the maximum dosage recommended by the admixture producer and not exceed 50 g of admixture (as supplied) per kg cement unless the influence of the higher dosage on the performance and the durability of the concrete has been established to the satisfaction of the Engineer.

If the total quantity of liquid admixtures exceeds 3 ℓ/m^3 of concrete, its water content shall be taken into account when calculating the water/cement ratio.

Where more than one admixture is used, the compatibility of the admixtures shall be checked in the initial tests.

In all cases the Contractor shall submit to the Engineer full details of the admixture he proposes to use and the manner in which he proposes to add it to the mix. The information provided shall include:-

(i) The typical dosage, the method of dosing and the detrimental effects of an excess or deficiency in the dosage.

(ii) The chemical names of the main active ingredients in the admixture.

(iii) Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a percentage by mass of admixture.

(iv) Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage and if so, the extent to which it does so.

(v) Details of previous uses of the admixture.

18.3.6 Curing Agents

Curing agents shall be tested in accordance with ASTM C 156 and shall comply with the requirements of ASTM C 309 except that the loss of water within 72 hours shall not exceed 0.40 kg/m^2.

Only approved curing agents shall be used.

18.4. Storage of materials

18.4.1 Cement

Cement shall be free flowing and free of lumps. It shall be supplied in the manufacturer's sealed unbroken bags or in bulk. Bagged cement shall be transported in weatherproof vehicles.

Bulk cement shall be transported in vehicles or in containers built and equipped for the purpose.

Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level and shall be so constructed that no moisture rises through it. Cement from broken bags shall not be used. Cement in bags shall be used in the order in which it is delivered.

Each delivery of cement in bags shall be stacked together in one place. The bags shall be closely stacked so as to reduce air circulation but shall not be stacked against an outside wall. If pallets are used, they shall be constructed so that bags are not damaged during handling and stacking. No stack of cement bags shall exceed 3 m in height. Different types of cement in bags shall be clearly distinguished by visible markings and shall be stored in separate stacks.

Bulk cement shall be stored in weatherproof silos which shall bear a clear indication of the type of cement contained in them. Different types of cement shall not be mixed in the same silo.

Cement that has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the Site and discarded in an approved location and manner in accordance with the Environmental Management Plan.

Cement that is stored on Site for longer than one month shall be retested at the rate of one set of tests as shown in Section 2 of the Specification for every 200 tonnes, and at monthly intervals thereafter.

18.4.2 Aggregates

Aggregates shall be delivered to Site in clean and suitable vehicles. Different types or sizes of aggregate shall not be delivered in one vehicle.

Each type or size of aggregate shall be stored in a separate bin or compartment having a base such that contamination of the aggregate is prevented. Dividing walls between bins shall be substantial and continuous so that no mixing of types or sizes occurs.

The storage of aggregates shall be arranged so that, as far as possible rapid drying out in hot weather is prevented in order to avoid sudden fluctuations in water content. Storage of fine aggregates shall be arranged so that they can drain sufficiently before use in order to prevent fluctuations in water content of the concrete.

18.4.3 Storage capacity

The storage capacity and the quantity of material (whether it is water, cement or aggregates) stored shall be sufficient to ensure that no interruptions to the progress of the work will be caused by a lack of materials.

18.5. Concrete quality

18.5.1 General

The concrete composition and the constituent materials for designed or prescribed concrete shall be chosen to satisfy the requirements specified for fresh and hardened concrete, including consistence, density, strength, durability and protection of embedded steel against corrosion, taking into account the production process and the intended method of execution of concrete works. Concrete shall comply with the requirements for strength of concrete or prescribed mix concrete as specified in 18.5.2 and 18.5.3 respectively.

The total chloride content, expressed as chloride ion, arising from all ingredients in a mix including cement, water and admixtures shall not exceed the following limits, expressed as a percentage of the mass of cement in the mix:

(i) For prestressed concrete, steam cured concrete or concrete containing sulfate resisting or supersulfated cement: 0.05%.

(ii) For any other reinforced concrete: 0.2% in 95% of all test results provided no result is more than 0.4%.

The total sulfate content expressed as SO_3 of all the ingredients in a mix including cement, water and admixtures shall not exceed 0.4% by mass of the aggregate or 4.0% of the mass of cement in the mix, whichever is the lesser.

When determining conformity of chloride content in accordance with BS EN 206, the method for determining the chloride content of constituent materials shall be in accordance with the following tests methods:

Cement, fly ash, GGBS, limestone fines, PFA, metakaolin:	BS EN 196–21
Aggregate:	BS EN 1744-1
Admixture:	BS EN 480-10
Water:	BS EN 196-21

(Testing of water is not required if the water is from a potable supply.)

The total alkaline content (Na_2O - equivalent) of concrete shall be limited to 2.1 kg/m^3.

18.5.2 Strength concrete

The Contractor shall be responsible for the design of the concrete mix and for the proportions of the constituent materials necessary for producing concrete that complies with the requirements specified below for each class of concrete. The characteristic strength of structural concrete shall be determined from cubes or cylinders and the strength shall be one of the strength classes as indicated on the Drawings and listed in Table 18.3. Where the compressive strength is to be determined, it shall be expressed as $f_{c,cube}$ where determined using cubical specimens and $f_{c,cyl}$ where determined using cylindrical specimens, in accordance with BS EN 12390-3. The characteristic strength of the concrete shall be equal to or greater than the minimum characteristic compressive strength for the specified compressive strength class in Table 18.3.

The Contractor shall indicate whether the compressive strength is to be assessed on the basis of cube or cylinder tests in due time before delivery. If a different method is to be used, this shall be agreed between the Engineer and the Contractor.

Unless specified otherwise in the Special Specification, the compressive strength is determined on specimens tested at 28 days. For particular uses, it may be necessary to specify the compressive strength at ages earlier or later than 28 days (e.g. for massive structural elements) or after storage under special conditions (e.g. heat treatment).

Table 18.3: Classes of concrete

Class of concrete	**Characteristic cylinder strength** (N/mm^2)	**Characteristic cube strength** (N/mm^2)	**Maximum water/cement ratio**		**Minimum cement content** (kg/m^3)
			A	**B**	
C20/25	20	25	0.7	0.65	260
C25/30	25	30	0.6	0.55	280
C30/37	30	37	0.55	0.5	300
C35/45	35	45	0.5	0.45	320
C40/50	40	50	0.45	0.4	340
C45/55	45	55	0.45	0.4	360
C50/60	50	60	0.45	0.4	360

NOTE: Under water/cement ratio, column A applies to moderate and intermediate exposure, and column B to severe exposure.

The Contractor shall design all the concrete mixes called for on the Drawings, making use of the ingredients that have been approved by the Engineer for use in the Works and in compliance with the following requirements:-

(i) The aggregate portion shall be well graded from the nominal maximum size of stone down to the 125 micron size.

(ii) The cement content shall be such as to achieve the strengths required but in any case not less than the minimum necessary for impermeability and durability shown in Table 18.3.

(iii) The workability shall be consistent with ease of placing and proper compaction having regard to the presence of reinforcement and other obstructions.

(iv) The water/cement ratio shall be the minimum consistent with adequate workability but in any case not greater than that shown in Table 18.3 taking due account of any water contained in the aggregates. The Contractor shall take into account that this requirement may in certain cases require the inclusion of a workability agent in the mix.

(v) The drying shrinkage determined in accordance with BS 1881 shall not be greater than 0.05%.

18.5.3 Trial mixes

At least six weeks before commencing placement of concrete in the Permanent Works, trial mixes shall be prepared by the Contractor for each class of concrete specified.

For each mix of concrete for which the Contractor has proposed a design, he shall prepare three separate batches of concrete using the materials that have been approved for use in the Works and the mixing plant that he proposes to use for the Works. The volume of each batch shall be the capacity of the concrete mixer proposed for full production.

Samples shall be taken from each batch and the following action taken:

(i) The slump of the concrete shall be determined according to BS EN 12350-2. If the consistence of the mix is such that no meaningful slump measurement can be taken, an alternative means of measurement shall be used as indicated in Section 18.5.5.

(ii) Six test cubes or cylinders shall be cast from each batch. In the case of concrete having a maximum aggregate size of 40 mm or less, 150 mm cubes or 150 diameter by 300 mm high cylinders shall be used. In the case of concrete containing 75 mm or larger aggregate, 200 mm cubes shall be used and in addition any pieces of aggregate retained on a 63 mm sieve shall be removed from the mixed concrete before casting the cubes.

(iii) Test samples shall be demoulded 24 hours after casting and cured in water at 27 ±2°C up to the time of testing.

(iv) Three samples from each batch shall be tested for compressive strength at seven days and the remaining three at 28 days.

(v) The density of all the samples shall be determined before the strength tests are carried out.

(vi) Samples shall be loaded according to BS EN 12390-3 in a press that meets the requirements set out in BS EN 12390-4.

The average strength of the nine samples tested at 28 days shall exceed the prescribed characteristic strength by not less than 4 N/mm^2. No individual strength result shall be more than 4 N/mm^2 less than the required characteristic strength.

The Contractor shall also carry out tests to determine the drying shrinkage of the concrete unless otherwise directed by the Engineer.

Based on the results of the tests on the trial mixes, the Contractor shall submit full details of his proposals for mix design to the Engineer, including the type and source of each ingredient, the proposed proportions of each mix and the results of the tests on the trial mixes.

If the Engineer does not agree to a proposed concrete mix for any reason, the Contractor shall amend his proposals and carry out further trial mixes. No mix shall be used without the written consent of the Engineer.

18.5.4 Nominal prescribed mix for non-structural concrete

The Contractor shall submit samples of every constituent of the concrete in accordance with the appropriate provisions in Section 2 for approval.

The nominal prescribed mixes for non-structural (NS) concrete are given in Table 18.4. The class of concrete is indicated by the mix; for example a class 1:3:6 concrete shall mean a concrete with a prescribed mix in a volume ratio of one part cement: three parts sand and six parts stone as well as the nominal cube compressive strength (eg, NS 10).

Table 18.4: Nominal prescribed mix for non-structural concrete

Constituent or property	Mix		
	1: 4: 8	1: 3: 6	1: 2: 4
Class	**NS 10**	**NS 15**	**NS 20**
Cement (kg)	50	50	50
Aggregate (m^3)	0.41	0.31	0.21
Maximum water (ℓ)	46	35.5	28.5
Maximum water/cement ratio (by mass)	0.92	0.71	0.57
28 day Compressive Strength (MPa)	10	15	20

18.5.5 Consistence and workability

The concrete shall be of suitable workability without the excessive use of water so that it can be readily compacted into the corners of the formwork and around the reinforcement, tendons and ducts without material segregating.

Where the consistence of concrete is to be determined, it shall be measured either by means of:

i. slump test conforming to BS EN 12350-2;
ii. Vebe test conforming to BS EN 12350-3;
iii. degree of compactability conforming to BS EN 12350-4;
iv. flow table test conforming to BS EN 12350-5;
v. specific methods to be agreed upon between the Engineer and the Contractor for concrete for special applications.

Due to the lack of sensitivity of the test methods beyond certain values of consistence, the above tests shall only be used on concrete with properties within the following limits:

i. slump between 10 mm and 210 mm;
ii. Vebe time between 30 and 5 seconds;

iii. degree of compactability between 1.04 and 1.46;
iv. flow diameter between 340 mm and 620 mm.

Where the consistence of concrete is to be determined, it shall be tested at the time of use of the concrete or in the case of ready-mixed concrete, at the time of delivery. If concrete is delivered in a truck mixer or agitating equipment, the consistence may be measured using a spot sample obtained from the initial discharge. The spot sample shall be taken after a discharge of approximately 0.3 m^3 in accordance with BS EN 12350-1.

The consistence may be specified by a target value on the design drawings. For target values, the related tolerances are given in Table 18.5. If no specific target value is specified the Contractor shall produce concrete with a target slump of 75 mm. The Contractor may only produce concrete with a consistence outside the range specified, with the written approval of the Engineer.

Table 18.5: Tolerances for target values of consistence according to BS EN 206.

Slump			
Target value (mm)	≤ 40	50 to 90	≥ 100
Tolerance (mm)	± 10	± 20	± 30
Vebe time			
Target value (sec)	≥ 11	10 to 6	≤ 5
Tolerance (sec)	± 3	± 2	± 1
Degree of compactability			
Target value	≥ 1.26	1.25 to 1.11	≤ 1.10
Tolerance	± 0.10	± 0.08	± 0.05
Flow diameter			
Target value (mm)	All values		
Tolerance (mm)	± 30		

18.5.6 Bleeding

The concrete shall be so proportioned with suitable materials that bleeding is not excessive as assessed by the Engineer.

18.5.7 Pumped concrete

Where pumping of concrete is approved by the Engineer, the concrete shall be so designed that suitable graded aggregate and admixtures are used to improve the pumpability of the mix.

The shrinkage capacity of the concrete to be pumped shall not be higher than that of ordinary concrete mixes.

18.6. Plant for Concreting Operations

The Contractor shall submit to the Engineer full details, including drawings, of all the plant that he proposes to use and the arrangements and procedures he proposes to follow, for batching, mixing, transporting, placing, compacting and finishing concrete, before such plant is ordered or delivered to Site.

Batching and mixing plants shall be modern and efficient equipment complying with the requirements of BS 1305 and capable of producing a uniform distribution of the ingredients throughout the mass. If the plant proposed by the Contractor does not fall within the scope of BS 1305, it shall have been tested in accordance with BS 3963 and shall have a mixing performance within the limits of Table 6 of BS 1305.

Immersion vibrators shall operate at a frequency of between 7 000 and 10 000 cycles per minute. The Contractor shall ensure that vibrators are operated at pressures and voltages not less then those recommended by the manufacturer in order that the compactive effort is not reduced.

18.7. Measuring the materials

18.7.1 General

The weighing and water dispensing mechanisms shall be maintained in good order. Their accuracy shall be maintained within the required tolerance and checked against accurate masses and volumes when required by the Engineer.

The masses of cement and of each size of aggregate as indicated by the mechanisms employed shall be within a tolerance of plus or minus 2% of the respective masses per batch approved by the Engineer.

The Contractor shall provide standard test masses at least equivalent to the maximum working load used on the most heavily loaded scale and other auxiliary equipment required for checking the satisfactory operation of each scale or other measuring device. Tests shall be made by the Contractor at least once a week or at intervals to be determined by the Engineer and shall be carried out in his presence. For the purpose of carrying out these tests, there shall be easy access for personnel to the weigh hoppers. The Contractor shall furnish the Engineer with copies of the complete results of all check tests and shall make any adjustments, repairs or replacements necessary to ensure satisfactory performance.

18.7.2 Cement

Where cement is supplied in standard bags, the bag shall be assumed to contain 50 kg. All cement taken from bulk containers or partly used bags shall be batched by mass, accurate to within 2% of the required mass.

The batching of cement in gauge boxes shall not be permitted. Volume batching shall be planned as to use full bags of cement.

18.7.3 Water

The mixing water for each batch shall be measured either by mass or by volume, accurate to 2% of the required quantity.

18.7.4 Aggregate

(a) Aggregate for strength concrete

All aggregate for strength concrete shall be measured separately by mass, accurate to 2% of the required mass. The aggregate storage bins shall be provided with drainage facilities arranged so that drainage water is not discharged to the weigh hoppers. Each bin shall be drawn down at least once per week and any accumulations of mud or silt removed.

(b) Aggregate for prescribed mix concrete

Aggregates for prescribed-mix concrete as specified in 18.5.4 may be measured separately by volume. Batching boxes for volume batching shall be filled without any tamping, ramming or consolidating of material other than that occurring naturally. Boxes shall be screened off level with their topmost edges.

Any adjustment to the volume shall be made by supplementary boxes of a suitable size being used. Adjustment of the volume of boxes by incomplete filling will not be permitted.

Fine aggregate shall be tested for bulking at the beginning and halfway through every concreting shift and adjustment shall be made to the batch volume to give the true volume required.

18.8. Mixing Concrete

18.8.1 General

Concrete shall be batched and mixed in one or more central plants unless the Engineer agrees to some other arrangement. . Batching and mixing plants shall be modern and efficient equipment capable of producing a uniform distribution of the ingredients throughout the mass. Truck mixers shall only be used with the prior approval of the Engineer.

All mixing operations shall be under the control of an experienced supervisor. Unless otherwise authorised, mixing shall be carried out in a mechanical mass batch-mixer of an approved type which will be capable of producing a uniform distribution of ingredients throughout the batch.

18.8.2 Charging the mixer

The sequence of charging the ingredients shall be subject to approval of the Engineer, and, unless otherwise instructed, the same mixing sequence of charging ingredients shall be maintained. The volume of mixed material by batch shall not exceed the volume recommended by the manufacturer of the mixer.

18.8.3 Mixing and discharging

The nominal drum or pan capacity of the mixer shall not be exceeded. The turning speed and the mixing time shall be as recommended by the manufacturer, but in addition, when water is the last ingredient to be added, mixing shall continue for at least one minute after all the water has been added to the drum or pan.

The water to be added to the mix shall be reduced by the amount of free water contained in the coarse and fine aggregates. This amount shall be determined by the Contractor by a method approved by the Engineer immediately before mixing begins each day and thereafter at least once per hour during concreting and for delivery of aggregates during concreting. When the correct quantity of water, determined as set out in the Specification, has been added to the mix, no further water shall be added, either during mixing or subsequently.

After mixing for the required time, each batch shall be discharged completely from the mixer before any materials for the succeeding batch are introduced.

Mixers that have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed and thereafter the first batch of concrete through the mixers shall contain only half the normal quantity of coarse aggregate. This batch shall be mixed for one minute longer than the time applicable to a normal batch.

18.8.4 Maintaining and cleaning the mixer

The blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

Mixers shall be cleaned out before changing to another type of cement.

If the mixer has stopped running for a period in excess of 30 minutes, it shall be thoroughly cleaned out.

Before any concrete is mixed, the inner surfaces of the mixer shall be cleaned and all hardened concrete shall be removed.

18.8.5 Standby mixer

When sections are cast where it is important for the casting to continue without interruption, a standby mixer shall be held in readiness to run on 15 minutes notice should the stock mixer break down.

18.8.6 Ready mixed concrete

If the Contractor proposes to use ready mixed concrete he shall submit to the Engineer for his approval full details and test results of the concrete mixes. The Engineer may approve the use of ready mixed concrete provided that:

i. the proposed mixes, the material to be used and the method of storage and mixing comply with the requirements of the Specification; and
ii. adequate control is exercised during mixing.

Approval for the use of ready mixed concrete shall be withdrawn if the Engineer is not satisfied with the control of the materials being used and control during mixing.

18.8.7 Hand Mixed Concrete

Concrete for structural purposes shall not be mixed by hand. Where non-structural concrete is required, hand mixing may be carried out subject to the approval of the Engineer.

The mixing shall be done on a hard impermeable surface. The materials shall be turned over not less than three times dry, water shall then be sprayed on and the materials again turned over not less than three times in a wet condition and worked together until a mixture of uniform consistency is obtained.

For hand mixed concrete the specified quantities of cement shall be increased by 10% and not more than 0.5 m^3 shall be mixed at one time. During windy weather efficient precautions shall be taken to prevent cement from being blown away during the process of gauging and mixing.

18.9. Transport of Concrete

The concrete shall be discharged from the mixer and transported to the Works by means that shall prevent contamination, segregation or loss of ingredients and, which shall ensure that the concrete is of the required workability at the point and time of placing. The loss of slump between discharge from the mixer and placing shall not exceed 25 mm.

The time elapsing between mixing and placing a batch of concrete shall be as short as practicable and in no case longer than will permit completion of placing and compaction before the onset of initial set. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the Works.

The concrete shall be deposited as close as practicable in the final position to avoid rehandling or moving of the concrete horizontally by vibration.

Ready-mixed concrete shall be transported and delivered in accordance with BS EN 206.

18.10. Placing of Concrete

18.10.1 Consent for placing

Concrete shall not be placed until the Engineer's consent has been given in writing, and the Contractor shall give the Engineer at least one full working day's notice of his intention to place concrete. If concrete placing is not commenced within 24 hours of the Engineer's consent the Contractor shall again request consent as specified above.

Concreting operations shall only be carried out during daylight hours unless adequate lighting arrangements have been made and the lights are in working order by noon. Workmen shall not be allowed to work double shifts, and the Contractor shall provide a fresh team for night shifts.

All placing and compaction of concrete shall be carried out under the direct supervision of an experienced concrete supervisor.

Once the casting of concrete has begun, it shall be carried out in a continuous process between construction joints.

18.10.2 Time for placing

Concrete shall be placed within 60 minutes of mixing.

18.10.3 Preparation of surface to receive concrete

Excavated surfaces on which concrete is to be deposited shall be prepared as set out in Section 7.4 of the Specification. Where specified or directed by the Engineer, excavated surfaces, shall be lined with an approved sheeting to provide a clean impervious layer. The lining material shall be of sufficient strength to provide a durable working surface, and to support the concrete and reinforcement without tearing. The joints of the material between strips shall have a 150 mm overlap, and the lining shall be held firmly in position by nails, pegs, etc. Polyethylene sheeting shall have a minimum thickness of 0.15 mm, and waterproof paper shall comply with BS 1521 Waterproof Building Paper, Class B, and shall have fibrous reinforcement.

Existing concrete surfaces shall be prepared as set out in Clause 18.19.

All excavations and other contact surfaces of an absorbent nature shall be damp but no standing water shall be permitted to remain on these surfaces. All formwork shall be clean on the inside.

If so required by the Engineer excavated surfaces against which concrete is to be placed shall receive a prior coating of mortar mixed in the proportions similar to those of the fines portion in the concrete to be placed. The mortar shall be kept ahead of the concrete, it shall be well worked into all parts of the excavated surface and it shall be not less than 5 mm thick. Fissures that have been cleaned out shall be filled with mortar or with concrete as instructed by the Engineer.

The amount of mortar placed at any one time shall be so controlled that it does not dry out or set before being covered with concrete.

Any flow of water into an excavation shall be diverted through proper side drains to a sump, or be removed by other suitable methods, so as to prevent the washing away of the freshly deposited concrete or any of its constituents. Any underdrains constructed for this purpose shall be fully grouted up when they are no longer required.

The Contractor shall take precautions to ensure that no cement or concrete is dropped into water courses. If required by the Environmental Management Plan, the Contractor shall monitor the pH and turbidity of water courses and bodies in the vicinity of construction to ensure that water quality levels are maintained.

18.10.4 Placing procedures

The concrete shall be deposited as near as possible to its final position. Where possible, concrete shall be deposited vertically into its final position. It shall be placed so as to avoid segregation of the concrete and displacement of the reinforcement, other embedded items, or formwork. When it is discharged above its place of final deposition, segregation shall be prevented by the use of chutes, downpipes, trunking, baffles or other appropriate devices.

Forms for walls, columns and other thin sections of significant height shall be provided with openings or other devices that will limit the height through which the fresh concrete has to fall, and thereby prevent segregation and accumulation of hardened concrete on the formwork or reinforcement above the level of the placed concrete.

In vertical elements such as walls or columns, concrete shall be brought up in layers of approximately uniform thicknesses parallel to the construction joint planes and between 200 and 500 mm thick unless otherwise permitted or directed by the Engineer. The layers shall be placed such that no feather edges are formed and before the preceding layer has taken its initial set. In order to comply with this requirement, a layer may be started before completion of the preceding layer.

Fresh concrete shall not be placed against concrete that has been in position for more than 30 minutes, unless a construction joint is formed.

In bridge decks of substantial thickness, care shall be taken to avoid layering of the concrete, and each panel or bay shall be placed to the full depth in one pass before proceeding to the next panel or bay.

All of the concrete in a single bay or pour shall be placed as a continuous operation. It shall be carefully worked round all obstructions, irregularities in the foundations and the like so that all parts are completely filled with compacted concrete with no segregation or honeycombing. It shall also be carefully worked round and between waterstops, reinforcement, embedded steelwork and similar items that protrude above the surface of the completed pour.

All work shall be completed on each batch of concrete before its initial set commences and thereafter the concrete shall not be disturbed before it has set hard. No concrete that has partially hardened during transit shall be used in the Works.

Concrete shall not be placed during rain, which is sufficiently heavy or prolonged to wash mortar from coarse aggregate on the exposed faces of fresh concrete. Means shall be provided to remove any water accumulating on the surface of the placed concrete. Concrete shall not be deposited into such accumulations of water.

In drying weather, covers shall be provided for all fresh concrete surfaces that are not being worked on. Water shall not be added to concrete for any reason.

18.10.5 Placing under water

Placing under water shall be allowed only in exceptional circumstances where it is unfeasible to dewater the location before the concrete is placed, and only if approved in the Environmental Management Plan. The pH of the water shall be monitored. No concrete shall be placed in running water.

When it is necessary to place concrete under water the Contractor shall submit to the Engineer his proposals for the method and equipment to be employed. The concrete shall be deposited either by bottom-discharging watertight containers or through funnel-shaped tremies with a trapdoor or sliding plug fitted at the discharging end.

When concreting by tremie, the pipe shall be kept continuously full with concrete to a level above the water and shall have the discharge end kept well below the surface of the concrete, in order to prevent air and water from entering the tremie. Should this seal be broken, or the level of the concrete is allowed to fall sufficiently for water to enter the pipe, the tremie shall be lifted, plugged and re-filled before concreting is recommenced. Special care shall be taken to control the rate of descent so as to avoid segregation.

Distribution of concrete by lateral movement of the tremie will not be permitted.

During and after concreting under water, pumping or de-watering in the immediate vicinity shall be suspended if there is any danger that such work will disturb the freshly placed concrete.

The concrete mix to be placed under water shall be specially designed and approved for this purpose, to ensure good flowability, plasticity and cohesion. Increased sand and cement content over those of normal mixes will usually be required.

18.10.6 Interruptions to placing

If concrete placing is interrupted for any reason and the duration of the interruption cannot be forecast or is likely to be prolonged, the Contractor shall complete the compaction of the placed concrete and immediately take the necessary action to form a construction joint in accordance with Clause 18.19, Equipment and materials to comply with this requirement shall be readily available at all times during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remove all damaged, contaminated or uncompacted concrete, feather edges or any other undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing within 30 minutes of the stoppage and the Engineer consents to a resumption, the new concrete shall be thoroughly worked in and compacted against the surface of the existing concrete so as to avoid any cold joints.

18.10.7 Dimensions of pours

Unless otherwise approved by the Engineer, pours shall not be more than 2.0 m high and shall as far as possible have a uniform thickness over the plan area of the pour. Concrete shall be placed to the full planned height of all pours except in the circumstances described in Subclause 18.10.6.

The Contractor shall plan the dimensions and sequence of pours in such a way that cracking of the concrete does not take place due to thermal or shrinkage stresses.

18.11. Compaction of Concrete

The concrete shall be fully compacted throughout the full volumetric extent of the placed layer. It shall be thoroughly worked against the formwork and around any reinforcement, tendons, ducts and other embedded items, without displacing them. Particular care shall be taken at arrises and other confined spaces. Successive layers of the same pour shall be thoroughly worked together.

In bridge decks with void formers, adequate means to prevent flotation shall be employed, and care shall be taken to ensure adequate compaction of the concrete placed beneath the void formers.

Concrete shall be compacted with the assistance of mechanical immersion vibrators, unless the Engineer agrees to another method.

A sufficient number of vibrators shall be operated to enable the entire quantity of concrete being placed to be vibrated for the necessary period and, in addition, stand-by vibrators shall be available for instant use at each location where concrete is being placed.

Where the concrete contains aggregate with a nominal size of 63 mm or more, vibrators with a diameter of 100 mm or more shall be used.

Vibration shall be applied by experienced workmen, and over-vibration resulting in segregation, surface water and leakage, shall be avoided.

Vibration shall be continued at each point until the concrete ceases to contract, a thin layer of mortar has appeared on the surface and air bubbles have ceased to appear. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

Vibration shall not be applied by shaking the reinforcement nor shall vibrators be allowed to touch reinforcement or other embedded items. The vibrators shall be inserted vertically into the concrete to penetrate the layer underneath at regular spacing, which shall not exceed the distance from the vibrator over which vibration is visibly effective.

Special attention shall be given in prestressing anchor zones, behind anchor plates and in places where a high concentration of reinforcing steel or cables occurs.

18.12. Curing and Protection of Concrete

18.12.1 General

During the first stage of hardening, concrete shall be protected from loss of moisture and from the development of temperature differentials within the concrete, which may be sufficient to cause cracking. Curing shall be continued for at least 7 days for concrete made with CEM I cement and for at least 10 days for concrete made with CEM II and CEM III cement, or until the concrete is covered by later construction, whichever is the shorter period.

The curing process shall commence as soon as the concrete has hardened sufficiently to resist damage from the process. In the case of large areas or continuous pours, the curing process shall commence on the completed sections before completion of the remaining pour.

Details of the Contractor's proposals for curing concrete shall be submitted to the Engineer for approval before the placing of concrete commences.

In addition, the Contractor shall, where feasible, provide a suitable form of shading to prevent the direct rays of the sun reaching the concrete surfaces for at least the first four days of the curing period.

18.12.2 Loss of moisture

Protection against loss of moisture shall be achieved by one or more of the following methods:

(i) Retaining formwork in place for the full curing period.

(ii) Closely covering exposed concrete surfaces with impermeable sheeting, properly secured to prevent its removal by wind and the development of air spaces beneath it. Joints in the sheeting shall be lapped by at least 300 mm.

(iii) Covering with sand or with mats made from a moisture retaining material, and keeping the covering constantly wet.

(iv) Keeping the exposed surfaces continuously wet by means of a water spray, only where other methods are not possible. Alternate wetting and drying, and cold water on warm concrete surfaces shall be avoided. This method shall not be used in the case of thick concrete sections or in other situations where there is a risk of a high temperature differential between the concrete surface and its core.

Water used for curing shall comply with Subclause 18.3 (d).

(v) If use of the foregoing methods is inappropriate, surfaces that will not have further concrete bonded to them and which are not to receive an application of a finish may be cured by the application of a curing compound having an efficiency index of at least 90%. Curing compounds shall contain a fugitive dye to enable the extent of the spread to be seen easily.

Curing compound used on surfaces exposed to sunlight shall contain sufficient finely divided flake aluminium in suspension to produce a complete coverage of the surface with a metallic finish when applied at the rate recommended by the manufacturer.

Curing compounds shall become stable and impervious to the evaporation of water from the concrete surface within 60 minutes of application. The material shall not react chemically with the concrete and shall not crack, peel or disintegrate within three weeks after application.

18.12.3 Limitation of temperature differentials

The Contractor shall limit the development of temperature differentials in concrete after placing by any means appropriate to the circumstances including the following:

(i) limiting concrete temperatures at placing as set out in Subclause 18.14;
(ii) use of low heat cement, subject to the approval of the Engineer;
(iii) insulation of exposed concrete surfaces by insulating blankets. Such blankets shall have an insulation value at least equivalent to 50 mm of dry mineral wool;
(iv) leaving formwork in place during the curing period. Steel forms shall be suitably insulated on their external surfaces;
(v) preventing rapid dissipation of heat from surfaces by shielding from wind;
(vi) avoiding the use of water sprays when such use would cause rapid cooling of the surface.

18.13. Protection of Fresh Concrete

Freshly placed concrete shall be protected from rainfall and from water running over the surface until it is sufficiently hard to resist damage from these causes.

No traffic shall be allowed on any concrete surface until such time as it is hard enough to resist damage by such traffic.

Concrete placed in the Works shall not be subject to any loading until it has attained at least its nominal strength as defined in Clause 18.5.

No load shall be applied to any part of the structure until the specified curing period has expired, after which applied loading shall be allowed only when approved by the Engineer. The Engineer's decision will be based on the type of load to be applied, the age of the structure, the magnitude of stress induced and the propping of the structure.

If the Contractor desires to impose loads on newly-placed concrete, he shall make at least three test cubes and cure them in the same conditions as the concrete they represent. These cubes shall be tested singly at suitable intervals in order to estimate the time at which the required strength is reached.

No structure shall be opened to traffic until the test samples made from the concrete in all parts of the structure have attained the specified minimum 28-day compressive strength.

18.14. Concreting in Hot Weather

During hot weather the Contractor shall take all measures necessary to ensure that the temperature of concrete at the time of placing does not exceed 30°C and that the risk of moisture loss from the concrete during transporting and placing is minimised.

Such measures include but are not necessarily limited to the following:-

(i) Shielding aggregate stockpiles from direct sunshine.
(ii) Use of a mist water spray on aggregates to promote cooling down by evaporation.
(iii) Sun shields on mixing plants and transporting equipment.
(iv) Cooling the mixing water. If ice is used for this purpose it should preferably be in flake form. Lump ice shall not be allowed to enter the tank supplying the mixer drum.

(v) Covering skips closely with polythene sheet so that the latter is in contact with the concrete.

Areas in which concrete is to be placed shall be shielded from direct sunshine and hard rock or concrete surfaces shall be thoroughly wetted to reduce absorption of water from the concrete placed on or against them.

After concrete in any part of an area has been placed, the selected curing process shall be commenced as soon as possible. If any interval occurs between completion of placing and start of curing, the concrete shall be closely covered during the interval with polythene sheet to prevent loss of moisture.

In the event that conditions become such that even with the use of such precautions, the requirements cannot be met, concrete placing shall immediately cease until such time as the requirements can again be met.

18.15. Finishes on Unformed Surfaces

Horizontal or nearly horizontal surfaces, which are not cast against formwork shall be finished to the class shown on the Drawings and defined hereunder.

18.15.1 UF 1 finish

All surfaces on which no higher class of finish is called for on the Drawings or instructed by the Engineer shall be given a UF 1 finish.

The concrete shall be levelled and screeded to produce a uniform plain or ridged surface, surplus concrete being struck off by a straight edge immediately after compaction.

18.15.2 UF 2 finish

This is a floated finish surface where a steel trowelled surface is not required.

The surface shall first be treated as a Class UF 1 finish and after the concrete has hardened sufficiently, it shall be floated by hand or machine sufficient only to produce a uniform surface free from screed marks.

18.15.3 UF 3 finish

This is a steel trowelled surface for use where weather resistance or appearance is important, or where the surface will be subjected to a high velocity water flow.

The surface shall be floated as for a UF 2 Finish but to the tolerance stated below. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, it shall be steel trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

Where dimensional tolerances are given on the Drawings or in the Special Specification they shall take precedence over those given in Table 18.6.

Table 18.6 - Surface Tolerances

Class of Finish	Tolerance in mm. See Notes		
	A	B	C
UF 1 UF2 UF3	Not applicable Nil Nil	10 10 5	+ 20 or - 10 + 20 or - 10 + 12 or - 8
NOTES: 1. Col A is the maximum allowable value of any sudden change of level in the surface. 2. Col B is the maximum allowable value of any gradual irregularity of the surface, as indicated by the gap between the surface and a three metre long straight edge or correctly shaped template placed on the surface. 3. Col C is the maximum allowable value of the difference between the actual level and the specified level at the selected position.			

18.16. Mortar

This clause covers mortar for use ahead of concrete placing in construction joints, for filling small cavities in damaged concrete surfaces, and for any other uses as indicated on the Drawings or instructed by the Engineer, which are not covered elsewhere in the Specification.

Mortar shall be composed of Portland cement and fine aggregate complying with Subclause 18.3 (b) and (c) respectively. The mix proportions shall be as stated on the Drawings or elsewhere in the Specification or if not stated shall be one part of cement to two parts of fine aggregate by mass.

Small quantities of mortar may be hand mixed but for amounts over 0.5 m^3 a mechanical mixer shall be used

The water content of the mortar shall be as low as possible consistent with the use for which it is required but in any case the water/cement ratio shall not be more than 0.5.

Mortar that is specified as 'dry pack' shall be mixed with sufficient water for the mix to become cohesive but not plastic when squeezed in the hand. Dry pack mortar shall be rammed into the cavity it is required to fill, using a hand rammer with sufficient force to ensure full compaction.

18.17. Concrete for Secondary Purposes

(a) Non-structural concrete shall be used only for non-structural purposes where shown on the Drawings.

Non-structural concrete shall be weigh batched or volume batched in accordance with the prescribed nominal concrete mixes indicated in Clause 18.5.4, and mixed by machine or by hand to a uniform colour and consistency before placing.

Non-structural concrete shall be classified with the prefix NS and the nominal cube crushing strength. Class NS 15 concrete shall mean non-structural concrete with a nominal cube strength of 15 MPa or mixed in a volume ratio of one part cement: three parts sand: six parts stone (Table 18.4). The nominal stone size shall be appropriate to the use for which the non-structural concrete will be employed, and shall be subject to the approval of the Engineer.

Concrete shall be compacted by hand or by mechanical vibration.

Where non-structural concrete is required, but no class is specified, Class NS 15 shall be used.

(b) No Fines concrete (NF concrete) is intended for use where a porous concrete is required and shall only be used where shown on the Drawings or instructed by the Engineer.

The mix shall consist of Portland Cement complying with GS 22 or BS EN 197 and aggregate complying with BS EN 12620. The aggregate size shall be 40 mm to 10 mm only. The mass of cement mixed with 0.3 m^3 of aggregate shall not be less than 50 kg. The quantity of water shall not exceed that required to produce a smooth cement paste that will evenly coat the whole of the aggregate.

18.18. Records of Concrete Placing

Records, in a form approved by the Engineer, shall be kept by the Contractor of the details of every pour of concrete placed. These records shall include class of concrete, location of pour, date of pour, ambient temperature and concrete temperature at time of placing, moisture contents of aggregates, details of mixes, batch numbers, cement batch number, results of all tests undertaken, location of test cube sample points and details of any cores taken and any spillages in water courses.

The Contractor shall supply to the Engineer two copies of these records each week covering work carried out the preceding week. In addition he shall supply to the Engineer monthly histograms of all 28 day cube strengths together with accumulative and monthly standard deviations and any other information that the Engineer may require concerning the concrete placed in the Works.

18.19. Construction Joints

18.19.1 General

Where a concrete element has to be constructed in more than one concreting operation, the surface of contact between the sections shall be deemed a construction joint.

Construction joints shall be formed at the positions shown on the Drawings, or, approved by the Engineer. Where, in an emergency (such as a breakdown in the mixing or placing plant, or the occurrence of unsuitable weather), concreting has to be interrupted, a construction joint shall be formed at the place of stoppage, in a manner that will least impair the appearance, durability, and proper functioning of the concrete.

Unless otherwise indicated, construction joints shall be in horizontal or vertical planes, except in inclined members, where they shall be perpendicular to the line or plane of the member.

Where additional joints are required by the Contractor to suit his method of construction, they shall be so arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing, and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints. All joints additional to those shown on the Drawings, shall be subject to the Engineer's approval.

Feather edges of concrete at joints shall be avoided and any feather edges that may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal or near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 20% from the horizontal.

18.19.2 Preparation of surfaces

In horizontal joints, when the concrete has set but not yet hardened, the joint surface shall be thoroughly cleaned and roughened by means of a water jet, assisted by light brushing, to expose the aggregate without disturbing it, and to leave a sound irregular surface. Vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

Where concrete has become too hard for the above treatment to be successful, the joint surface, whether formed or free, shall be roughened by sand blasting, or by applying a scaling hammer or other mechanical means appropriate to the degree of hardness of the concrete, so as to expose the aggregate and leave a sound irregular surface. The roughened surface shall be thoroughly washed with clean water to remove all dirt and loose particles. The indentations produced by roughening shall not be less than 10 mm deep and shall not extend closer than 40 mm to a finished face.

Surface retarding agents shall not be used at construction joints without the Engineer's approval.

18.19.3 Placing of fresh concrete

Where fresh concrete is placed on the same day as the formation of the construction joint, the fresh concrete shall be cast directly against the prepared face of the construction joint.

Where fresh concrete is placed a day or more after formation of the construction joint, the joint surface shall be kept continuously wet for at least six hours before concreting commences. The surface shall be in a saturated, surface-dry condition when the concrete is placed.

If instructed by the Engineer, the surface of the concrete shall be thoroughly brushed with a thin layer of mortar composed of one part of cement to two parts of sand by mass and complying with Clause 18.16 immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete may be placed in position on or against a construction joint until the joint has been inspected and passed by the Engineer.

Where specified, bonding agents, designed for joining new concrete to old, shall be used in construction joints. The type and proprietary brand of bonding agent used shall be subject to the Engineer's approval. The preparation of the concrete surface and the application of the bonding agent shall be strictly in accordance with the manufacturer's recommendations.

18.20. Expansion and contraction Joints

Expansion and contraction joints are discontinuities in concrete designed to allow for thermal or other movements in the concrete.

Expansion joints are formed with a gap between the concrete faces to permit subsequent expansion of the concrete. Contraction joints are formed to permit initial contraction of the concrete and may include provision for subsequent filling.

Expansion and contraction joints shall be formed in the positions and in accordance with the details shown on the Drawings or elsewhere in the Specifications.

18.21. Precast Concrete

18.21.1 General

This clause covers all precast reinforced and prestressed concrete units, whether detailed in the original design, or proposed by the Contractor, but excludes precast concrete piles, pipes and culverts, in so far as they are covered separately elsewhere in the Specification.

18.21.2 Casting of Units

Precast units shall be manufactured in accordance with all relevant requirements specified for cast in-situ members, except as specified differently hereinunder.

All units shall be permanently marked with the reference number, location, orientation and date of casting. These markings shall be positioned such that they will not be visible in the completed structure.

The area in which units are cast shall be adequately protected from the weather so that the process is not affected by rain, sun or drying winds.

18.21.3 Curing of Precast Units

If curing of precast units at elevated temperatures is proposed, the method shall be subject to the Engineer's approval, and shall include means whereby units are heated and subsequently cooled evenly, without sudden changes of temperature. It shall furthermore, not cause staining, contamination or marring of the concrete surface.

18.21.4 Surface Finish of Unformed Surfaces of Precast Units

Unformed surfaces shall be finished to Class UF2 unless another class of finish is specified on the Drawings.

Those parts of the unit that are to be joined to other units or to in situ concrete shall be brushed with a stiff brush before the concrete has fully hardened. Alternatively, if the concrete has been allowed to harden, the surfaces shall be roughened by sand blasting or by the use of a needle gun.

18.21.5 Handling and Storage of Precast Units

Precast units shall be handled in a manner that will not cause damage of any kind and shall be stored on a hard impermeable base.

Prestressed units and large precast normally reinforced units shall be handled and stored so that no stresses will be induced in excess of those which they will incur in their final positions in the Works unless they have been designed to resist such stresses.

Units shall be marked indelibly with the reference number and date of casting and shall be stacked on suitable supports, which will not damage the concrete or stain the surfaces. Not more than two supports shall be placed under each unit and these shall be located either at the positions of the permanent support points or in positions such that the induced stresses in the unit will be a minimum.

18.22. Testing Precast Units

Precast units shall be capable of safely sustaining the loads that they have been designed to carry. The Contractor shall subject units selected by the Engineer to load tests simulating the working conditions. Details of such tests shall be agreed between the Engineer and the Contractor.

In the case of units subject to bending loads the test piece shall be supported at full span and a loading equivalent to 1.25 times the sum of the live and dead loads, which were assumed in the design shall be maintained for one hour without the appearance of any signs of distress. The recovery one hour after the removal of load shall be not less than 75% of the full load deflection.

If the unit fails to meet the above requirements, further tests shall be carried out on two more units. If either of these fails, the whole batch of units will be rejected.

If the Engineer so requires, a test to destruction shall also be carried out, which on units subject to bending shall be as follows:

> The units shall be supported at full span and a load applied in increments instructed by the Engineer up to 95% of the designed ultimate load. This load shall be held for 15 minutes without failure of the unit. The deflection at the end of this period shall be not more than l/40th of the span. The load shall then be further increased until failure occurs.
>
> If the unit fails to sustain the required load for the prescribed period or if the deflection exceeds the specified amount, the Engineer may order two further tests, and if either of these fails, the batch of units which they represent may be rejected.

SECTION 19

FALSEWORK AND FORMWORK FOR CONCRETE WORKS

CONTENTS

TABLES

19. FALSEWORK AND FORMWORK FOR CONCRETE WORKS

19.1. Scope

This section covers the design, supply and erection of falsework and formwork used in the construction of permanent work.

19.2. Definitions

The following definitions shall apply to these Specifications:

(a) Formwork means the surface against which concrete is placed to form a face, together with all the immediate supports to retain it in position while concrete is placed.

(b) Falsework means the structural elements supporting both the formwork and the concrete until the concrete becomes self supporting.

(c) A formed surface or face is one which has been cast against formwork.

(d) An exposed face is one which will remain visible when construction has been completed.

19.3. Construction of Formwork and Falsework

Before construction begins, the Contractor shall submit to the Engineer drawings showing details of the proposed formwork and falsework.

Formwork and falsework shall be so designed and constructed that they will support the loads imposed on them by the fresh concrete together with additional stresses imposed by vibrating equipment and by construction traffic, so that after the concrete has hardened the formed faces shall be in the positions shown on the Drawings within the tolerances set out in Clause 19.7.

Ground supports shall be properly founded on footings designed to prevent settlement.

Joints in formwork for exposed faces shall, unless otherwise specified, be evenly spaced and horizontal or vertical and shall be continuous or form a regular pattern.

All joints in formwork including formwork for construction joints shall be tight against the escape of cement and fines. Where reinforcement projects through the formwork, the form shall fit closely round the bars.

Formwork shall be so designed that it may easily be removed from the work without damage to the faces of the concrete. It shall also incorporate provisions for making minor adjustments in position, if required to ensure the correct location of concrete faces. Due allowance shall be made in the position of all formwork for movement and settlement under the weight of fresh concrete.

Where overhangs in formwork occur, means shall be provided to permit the escape of air and to ensure that the space is filled completely with fully compacted concrete.

Formwork shall be provided for concrete surfaces at slopes of 30° to the horizontal or steeper. Surfaces at slopes less than 20° may be formed by screeding. Surfaces at slopes between 20° and 30° shall generally be formed unless the Contractor can demonstrate to the satisfaction of the Engineer that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration.

Horizontal or inclined formwork to the upper surface of concrete shall be adequately secured against uplift due to the pressure of fresh concrete. Formwork to voids within the body of the concrete shall also be tied down or otherwise secured against floating.

The internal and external angles on concrete surfaces shall be formed with fillets and chamfers of the sizes shown on the Drawings unless otherwise instructed by the Engineer.

Supports for formwork may be bolted to previously placed concrete provided the type of bolt used is acceptable to the Engineer. If metal ties through the concrete are used in conjunction with bolts, the metal left in shall not be closer than 50 mm to the face of the concrete.

Formwork shall not be re-used after it has suffered damage which is sufficient to impair the finished surfaces of the concrete.

Where circumstances prevent easy access within the form for cleaning and inspection, temporary openings for this purpose shall be provided through the formwork.

Shear keys shall be provided in all construction joints of the size and shape indicated on the Drawings.

Where precast concrete elements are specified for use as permanent formwork, or proposed by the Contractor and approved by the Engineer, they shall comply with the requirements of the Specification. Such elements shall be set true to line and level within the tolerances prescribed for the appropriate class of finish in Clause 19.7 and fixed so that they cannot move when concrete is placed against them.

19.4. Preparation of Formwork

Before any reinforcement is placed into position within formwork, the latter shall be thoroughly cleaned and then dressed with a release agent. The agent shall be either a suitable oil incorporating a wetting agent, an emulsion of water suspended in oil or a low viscosity oil containing chemical agents. The Contractor shall not use an emulsion of oil suspended in water nor any release agent which causes staining or discolouration of the concrete, air holes on the concrete surface, or retards the set of the concrete.

In order to avoid colour differences on adjacent concrete surfaces, only one type of release agent shall be used in any one section of the Works.

Release agents shall be applied strictly in accordance with the manufacturer's instructions, and every precaution shall be taken to avoid contamination of reinforcement, prestressing tendons and anchorages. In cases where it is necessary to fix reinforcement before placing formwork, all surface preparation of formwork shall be carried out before it is placed into position.

Before placing concrete all dirt, construction debris and other foreign matter shall be removed completely from the interior of the forms, and the interior of the forms shall be thoroughly wetted with water.

Before concrete placing commences, all wedges and other adjusting devices shall be secured against movement during concrete placing and the Contractor shall maintain a watch on the formwork during placing to ensure that no movement occurs.

19.5. Removal of Formwork

Falsework and formwork shall be carefully removed without shock disturbance or damage to the concrete. No falsework or formwork shall be removed until the concrete has gained sufficient strength to support its own mass, and any other loads that will be imposed on it. This condition shall be considered to have been achieved when the falsework and formwork has remained in place after casting of the concrete for the minimum period of time indicated in Table 19.1, or when the concrete has attained the strength indicated therein.

Arched linings in tunnels and under ground work shall have a minimum 24 hour strength of 5 N/mm2.

If cement other than Portland cement (CEM I) is used, the Engineer may require the falsework and formwork to remain in place for longer periods.

Table 19.1: Minimum Periods for Removal of Falsework and Formwork

Position of Formwork	Minimum Period	Percentage of characteristic strength
Vertical or near vertical faces to mass concrete	24 hours	20
Vertical or near vertical faces of reinforced walls, beams and columns	48 hours	40
Underside of arches beams and slabs (formwork only)	4 days	60
Supports to underside of arches, beams and slabs		
(a) Spans up to 5m	7 days	80
(b) Spans greater than 5m	14 days	95

Compliance with these requirements shall not relieve the Contractor of his obligation to delay removal of formwork until the removal can be completed without damage to the concrete.

The Contractor may, if he so elects, strip formwork from the soffits of arches, beams and slabs before the expiry of the period for supports as indicated in Table 19.1 provided that the formwork has been designed so that it can be removed without disturbing the supports. The Contractor shall not remove supports temporarily for the purpose of stripping formwork, On continuous reinforced concrete structures, the falsework and supporting formwork shall not be removed until the concrete in the last pour has reached the minimum age or the minimum strength, as given in Table 19.1. Where a structure is constructed in stages, the falsework and supporting formwork shall be removed as specified or authorised.

On prestressed concrete structures, the falsework and supporting formwork shall, unless otherwise specified or authorised, be removed after the full prestressing force for the relevant stage has been applied.

As soon as the formwork has been removed, bolt holes in concrete faces, other than construction joints, not required for subsequent operations shall be completely filled with mortar sufficiently dry to prevent any slumping at the face. The mortar shall be mixed in the same proportions as the fine aggregate and cement in the surrounding concrete and with the same materials and shall be finished flush with the face of the concrete.

19.6. Surface Finishes

The surface finish to be achieved on formed concrete surfaces shall be as shown on the Drawings and defined hereunder:

19.6.1 Class Fl finish

This finish is for surfaces against which backfill or further concrete will be placed. Formwork may be sawn boards, sheet metal or any other suitable material which will prevent the loss of fine material from the concrete being placed. After the repair of any surface defects in accordance with Clause 19.9, no further treatment of the as stripped finish will be required.

19.6.2 Class F2 finish

This finish is for surfaces which are permanently exposed to view but where the highest standard of finish is not required. Forms to provide a Class F2 finish shall be faced with planed tongued and grooved boards with square edges arranged in a uniform pattern and close jointed or with suitable sheet material. The thickness of boards or sheets shall be such that there shall be no visible deflection under the pressure exerted by the concrete placed against them. Joints between boards or panels shall be horizontal and vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting, but fins, surface discolouration and other minor defects shall be remedied by methods approved by the Engineer.

Where a class F2 Board Finish is specified, this shall be obtained with tongued and grooved boards arranged in an approved pattern.

19.6.3 Class F3 finish

This finish is for surfaces which will be in contact with water flowing at high velocity, and for surfaces prominently exposed to view where good appearance is of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be faced with plywood complying with BS 1088 or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surface.

All joints between panels shall be vertical and horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced wrought boarding or standard steel panels will not be permitted for Class F3 finish. The Contractor shall ensure that the surface is protected from rust marks, spillages and stains of all kinds.

19.6.4 Curved surfaces

For curved surfaces where F2 or F3 finishes are called for, the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

Alternatively, single curvature surfaces may be faced with plastic or plywood linings attached to the backing with adhesive or with escutcheon pins driven flush. Linings shall not bulge, wrinkle or otherwise deform when subjected to temperature and moisture changes.

19.7. Tolerances

All parts of formed concrete surfaces shall be in the positions shown on the Drawings within the tolerances set out in Table 19.2.

In cases where the Drawings call for tolerances other than those given in Table 19.2 the Drawings shall rule.

Table 19.2: Tolerances

Class of Finish	Tolerances in mm (See Notes)		
	A	B	C
Fl	10	10	+ 25 to -10
F2	5	10	+ 15 to -10
F3	2	5	± 10

NOTE: The tolerances A, B and C given in the table are defined as follows:
A is an abrupt irregularity in the surface due to misaligned formwork or defects in the face of the formwork.
B is a gradual deviation from a plane surface as indicated by a straight edge 3m long. In the case of curved surfaces the straight edge shall be replaced by a correctly shaped template.
C is the amount by which the whole or part of a concrete face is displaced from the correct position shown on the Drawings.

19.8. Surface Finish and Dimensional Tolerances of Precast Units

The formed faces of precast units shall be finished to Class F3 as set out in Clause 19.6 unless otherwise specified on the Drawings.

Where a special finish is required a trial panel shall be constructed by the Contractor, which after approval by the Engineer, shall be kept available for inspection at the place of casting and production units shall thereafter match the approved pattern.

In addition to the specified tolerances for Class F1 surface finish indicated in Table 19.2, the dimensions indicated in Table 19.3, shall not deviate from the theoretical by more than the maximum deviations indicated, within the tolerance ranges indicated, unless closer tolerances are called for in the Special Specification or on the Drawings.

Table 19.3: Tolerances in Precast Units

i) Dimension	**Maximum Deviation***	**Tolerance Range***
Length (major dimension of unit)	1.5 mm/me	6 to 25 mm
Cross section (each direction)	1.0 mm/m	5 to 10mm
Straightness or bow (deviation from intended line on overall length of unit):		
Horizontal	0.5 mm/m length of unit	6 to 15mm
Vertical	1.5 mm/m length of beam	6 to 20mm
* The permissible deviations given in the table are only applicable before any prestress is applied.		

19.9. Remedial Work to Defective Surfaces

If on stripping any formwork the concrete surface is found to be defective in any way, the Contractor shall make no attempt to remedy such defects prior to the Engineer's inspection and his approval or instructions on the remedial treatment to be applied. Defective surfaces shall not be made good by plastering.

Minor surface defects such as small areas of honeycombing, cavities produced by form ties, large isolated blowholes and broken corner edges, shall be repaired with mortar with a cement to sand ratio equal to that of the concrete being repaired.

Larger areas of honeycombing which in the opinion of the Engineer can be repaired shall be cut back to sound concrete or to at least 25 mm behind the reinforcement or to 75 mm, whichever is the greater distance and the extremities of the cavity shall be recessed at least 20 mm to avoid feather edges. After cleaning out with water and compressed air, a thin layer of cement grout shall be brushed on to the concrete surfaces in the cavity and it shall then be filled immediately with concrete of the same class as the main body but with aggregate larger than 20 mm nominal size removed. A form shall be used against the cavity, provided with a lip to enable concrete to be placed. The form shall be filled to a point above the top edge of the cavity.

After 7 days the lip of concrete shall be broken off and the surface ground smooth.

If so required by the Engineer, an approved proprietary bonding agent and/or repair mortar or grout, applied strictly in accordance with the manufacturer's instructions, shall be used to repair large or deep areas of honeycombing.

Surface irregularities which are outside the limits of tolerance set out in Clause 19.7 shall be ground down in the manner and to the extent instructed by the Engineer.

Defects other than those mentioned above shall be dealt with as instructed by the Engineer.

SECTION 20

STEEL REINFORCEMENT FOR CONCRETE WORKS

CONTENTS

20. STEEL REINFORCEMENT FOR CONCRETE WORKS

20.1. Scope

This section covers the furnishing and placing of reinforcing steel in concrete structures.

20.2. Materials

20.2.1 Steel Bars

Steel reinforcement for concrete shall, unless otherwise specified in the Drawings or Special Specification, comply with BS 4449 for hot rolled plain bar, high yield deformed bar and cold worked steel bar.

For each consignment of steel reinforcement delivered to site, the Contractor shall submit a certificate issued by a recognised authority, to confirm that the steel complies with the specified requirements. The provision of such certificate not withstanding, the Engineer may call for additional tests to be carried out on steel delivered to the site. The costs of such additional tests will be borne by the Contractor if the test results indicate that the steel does not comply with the specified requirements.

Deformed mild steel bars complying in all aspects other than those relating to the deformations, with hot rolled plain bar as specified in BS 4449, may, if approved by the Engineer, be used in the place of hot rolled plain bars, if the deformations on the mild steel bars are significantly different from those on the high yield deformed bars in use on the site, and if the Contractor can satisfy the Engineer that there is no likelihood of confusion between the mild steel bars and the high yield deformed bars. No deformed mild steel bars will be delivered to the site, without the written permission of the Engineer.

20.2.2 Welded Steel Fabric

Welded steel fabric shall, unless otherwise specified on the Drawings, or Special Specification, comply with BS 4483.

20.2.3 Mechanical Couplers

The tensile properties of a test sample with maximum length of 600 mm, made up of reinforcing bars, butt-jointed with a mechanical coupler, shall comply with the following requirements:

(a) When tested in accordance with the relevant requirements of the specified standard, the tensile properties of the test sample shall show at least a 10% improvement on the requirements of the specified standard.

(b) When subjected to a load equal to 60% of the specified minimum yield force of the bar, the elongation measured, shall not exceed the calculated theoretical elongation of a 600 mm long bar subjected to the same load, using a Young's modulus of 200 GPa.

Test certificates from a recognised testing authority, confirming that the tensile couplers offered, comply with the specified requirements, shall be submitted to the Engineer.

All mechanical couplers used shall be subject to the approval of the Engineer.

20.3. Storage of Materials

All steel reinforcement shall be delivered to Site either in straight lengths or cut and bent in accordance with the details shown on the Drawings. No steel reinforcement shall be accepted in long lengths which have been transported bent over double.

Deformed mild steel bars, if approved for use, shall be stored separately from deformed high yield bars.

Reinforcing steel shall be stacked off the ground and in aggressive environments it shall be stored under cover. Any steel reinforcement that has become corroded or pitted to an extent which, in the opinion of the Engineer, will affect its properties shall either be removed from Site and returned to the supplier for appropriate disposal or may be tested for compliance with the appropriate Standard in accordance with Clause 20.2 of this Specification at the Contractor's expense.

20.4. Bending of Steel Reinforcement

Unless otherwise shown on the Drawings, bending and cutting of reinforcement shall comply with BS 8666.

The Contractor shall satisfy himself as to the accuracy of any bar bending schedules supplied and shall be responsible for cutting, bending, and fixing the reinforcement in accordance with the Drawings.

Bars shall be bent cold by the application of slow steady pressure, without jerking or impact.

After bending, bars shall be securely tied together in bundles or groups and legibly labelled as set out in BS 8666 or as otherwise specified.

Reinforcement shall be thoroughly cleaned and all dirt, scale, loose rust, oil and other contaminants removed before it is placed.

Any bar that has already been bent shall not be re-bent at the location of the original bend without authorisation.

20.5. Fixing Reinforcement

Reinforcement shall be securely fixed in position within a dimensional tolerance of 20 mm in any direction parallel to a concrete face and within a tolerance of 5 mm at right angles to a face, provided that the cover is not thereby decreased below the minimum shown on the Drawings, or if not shown shall be not less than 40 mm except that for concrete in contact with sea water the cover shall be not less than 75 mm.

Unless otherwise approved by the Engineer, all intersecting bars shall either be tied together with 1.6 mm diameter soft annealed iron wire and the ends of the wire turned into the body of the concrete, or shall be secured with a wire clip of a type approved by the Engineer.

Spacer blocks shall be used for ensuring that the correct cover is maintained on the reinforcement. Blocks shall be as small as practicable and of a material, shape and design acceptable to the Engineer. Concrete spacer blocks shall be made in specially manufactured moulds of mortar mixed in the proportions of one part of cement to two parts of sand. Wires cast into the block for tying in to the reinforcement shall be 1.6 mm diameter soft annealed iron, and shall not extend into the block deeper than half the depth of the spacer block.

Reinforcement shall be rigidly fixed so that no movement can occur during concrete placing. Any fixings made to the formwork shall not be within the space to be occupied by the concrete being currently placed.

No splices shall be made in the reinforcement except where shown on the Drawings or approved by the Engineer. Splice lengths shall be as shown on the Drawings, and where not shown on the Drawings, as directed by the Engineer.

Mechanical couplers shall not be used unless indicated on the Drawings, or authorised by the Engineer.

Reinforcement left exposed for an indefinite period, shall be adequately protected against corrosion, distortion, displacement or other damage, and shall be properly cleaned before being encased in concrete. When it is necessary to bend protruding reinforcement aside temporarily, the radius of the bend shall not be less than four times the bar diameter for mild steel bars or six times the bar diameter for high yield bars. Such bends shall be carefully straightened before concrete placing continues, without leaving residual kinks or damaging the concrete round them. In no circumstances will heating and bending of high yield bars be permitted.

Cold worked steel bars shall not be bent after placing in the Works.

20.6. Welding of Reinforcement

Reinforcement shall not be welded except where indicated on the Drawings or authorised by the Engineer.

If welding of reinforcement is specified or approved, it shall be carried out in accordance with BS EN 1011-1 & 2 for metal arc welding and the recommendations of the reinforcement manufacturer, subject to approval by the Engineer and the satisfactory performance of trial joints.

Trial welding joints shall be made on the site, in conditions similar to those which will govern during the making of the production welding joints, by the person who will be responsible for the production welding joints.

Structural welds shall be full strength welds, and their strength shall be assessed by destruction tests on samples selected by the Engineer. Structural welds shall not occur at bends.

In welded lap joints, the length of run deposited, shall not exceed five times the diameter of the bar. If a longer length of weld is required, it shall be divided into sections, and the space between the runs shall not be less than five times the diameter of the bar. Unless otherwise approved by the Engineer, welded lap joints in parallel bars forming the principal tension reinforcement, shall be staggered, and the distance between the joints shall not be less than forty times the bar diameter.

20.7. Surface Condition

Immediately before concrete is placed around it, reinforcement shall be completely clean and free from all contamination including concrete that may have been deposited on it from previous operations.

20.8. Reinforcement for Precast Units

Preformed reinforcement cages for precast units shall be made up on jigs to ensure dimensional accuracy and shall be carefully supported within the mould in such a way that they cannot move when concrete is placed. Reinforcement complying with BS 4449 may, if authorised by the Engineer, be tack welded where bars cross to provide rigidity in the cage. Cold worked steel bar shall not be welded.

Cover to main reinforcement shall be as shown on the Drawings, or if not shown shall be not less than 40 mm.

Bars shall be spaced so that the minimum clear distance between them is the maximum nominal aggregate size plus 5 mm but in any case not less than the diameter of the bars.

Bars may be placed in pairs provided that there are no laps in the paired lengths.

SECTION 21

PRESTRESSING FOR CONCRETE WORKS

CONTENTS

21. PRESTRESSING FOR CONCRETE WORKS

21.1. Scope

This section covers the materials, equipment and methods required for carrying out prestressing operations on cast in-situ and precast concrete members.

21.2. General

The Contractor shall submit to the Engineer for approval, full details of all materials, prestressing systems and procedures he proposes to use for the prestressing of structural concrete.

21.3. Materials

21.3.1 Prestressing Steel

(a) General

Prestressing steel shall comply with the following standards in addition to any other standards indicated on the Drawings.

Steel Wire:	BS 5896
Cold worked high tensile alloy bar:	BS 4486
Stress-relieved seven-wire strand:	BS 5896

(b) Straightness

Prestressing bars as delivered at the site shall be straight. Any small adjustments for straightness that are necessary on site shall be carried out by hand under the supervision of the Engineer. If heating of the bars is necessary, this shall be by means of steam, or hot water. Bars bent in the threaded portion shall not be used.

Prestressing wire and strand shall be supplied in coils with a sufficiently large diameter to ensure that the wire or strand will pay off straight.

(c) Surface condition

Prestressing steel shall be clean and free from pitting, loose rust and loose scale at the time of incorporation in the work.

(d) Galvanizing

Galvanized prestressing steel shall not be used unless specified. Under no circumstances shall prestressing steel be subjected to galvanizing after manufacture.

(e) Welds

Prestressing steel used in prestressed concrete shall be weld-free.

21.3.2 Anchorages and Couplers

Anchorages and couplers shall comply with the requirements of BS EN 13391. They shall be of a proven and approved type, appropriate for the prestressing system used. The characteristic value for anchorage and coupler efficiency, determined in accordance with BS EN 13391, shall not be less than 90%.

Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's recommendations.

21.3.3 Sheaths

Sheaths shall be grout-tight and of such material and configuration that bond forces can be transferred from the grout to the surrounding concrete. The properties of the sheath material shall be such that no corrosion attack of the prestressing steel will be induced. Sheaths shall be sufficiently flexible to accept the required curvature without kinking, and sufficiently strong to withstand without damage the stresses which they will be subjected to during handling and after being fixed in position.

Internal and external surfaces of metal sheaths shall be clean and free from pitting, loose rust, loose scale, lubricants and harmful matter at the time of incorporation in the work.

Galvanized sheathing shall not be used, unless specified.

21.3.4 Cable Supports

The stools, saddles or supports for the sheaths shall be of reinforcing or structural steel, and of such form that they remain securely in position and maintain the correct profile of the cables until the concrete placed around them has hardened. Normal web reinforcement shall not be used to support cables, nor shall sheaths or duct formers be placed on previous layers of fresh concrete.

21.3.5 Tendon Spacers

Tendon spacers used inside the ducts to separate individual bars, wires or strands of the tendon shall be of a proved and approved type and manufactured from material which will not induce corrosion of the prestressing steel.

21.3.6 Grout

Grout for filling the ducts of post-tensioned tendons shall, unless otherwise directed or approved by the Engineer as a result of grouting trials, be a colloidal mix of water and Portland cement.

Admixtures of an approved type may be authorised by the Engineer for incorporation in the grout, if tests have shown that their use improves the properties of the grout, eg, by increasing the workability, reducing bleeding, entraining air or expanding the grout. Admixtures shall be free from any product liable to damage the steel or the grout itself, such as chlorides, nitrates, sulfates or sulfides. When an expanding agent is used, the total unrestrained expansion of the grout shall not exceed 10%.

Admixtures shall be applied strictly in accordance with the manufacturer's instructions.

The mixed grout shall have the following properties:

(a) The chloride ions content shall not exceed 750 mg/ℓ
(b) The viscosity of the grout measured in accordance with Clause 2.11 shall be 500 to 2500 cP for horizontal cables and 400 to 1500 cP for vertical cables. The viscosity of the grout 20 minutes after mixing shall not exceed 2500 cP and 1500 cP for horizontal and vertical cables respectively.
(c) Bleeding at 20^{o}C measured in accordance with Clause 2.11 shall not exceed 2% by volume, 3 hours after the grout has been mixed, and the maximum bleeding shall not exceed 4%. In addition, the separated (bleed) water must be reabsorbed after 24 hours.
(d) The cube compressive strength of 100 mm cubes made of the grout and cured in moist atmosphere for the first 24 hours and then in water at 20^{o}C shall exceed 20 N/mm^2 at 7 days.

21.3.7 Protecting agents for unbonded tendons

The material used for permanent protection of unbonded tendons shall not become brittle or fluid with time, and shall be chemically stable for the entire life of the structure. It shall be non-reactive with the surrounding materials, i.e. concrete, tendons wrapping or sheathing, and shall be non-corrosive or corrosion-inhibiting. It shall be impervious to moisture, and shall have no appreciable shrinkage or excessive volume increase. It shall be suitably viscous to permit injection, and sufficiently tough to withstand the abrasion caused when a tendon, precoated with the material, is drawn into the sheath.

21.4. Equipment

21.4.1 General

All equipment shall be in good working order and properly maintained.

21.4.2 Tensioning and Measuring Equipment

Tensioning equipment shall be hydraulically operated and capable of gradually applying a controlled total force without inducing dangerous secondary stresses in the tendon, anchorage or concrete.

The force in the tendon 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.

Tensioning equipment shall be calibrated with a master gauge or proving ring, before the tensioning operation and thereafter at frequent intervals, as directed by the Engineer. The Engineer shall be furnished with a calibration chart showing the relationship between gauge readings and force on the ram for both ascending and descending ram movements. Load measuring devices shall be calibrated to an accuracy of ± 2%.

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 extension of tendons shall be measured to an accuracy of 2% or 2 mm, whichever is the most accurate, and pull-in or release, to an accuracy of 2 mm.

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

21.4.3 Grouting Equipment

The mixer shall be mechanically operated and of a type capable of producing high local turbulence while imparting only a slow motion to the body of the grout. It shall be equipped with a screen with openings not exceeding 1 mm, and shall be capable of producing grout of uniform consistency with fully dispersed cement particles.

Where the capacity of the mixer is insufficient to fill the duct completely with grout a mechanically operated agitator shall be used, capable of maintaining the colloidal condition of the grout during the storing and injection processes. The grout shall be delivered at the structure from the agitator, and the system shall make provision for recirculating the grout from the pump back to the agitator.

The pump shall be of the positive displacement type (piston, screw or similar), capable of exerting a constant delivery pressure of at least 1.0 N/mm^2, and shall incorporate a safety device for preventing the build-up of pressure above 2.0 N/mm^2. The pump shall be fitted with a pressure gauge and a valve, which can be locked-off without loss of pressure in the cable.

All connections in the pipes and between the pipe and the cable shall be airtight. Only bayonet, threaded, or similar types of connectors shall be used.

21.5. Handling and Storage

During storage, transit, construction, and after installation, the sheaths, prestressing steel, anchorages and couplers shall be protected against corrosion, damage or permanent deformation.

All materials shall be stored on site clear of the ground and under cover.

Materials shall be protected from the weather, from splashes from any other materials and from splashes from flame cutting, or arc-welding processes in the vicinity. Suitable protection shall be provided to the threaded ends of bars.

Where there is evidence of deterioration of prestressing steel that has been stored for a prolonged period, the Contractor may be called on to prove by tests that the quality of the steel has not been significantly impaired, and that it still complies with the provisions of the Specification.

When tendons are left untensioned for a prolonged period after installation, they shall not be allowed to become affected by excessive rusting or pitting of the surface. The ends of post-tensioning cables shall be covered with protective wrapping to prevent the ingress of moisture into the duct. Corrosion inhibitors, oils or similar materials used as lubrication or to provide temporary protection, shall be such that they can be completely removed before permanent protection is effected.

21.6. Installation of Tendons, Sheaths and Duct Formers

Where possible, all wires, strands or bars that are to be stressed in one operation shall be taken from the same parcel of prestressing steel. The tendon or cable shall be labelled to show the cable or tendon number, as well as identify from which parcel the steel has been taken.

All cutting of wire, strand or bar shall be performed with a rotating disc or blade cutters or by a method approved by the Engineer. Flame cutting will not be permitted.

Before being installed, prestressing tendons shall be thoroughly cleaned of mill scale, mortar, oil, paint, dust, grease or other deleterious matter.

The tendons, sheaths and duct formers shall be accurately installed to the specified alignment and securely held in position both vertically and horizontally at intervals appropriate to their rigidity and so as not to be displaced during concreting. Unless otherwise shown on the Drawings, the tolerance in the location of the centreline of sheaths or ducts shall be ± 5mm.

Cables shall not be kinked or twisted and no strand that has become unravelled shall be used.

In post-tensioning, cables shall be fitted at both ends with pipes of at least 10 mm diameter, for the injection of grout or protection agents. Vent pipes of at least 15 mm diameter and extending at least 500 mm above the concrete, shall be provided in the ducts at every high point, and at intermediate points approximately 5 m apart, or as indicated on the Drawings or specified by the Engineer. The ends of the injection and vent pipes shall be fitted with clamping or plugging devices capable of withstanding a pressure of at least 1.5 N/mm^2.

Connections to and joints in sheaths shall be made grout tight by using special sheathing couplings and taping.

Individual wires and strands for which extensions are to be measured, shall be readily identifiable at each end of the member.

21.7. Tensioning of Tendons

The prestressing force, whether partial or full, shall not be transferred to the concrete until cube crushing tests have indicated that the concrete has attained the strength specified on the Drawings, and the Engineer has given his approval for the work to proceed.

Stressing of tendons shall be carried out with due care by experienced workmen under the supervision of a technician skilled in the use of the prestressing system and equipment, and the methods of tensioning to be adopted. All possible precautions shall be taken, during and after tensioning, to safeguard persons from injury, and equipment from damage, that may be caused by the sudden release of the energy stored in tensioned tendons.

The supervisor in charge of stressing shall be provided with a schedule sheet indicating the sequence of stressing the various tendons, and a tensioning record sheet showing the theoretical gauge readings, jacking forces, theoretical extensions, release and pull in for each tensioning operation. The sheet shall provide space for entering the corresponding information recorded and observations made during tensioning. The recorded extensions shall be regarded as an indirect measurement of the tensioning force, and shall serve as a control on the force applied. Copies of the completed record sheets shall be submitted to the Engineer within 24 hours of each tensioning operation having been completed.

At the commencement of tensioning, the jacking force shall be taken to 10% of the final jacking force, in order to take up any slack in the tendon, to establish a datum for measuring the extension, and to check the gripping devices and position and alignment of the jacks. The load shall then be increased gradually to the full specified tensioning force, with intermediate gauge readings and corresponding extensions being recorded at regular intervals.

21.8. Pre-tensioning

During the period between tensioning and transfer, the force in the tendon shall be fully maintained by some positive means. The transfer of stress shall take place slowly to minimise any shock, which could affect the transmission length of the tendon. All tendons shall be de-tensioned simultaneously.

In the long-line method of pre-tensioning, sufficient locator plates shall be distributed throughout the bed, to ensure that the wires or strands are maintained in their proper position during concreting. Where a number of units are made in line, they shall be free to slide in the direction of their length, and thus permit transfer of the prestressing force to the concrete along the whole line.

In the individual mould system, the moulds shall be sufficiently rigid to provide the reaction to the prestressing force without distortion.

Where possible, the mechanism for holding down or holding up deflected tendons, shall ensure that the part in contact with the tendon will be free to move in the line of the tendon, so that friction losses are eliminated. If, however, a system is used which develops a frictional force, this force shall be determined by test, and due allowance made for it. For single tendons, the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire, or 10 times the tendon diameter for strand, and the total angle of deflection shall not exceed 15^{o}. Transfer of the tendon force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces, in accordance with an approved method.

After the transfer of force to the member has been effected, the tendons shall be cut off flush with the end of the member, and the exposed ends covered with a heavy coat of an approved bituminous material or epoxy resin.

21.9. Post-tensioning

21.9.1 General

Bursting reinforcement shall be provided in all post-tensioned concrete members, in and adjacent to the anchorage zones, in order to resist the tensile stresses induced in the concrete. Bursting reinforcement shall be detailed on the Drawings, and shall be additional to the spiral or other reinforcement which forms part of the anchorage and is required for strengthening the anchorage and/or assisting in transmitting the tendon forces to the concrete.

Immediately before concreting, the Contractor shall inspect the sheaths for grout-tightness and shall seal all damaged and suspect sections.

Within 2 hours of the concrete having been placed, the Contractor shall demonstrate that sheaths are free from obstructions, that extractable cores can be removed and, where the design permits, that all tendons are free to move in the ducts. All water shall then be expelled with compressed air, and the cables sealed until tensioning takes place.

Before commencement of tensioning, side forms and other restraining elements shall be released or removed, to enable the structural member to deform under the induced force.

21.9.2 Permanent Protection and Bonding of Tendons

(a) General

After tensioning, all tendons shall be permanently protected against mechanical damage and corrosion.

Internal tendons shall, unless otherwise specified, be protected and intimately bonded to the structural member with cement grout.

Where tendons are specified as unbonded, protection may be effected by the use of bitumen, petroleum based compounds, epoxy resins, plastics and similar products, all complying with the requirements of Subclause 21.3.7, and subject to approval.

External tendons (tendons located outside the concrete section) shall be protected in accordance with the details indicated on the Drawings or specified.

(b) Preparation of ducts

Before permanent protection and/or bonding of tendons are effected, ducts shall be checked for blockages and thoroughly cleaned by blowing through compressed air and flushing with clean water. Surplus water shall be removed by compressed air or other approved means. Any blockages, leakages or factors, which may in any way affect the permanent protection or bonding, shall be immediately reported to the Engineer.

Openings at the anchorages other than injection nozzle openings for grout or other permanent protection agents shall be plugged with mortar or other suitable material.

(c) Mixing of protecting agents for unbonded tendons

Mixing of protecting agents shall be strictly in accordance with the manufacturer's instructions.

(d) Mixing of grout

Water shall be put into the mixer first, then the cement. When these are thoroughly mixed, the admixture, if any, shall be added. Mixing shall continue until a uniform consistency is obtained. The water/cement ratio of the mix shall be between 0.40 and 0.45.

Mixing shall not be carried out by hand.

(e) Injection

The injection of permanent protecting agents or grout shall be carried out as soon as practicable after the tendons have been stressed and the Engineer's permission to commence has been obtained.

The injection of protecting agents for unbonded tendons shall be strictly in accordance with the instructions, and the equipment specified by the manufacturer.

Grout injection shall be continuous and shall be slow enough (6 m to 12 m per minute) to avoid producing segregation of the grout. It shall be carried out from one end only, and its progress shall be monitored by the appearance of grout at successive vent holes. When the consistency of the grout emerging from a vent is equal to that of the grout being injected, that vent shall be plugged. Injection shall continue until grout of a consistency equal to that being injected appears at the far end of the duct. The vent at the far end shall be closed and the final pressure shall be maintained on the column for 5 minutes before the valve at the injection end is closed.

All vents shall be kept closed and supported vertically until the grout has finally settled. The filled ducts shall not be subjected to vibration within one day of grouting.

Not less than 2 days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good if necessary.

During the course of grouting, 100 mm cubes shall be made for testing the compressive strength of the grout, as required by the Engineer. Whilst the grout is being poured into the moulds, the sides of the mould shall be slightly tapped to permit any entrapped air to escape.

The Contractor shall keep full records of grouting, including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. Copies of these records shall be supplied to the Engineer within 3 days of grouting.

21.10. Camber of Prestressed Precast Beams

Where the predicted camber due to stressing of precast beams is indicated on the Drawings, the actual camber shall not exceed the stated figure by more than 50 percent.

Where a number of similar units are to be placed side by side, the variation in camber between adjacent units shall not be more than 6.0 mm for units up to 4.5 m in length, or more than 9.0 mm for longer units.

21.11. Rejection of Prestressed Work

Any structural element in which the prestressing tendons, the anchorages, or any part of the prestressed element has been damaged, or in which excessive loss of prestress has occurred, or in which the grouting has not been satisfactorily carried out, or which is deficient in any other manner, will be rejected, and the Contractor shall rectify the deficiency to the satisfaction of the Engineer, failing which the element shall be replaced by the Contractor.

21.12. Testing Prestressed Concrete Members

If instructed by the Engineer, load testing of structures containing prestressed units shall be carried out generally as set out in BS 5400 Part 8.

SECTION 22

STRUCTURAL STEELWORK

CONTENTS

22. STRUCTURAL STEELWORK

22.1. Scope

This section covers the fabrication, transport and erection of structural steelwork for minor structures, eg, overhead road signs and pedestrian bridges. It also covers the preparation and application of protective coatings to steelwork. It does not apply to major steel structures such as large bridges, which shall be covered in the Special Specifications where such work is required.

22.2. Materials

22.2.1 Structural steel

Structural steel shall, unless otherwise specified on the Drawings or Special Specification, comply with the following requirements:

Mild steel: BS 7668, Grade 43A

High-yield stress steel: BS 7668, Grade 50B

The dimensions and properties of rolled steel sections shall comply with the prescriptions given in the structural steel tables issued by the British Standards Institution or equivalent.

22.2.2 Steel tubes

Steel tubes shall comply with the requirements of BS EN 39 or equivalent.

22.2.3 Bolts, nuts and washers

Ordinary bolts and nuts shall be bolts and nuts used for transferring forces by tensile stress, compressive stress and shear stress without any friction-grip action being considered. Ordinary bolts and nuts shall comply with BS 3692 or BS 325 or equivalent. Washers for ordinary bolts and nuts shall comply with the requirements of BS EN 2138 or equivalent.

High-strength friction-grip bolts, nuts and washers shall comply with the requirements of BS 4395-2 (partly replaced by BS EN 14399) or equivalent.

Other friction-grip fasteners equivalent to the above may be used with the approval of the Engineer.

22.2.4 Rivets

Mild-steel rivets shall comply with the requirements of BS 1109 or equivalent. High-tensile rivets shall be so manufactured that they can be driven and their heads formed satisfactorily without the physical properties of the steel being impaired (ASTM A 502).

22.2.5 Welding consumables

Welding electrodes shall comply with the requirements of BS EN 1011-1 or equivalent.

The quality, handling and storage of all consumables shall be so as to achieve the desirable properties of the weld metal.

The welding consumables used shall be appropriate to produce weld metal which will yield all the weld-metal test specimens as specified in BS EN 1043 having both minimum yield and minimum tensile strengths not less than those of the parent metal.

22.2.6 Test certificates

The Contractor shall submit test certificates, as required by the Engineer, of the structural steel, anchor bolts and all other components used for the structural steelwork that will be used.

22.3. Codes of Practice

The design, where undertaken by the Contractor, of all work shall comply with the requirements of BS 5950 Parts 1-9 or equivalent.

22.4. Shop Details

Where shop details have not been furnished on the Drawings, the Contractor shall prepare his own shop details. Shop details shall be approved and signed by the Engineer prior to the fabrication of any items. Approval by the Engineer does not relieve the Contractor of his obligations for any fabrication defects.

22.5. Fabrication and Assembly

22.5.1 General

All structural steel both before and after fabrication shall be within the tolerances specified in Subclause 22.12 and shall be flat, straight (unless required to be formed to another shape) and free from twists.

22.5.2 Marking the steel

At all stages of fabrication, all structural steel other than Grade 43A steel shall be clearly marked by grade by means of a suitable marking system.

22.5.3 Cutting

Steel shall be cut by sawing, shearing with shears, cropping, or flame-cutting.

Edges shall be free from any defects or distortions and all burrs, notches and similar defects shall be removed.

All structural welds shall be full-strength joints.

22.5.4 Holes for fasteners

Holes for fasteners shall not be formed by flame cutting. Holes in light members not thicker than 12 mm or the diameter of the hole, whichever is the smaller, may be punched or drilled.

Holes for fasteners of up to 25 mm in diameter shall not be more than 2 mm larger than the diameter of the fastener and holes for larger fasteners not more than 3 mm larger than the diameter of the fastener.

Holes for friction-grip fasteners shall be in accordance with BS 4604-2 or equivalent.

All burrs shall be removed from holes before assembly.

22.5.5 Joints in compression

The abutting surfaces of joints dependent on contact for the transmission of load shall be accurately prepared so that the full area intended for bearing will be in contact as specified in Subclause 22.12.

22.5.6 Hollow sections

Unless protection against corrosion is provided by other means, the interior of any hollow section shall be sealed to prevent the ingress of moisture. Where a sealed hollow member is holed for a fastener or pin, precautionary measures shall be taken to prevent the ingress of water to the interior of the member. Vent holes for galvanising shall be sealed after galvanizing has been completed.

22.5.7 Alignment of holes

All matching holes for fasteners or pins shall be accurately aligned so that the fasteners can be inserted freely through the assembled members in a direction at right angles to the faces in contact. Drifting for aligning the holes shall not distort the metal or enlarge the holes.

22.5.8 Welding

Welding shall be done in accordance with the requirements of BS EN 1011-1 & 2.

The welding techniques shall be such as to avoid undue distortion and to minimise shrinking stresses.

All slag shall be removed.

Where required for certain welding:

(a) The manufacturer shall hold a valid welding procedures certificate in accordance with BS EN ISO 15611 or equivalent for Grade B welding joints, and the welding shall be done by a welder qualified in accordance with BS EN 287 or equivalent; or

(b) The welder shall hold a valid certificate of competency in accordance with BS 4872-1 or equivalent for the specified type of welding.

22.5.9 Bolting

The jointed parts shall be firmly drawn together. Where necessary, tapering washers shall be used for each bolt head and nut to transfer the compressive stress over its full surface. Where bolt holes have greater than normal clearance, washers shall be placed under the bolt heads and nuts.

The length of each bolt shall be such that, after tightening, at least one full thread projects through the nut on the outside and at least one full thread (in addition to the thread run-out) remains clear between the nut and the bolt head.

22.5.10 Friction-grip fastening

The use of friction-grip bolts shall be in accordance with BS 4604-2 or equivalent. Where use is made of equivalent types of friction-grip fasteners, they shall comply with the requirements of BS 4604-2 or equivalent for equivalent fasteners and shall be installed in accordance with the appropriate requirements of BS 4604-2 or equivalent.

22.5.11 Riveting

Wherever possible, riveting shall be done with pneumatic equipment.

Riveted units shall have all parts firmly drawn together and aligned before riveting. Every rivet shall, when driven, completely fill the hole and shall have a well formed head or, if countersunk, fill the countersink completely.

All loose, eccentric-headed, badly formed, burnt or otherwise defective rivets shall be cut out and replaced.

22.5.12 Trimming

All fabricated steel work shall be neatly trimmed so as not to show any sharp edges. Acute angles shall be rounded off to a radius of at least 1.0 mm.

22.5.13 Corrosion prevention

(a) Painting

Before removal from the place of manufacture the steelwork shall be painted as specified in Subclause 22.11.

Where the finishing coats are to be applied on the site, the shop painting shall include the application of an undercoat as specified in Subclause 22.11.

Galvanized steel shall not be painted unless painting is specifically called for in the Specification.

(b) Sprayed metal coatings

Where the sprayed metal coating of steel surfaces is called for, it shall be done in accordance with the requirements of BS EN ISO 14713 or equivalent. The type of metal used shall be as specified, and, unless otherwise specified, the metal coating shall comply with the requirements of Type AI 150 or Type Zn 150.

(c) Galvanizing

Where the galvanizing of structural steelwork is required, the members shall be hot-dip galvanized. Structural steel members shall be given an 85µm coating or such other thickness as may be specified, in accordance with BS EN ISO 1461 or equivalent. Sheet steel and strip shall be given a Class M coating in accordance with BS EN 10326 or equivalent.

All nuts, bolts, screws and threaded articles shall be hot-dipped galvanized in accordance with the appropriate requirements of BS EN ISO 1461 or equivalent for Type C1 or Type C2 articles.

Cut ends and small damaged areas shall be repaired by the application of a zinc-rich paint or by zinc spraying.

22.6. Erection

22.6.1 General

Where specified, details of the method of erection shall be submitted to the Engineer for approval.

All structural steel shall be stored, transported, handled and erected so as not to subject it to undue stress or damage.

Erection over traffic is not permitted, and a temporary diversion for traffic shall be provided.

Provision for traffic accommodation will be paid for in accordance with the appropriate items under Section 9.

22.6.2 Safety during erection

During the erection of a structure, the steelwork shall be bolted, braced or otherwise secured so as to make adequate provision for all erection loads.

22.6.3 Alignment

Each part of a structure shall be aligned as soon as possible after erection. Members shall not be permanently connected until sufficiently large members of the structure have been aligned, plumbed, levelled, and temporarily secured to prevent their displacement during the erection or alignment of the remainder of the structure.

22.6.4 Corrections

Drift pins, jacking equipment and the like shall not be used for bringing improperly fabricated members into place. A moderate degree of cutting and reaming may be done to correct minor misfits if, in the opinion of the Engineer, this will not be detrimental to the appearance or strength of the structure. The burning of holes will not be permitted without written approval.

22.6.5 Repairs to painting and site painting

Repairs to painting and site painting shall be effected in accordance with the provisions of Subclause 22.11.

22.6.6 Grouting

The grout shall be poured under and around the base plates of columns after the steelwork has been finally checked for alignment and height and after the approval of the Engineer has been obtained to proceed with the grouting. The column base plates shall be supported by the top and bottom nuts and by steel wedges. The area under the steel shall be thoroughly cleaned and shall be dust and oil-free, and the concrete shall be thoroughly rinsed with water to leave the surface clean and moist.

The grout shall be an approved non-shrinking, pourable, cementitious grout. The grout shall be prepared and applied strictly in accordance with the manufacturer's recommendations and the Engineer's directives.

Leak-proof formwork shall be used for the pourable grout, and all corners shall be chamfered. The surface finish shall be Class F2 and Class U2 as applicable.

22.7. Testing

22.7.1 Testing by the Engineer

The Engineer may nominate a testing authority to inspect the Works and to conduct such tests as he may deem to be necessary to test compliance with the Specification.

Where required, test samples of welds shall be prepared by the Contractor, free of charge.

22.7.2 Process control

Welds shall be regularly inspected and tested by the Contractor in terms of his obligations in regard to process control, as described in Section 2. This shall include visual inspection of welds to ensure that no undercutting, uneven lengths, porosity, or evidence of cracking occurs and that full fusion of the metals has been achieved. In doubtful areas, cores containing weld metal and adjacent parent material shall, if so required by the Engineer, be cut out, polished and examined and the hole repaired.

At least 30% of the welds shall be examined by ultrasonic or radiographic means. If more than 5% of the examined welds show unsatisfactory results, additional examinations covering all welds shall be performed.

Certificates of the examination shall be submitted to the Engineer.

22.8. Corrosion Protection of Steel Work

22.8.1 General

This section deals with the protection against corrosion of steelwork.

All corrosion protection work shall be carried out generally according to the relevant sections of BS 5493, BS EN ISO 12944 and BS EN ISO 14713 and with the requirements of this section.

22.8.2 Protective systems

The protective coatings to be applied prior to delivery and/or on Site shall be as stated in the Special Specification and/or the Drawings.

In addition to his other obligations, the Contractor shall be responsible for:

(a) Selection of materials to meet the requirements set out in the Special Specification and/or Drawings

(b) Drawing up a full method specification for the application of the required coatings, based on the recommendation of BS 5493, BS EN ISO 12944 and BS EN ISO 14713

(c) Demonstrating to the Engineer his ability to apply the coatings correctly in accordance with the method specification.

Those parts of the structures that are to be encased in concrete shall be left bare, unless otherwise indicated, and shall be free of loose rust, loose scale, grease and any deleterious matter.

Structural steel bridge members shall be protected against corrosion by paint with a 3 coat polyurethane system manufactured by an internationally recognised company, which shall be approved by the Engineer prior to the painting of any steel. The surface preparation prior to application shall be as specified in Clause 22.9.

The polyurethane coating shall be applied as follows or as per the manufacturer's instructions, especially with respect to the coating thicknesses:

One primer coat -	anti corrosive
One under coat -	high build, anti-corrosive
One finish coat -	high build, protective

The various coats shall be mutually compatible.

22.9. Surface Preparation of Steelwork

Unless otherwise stated in the Special Specification, surface preparation of steelwork shall be by blast cleaning in accordance with the requirements of BS EN ISO 8501, Second Quality, or equivalent. The maximum amplitude of the blast cleaned surface shall not exceed 0.1 mm.

Manual cleaning of structural steelwork including mechanical wire brushing, chipping hammers, vibratory needle guns and the like shall not be permitted except for small parts and then only with the prior written permission of the Engineer.

Surfaces shall be painted with the specified primer paint within four hours of having been blast cleaned.

As soon as the first undercoat has dried, a further stripe coat of paint shall be applied by brush to all edges, corners, crevices, exposed parts of bolts, rivet heads and welds. The stripe coat shall have the same specification as the undercoat but be a contrasting shade.

Painted surfaces shall be cleaned of dust immediately prior to the application of further paint. All loose paint, dirt and grit shall be removed and areas contaminated with oil and grease shall be cleaned with emulsion cleaners followed by washing and rinsing with clean fresh water and allowed to dry thoroughly before paint is applied.

In the case of painted steelwork where the interfaces of High Strength Friction Grip (HSFG) bolts are bare steel, the primer coat shall be taken between 10 mm and 20 mm inside the perimeter of the joint area.

Where paints are to be applied to parent surfaces before making of a joint they shall be stepped back at 30 mm intervals commencing at 80 mm from welded joints and 10 mm from the perimeter of all other joints.

All bolted joints shall be sealed against the ingress of water. Gaps at joints shall be plugged with a filler approved by the Engineer and the perimeter of all joints shall be sealed with subsequent coats of paint.

All joints, welds and surfaces affected by welding shall receive the same protective system as applied to the parent surfaces.

Within 14 days of a joint being made and accepted by the Engineer, the parent material, exposed parts of bolts, nuts and washers, weld and affected areas shall be prepared and painted.

22.10. Damaged Surfaces

Any areas of paint which have been damaged following application shall be cleaned down to bare metal and the full specified painting system shall be re-applied. The new paint shall overlap the existing paint by at least 50 mm all round the affected area.

Galvanized surfaces damaged shall be repaired either by the use of low melting point zinc alloy repair rods or powders made specifically for this purpose or by the use of at least two coats of an approved good quality zinc rich paint to BS 4652.

22.11. Painting

22.11.1 General

Unless otherwise specified, the protection described in this Subclause shall be applied to all steel work. Corrosion protection of steel work exposed to aggressive or severe conditions shall comply with the requirements of the Special Specification or Clause 22.8 if not covered in the Special Specification.

All paint used in the Works shall be subject to the approval of the Engineer.

All paint shall be supplied from the store to the painters ready for application. Any addition of thinners shall be made in the store under the supervision of the Engineer and only as permitted by the manufacturer's data sheet. All the requirements of the manufacturer's data sheet shall be strictly complied with.

Paint shall be applied only to surfaces that have been prepared and cleaned in accordance with the requirements of Clause 22.9. Unless otherwise approved by the Engineer, the use of rollers shall not be permitted for the application of paint.

Paint shall not be applied under any of the following conditions:-

a) When the relative humidity is greater than 90%.
b) During fog, rain or mist.
c) When any moisture is present or likely to condense on the steel.

Each coat of paint shall be free from surface defects.

Successive coats of paint shall have different shades for identification.

The Contractor shall ensure that the proposed application rates shall enable the specified minimum dry film thickness to be achieved. If the total dry film thickness is less than the specified minimum, an extra finishing coat or coats shall be applied until the specified dry film thickness is obtained.

22.11.2 Surface preparation

(a) New structures

After all cutting, drilling, welding and punching have been completed, it shall be ascertained that all sharp edges have been uniformly rounded off and smoothed down. All physically adhering contaminants shall be removed and the surface shall then be abrasive-blasted to SA 2.5 finish in accordance with the BS EN ISO 8501 or equivalent. The profile limit of the surface finish shall be between 30 and 60 µm. The abrasive-blasting profile shall be measured in accordance with BS EN ISO 8503-3 or equivalent and shall comply with BS EN ISO 8503-1 or equivalent.

No abrasive-blasting shall be done during rainy weather or when corrosive air conditions prevail.

Unless the application of a primer follows within four hours of abrasive blasting and before any oxidation of the prepared surface takes place, the abrasive-blasted surface shall immediately after abrasive blasting be given one coat of a wash primer.

(b) Existing structures

The surface preparation of existing structures shall be carried out on site in accordance with BS EN ISO 8504 or equivalent.

22.11.3 Primer

The prepared surface shall be given two coats of a zinc chromate primer in accordance with BS 4652 or equivalent. The first coat shall be applied within 12 hours in the case of wash-primed surfaces and within four hours, but before any oxidation of the surface takes place, in the case of abrasive-blasted surfaces that have not been wash-primed. A fast-drying zinc chromate in accordance with BS 4652 or equivalent may be used as primer. In all cases the dry-film thickness shall not be less than 30 µm per coat.

When steel has to be welded after the primer has been applied, the steel shall be left unpainted for a distance of 75 mm from the weld joint unless a weldable type of paint has been used. The welds shall be treated in accordance with the instructions of Clause 22.9.

22.11.4 Undercoat

Where the finishing coats are to be applied on the site, the primed surfaces shall be given one coat of a universal undercoat with a suitable colour in the fabricator’s shop before despatch. The undercoat shall be applied as soon as the prime coat has dried sufficiently. The dry-film thickness shall not be less than 25 µm.

22.11.5 Finishing coat

Two finishing coats of high-gloss structural paint (BS EN ISO 12944 or equivalent) of the specified colour shall be applied to leave a dry-film thickness of not less than 25 µm per coat.

Where the finishing coats are applied on the site, the undercoat shall be lightly sanded and the members washed and cleaned of all contaminants. The first finishing coat shall be applied as soon as the structural members are dry.

Where specified in the Special Specification, the second finishing coat shall consist of a micaceous iron-ore pigmented structural paint of the specified colour to a dry film thickness of not less than 30 µm. Unless otherwise specified, the second finishing coat shall be applied within 48 hours of the application of the first finishing coat.

The dry-film thickness of the total paint system shall not be less than 110 µm when no undercoat is used and not less than 135 µm when an undercoat is used. Where the second finishing coat is an iron-ore-pigmented paint, these thicknesses shall be increased by 5 µm.

22.11.6 Mating surfaces

When mating surfaces are brought together, both surfaces shall already have been covered with all the specified coats of paint, but, where this is impossible, each surface shall be given a copious coating of primer and the surfaces drawn up while the paint is still wet.

22.11.7 Back-to-back members and areas not easily accessible

Back-to-back members and areas not easily accessible shall be fully coated with all the specified coats of paint up to and including the finishing coats before erection.

22.11.8 Damaged areas

Damaged areas shall be sanded down to bright metal, cleaned and then spot primed with two coats of primer. When hard, the repaired area shall be sanded down lightly and rinsed off with water and allow to dry. Two finishing coats shall then be applied.

22.11.9 Structural steel to be embedded below ground

Those parts of structural-steel members to be embedded in soil and all bases to a height of 500 mm shall be given two coats of an epoxy-tar prime instead of the zinc-chromate prime specified for other surfaces.

22.12. Fabrication and Assembly Tolerances for Structural Steel

22.12.1 General

The fabrication and assembly tolerances on all dimensions for structural steel shall be +2 mm. Holes for connections shall be drilled/punched and aligned as specified in Subclauses 22.5.4 and 22.5.7 respectively.

22.12.2 Cross-section

The tolerances on cross-sectional dimensions of rolled sections shall be as specified in the Structural Steel Tables according to Eurocode 3 or equivalent.

22.12.3 Straightness

A structural member before erection shall not deviate from straightness (or the specified shape) by more than the following:

> For compression members and beams, one thousandth of the length between points which are laterally restrained. For other members, one five hundredth of the overall length, but not exceeding 25 mm.

22.12.4 Length

The length of a member shall not deviate from its prescribed length by more than the following:

For compression members faced at both ends for bearing: +1.0 mm
For other members: +0 mm and -4 mm
For such members as trusses and lattice girders, the above tolerances shall apply to the members as a whole. The lengths of component parts shall be such that the structural member can be properly assembled with the required accuracy.

22.12.5 Bearing surfaces

Where two steel surfaces are required to be in contact for transferring compressive forces, the maximum clearance between the bearing surfaces shall not exceed 1.0 mm when the members in contact are aligned.

22.12.6 Accuracy of erection

Steelwork shall not be out of plumb over any vertical distance by more than 5 mm or one thousandth of the distance, whichever is the greater.

SECTION 23

ROAD FURNITURE

CONTENTS

TABLES

23. ROAD FURNITURE

23.1. Scope

This section covers the supply and installation of items of road furniture including such things as road signs, road markings, various posts, fences and gates, barriers, kerbs and trees.

23.2. Road Reserve Boundary Posts

Where road reserve boundary posts are instructed by the Engineer, they shall be erected as early as possible after commencement of the Contract, on the boundary of the Road Reserve at intervals of 200 m or as otherwise instructed by the Engineer or shown on the Drawings, but not closer than 5 m to any reference point or peg.

Where required by the Special Specification, the Contractor shall immediately establish a reference point on top of each post co-ordinated to an accuracy of ± 5 mm. A schedule of the road reserve boundary posts together with their stake values, offset and co-ordinates shall be submitted to the Engineer before construction on adjacent sections of the Works begins.

Road reserve boundary posts shall be constructed of concrete Class C20/25 reinforced with 10 mm diameter high yield deformed bars as shown on the Drawings. The poles shall be at least 1.5 m above ground level and the top 0.7 m of the posts shall be painted with two coats of suitable white paint and the location and offset of the post shall be painted onto the front face in black.

The Contractor shall excavate for the posts in any material, embed the posts in concrete Class 20/25 all round and under the butt and backfill the remaining excavation, as shown on the Drawings.

The posts shall be maintained in position and kept in a clean and legible state until the issue of the Certificate of Completion.

23.3. Fencing and Gates

Where shown on the Drawings or directed by the Engineer the Contractor shall provide and erect fences and gates, including excavation and backfilling. Fences and gates shall comply with the details shown in the Drawings.

All timber for fencing and gates shall be well seasoned straight-grained hardwood. After all cutting and drilling is complete the timber shall be impregnated with an approved preservative as specified in the Special Specification. Prior to delivery of materials to Site samples are to be submitted by the Contractor to the Engineer for approval.

Galvanizing of fencing wires shall be in accordance with BS EN 10244-2 (ASTM A 123/A 123M).

23.4. Permanent Road Signs

Road signs shall be obtained from a manufacturer approved by the Engineer and before placing any order for the manufacture of the road signs, the Contractor shall submit to the Engineer two copies of the following information:-

(a) Name of the firm from which he proposes to obtain the signs together with place of manufacture or fabrication.

(b) A description of the items to be supplied with manufacturer's specification together with a description of quality, grade, mass and strength.

(c) Manufacturer's "type" test certificates or recent test results carried out on similar terms.

(d) Sample sign post and fittings, which samples shall be stored on site for the Engineer.

All colours on the permanent road signs, with the exception of black and grey, shall be reflectorized, unless otherwise specified or instructed by the Engineer. The reflective sheeting shall comply with the requirements given in Clause 23.5, and shall be applied by mechanical vacuum-heat application method to the approval of the Engineer. The sign plate shall be covered by clear lacquer of a make recommended by the manufacturer of the reflective material.

Permanent road signs shall comply with the requirements of BS 873 Parts 2, 6 (partly superseded by BS EN 12899-1) and 7 in respect of quality including the pre-treatment, preparation and protective coatings for the frame, posts and fittings. Unless directed otherwise posts, frames, fittings and the backs of signs shall be painted with a finish coat of grey. Bolts and nuts shall be spot welded after erection, and a grey epoxy paint shall be applied to all areas so treated.

Finished sign plates (with sign face attached) shall be clearly and durably marked on the back, with the following information:-

(a) The number of the relevant standard to which they have been manufactured.

(b) The name, trade mark or other means of identification of the manufacturer or vendor.

(c) The classification of any retro-reflective material used in the manufacture of the sign face.

(d) The month and year of assembly.

These markings shall be in characters legible at a normal reading distance as specified in the current Manual for Road Signs and Markings such that the total area of the marking does not exceed 3 000 mm^2 and shall be sufficiently durable to last the expected life of the sign plate to which it is applied.

The manufacturer or vendor shall make available the following information:-

(a) Instructions on the assembly and erection of the sign.

(b) Details of any limitations in location or usage.

(c) Instructions on the operation and maintenance of the sign.

The Contractor shall excavate in any material for the foundation of the road signs, provide and place concrete Class C20/25, embedded all round and under the posts and backfill the remaining excavation all as shown on the Drawings or as directed by the Engineer. Foundations for signs of areas over 5 m^2 shall not be covered up until they have been approved by the Engineer.

The Contractor shall cut back trees and vegetation to permit visibility and shall not permit material to be dumped so as to obscure the signs.

All signs shall be maintained in a clear and legible condition and shall be washed down when necessary.

Old signs and any other road furniture that needs to be removed and replaced shall be disposed of at a designated area in accordance with the Environmental Management Plan.

23.5. Reflective Materials on Road Signs

Unless otherwise shown, signs are to be fully reflectorized, using materials complying with BS 873 Part 6 and/or BS EN 12899-1. The photometric performance shall be in accordance with Tables 1 and 2 for Class 1 and 2 materials as set out in the Special Specification.

23.6. Colours for Road Signs

Standard colours to be used for signs, posts and fittings shall be as described in the relevant BS as follows:

Red	BS 381C No. 537
Blue	BS 4800 No. 18 E 53
Yellow	BS 381C No. 355
Green for primary route signs	BS 4800 No. 14 C 39
Grey for posts, fittings and backs of signs	BS 4800 No. 10 A 11
Cream	BS 381C No. 352
White	BS 873 Part 1 - Clause 1-3.2
Black	BS 873 Part 1 - Clause 1-3.3

23.7. Road Marking Paint

23.7.1 General requirements

Road markings shall be as shown on the Drawings or instructed by the Engineer and shall comply with the regulations laid down in the current Manual of Road Signs and Markings or as specified by the Engineer.

The paints to be used for road surface marking shall comply with BS EN 1871 and BS EN 1436. They shall be suitable for applying by screed box, low pressure spraying equipment or high pressure spraying equipment. Brushed application shall only be used with the Engineer's approval. The paint shall be reflectorized unless otherwise specified.

The Contractor shall submit to the Engineer the manufacturer's specification together with the manufacturer's Test Certificate and a sample of paint for possible confirmatory testing by the Engineer. The paint shall be of a type approved by the Engineer, and if not on the current approved list, samples shall be submitted to the Engineer at least 6 months prior to its proposed use for confirmatory testing. The cost of such testing shall be deemed to be included in the Contractor's rates.

23.7.2 Colour

(a) White

The colour of white markings shall be BS Colour No. OOE55 of BS 4800 (ASTM D 6628).

The pigment used for white materials shall be titanium dioxide Type A (Anatase) or Type R (Rutile) complying with BS EN ISO 591-1 (ASTM D 476).

(b) Yellow

The colour of yellow markings shall be to BS Colour No. 08E51 of BS 4800 (ASTM D 6628).

23.7.3 Drying time

The drying time allowed shall be as specified by the manufacturer, subject to the touch dry condition being reached in a maximum of 15 minutes.

23.7.4 Reflectorization

(a) Non-reflectorized

Paint specified to be non-reflectorized shall have minimum reflective brightness values, compared with magnesium oxide (MgO) for white of 80% and for yellow (using a yellow filter of 5800°A) of 65%.

(b) Internal reflectorization

Internally reflectorized paint shall be specifically manufactured for this purpose and shall contain solid glass beads to BS 6088 (partially replaced by BS EN 1423). The glass beads shall be reasonably spherical and free from flaws, and of a size suitable for this method of reflectorization, subject to a maximum size of 0.5 mm.

(c) Surface reflectorization

Surface reflectorization of the paint shall be by application of solid glass beads to BS 6088 (or BS EN 1423 where applicable) to the wet paint film. The glass beads shall be reasonably spherical and free from flaws and of a size suitable for this method of reflectorization, subject to a maximum nominal size of 0.8 mm.

23.7.5 Application

Prior to application of paints, the road surface to be marked shall be thoroughly cleaned of all loose material and shall be completely dry.

The application of paint shall be done by a purpose-made machine, unless brushing is specifically permitted by the Special Specification. All application instructions issued by the paint manufacturer shall be strictly adhered to.

The spraying rate for cold paint will vary with the roughness of the surface, but shall be such as to give continuous coverage and a minimum dry film thickness of 0.125 mm, visually approved by the Engineer.

23.7.6 Traffic control

Warning signs shall be erected when painting is in progress and traffic shall not be allowed to pass over wet paint. Any painting disfigured by traffic, or any painting not complying with the Specification shall be effaced by a method approved by the Engineer and repainted.

23.8. Hot-Applied Thermoplastic Material for Road Marking

23.8.1 General requirements

The material for hot-applied thermoplastic "paint" for road markings shall be in accordance with BS 3262: Part 1 and shall be of a type approved by the Engineer suitable for use in tropical conditions.

23.8.2 Colour

(a) White

The colour of white markings shall be BS Colour No. OOE55 of BS 4800 (ASTM D 6628).

(b) Yellow

The colour of yellow markings shall be to BS Colour No. 08E51 of BS 4800 (ASTM D 6628).

23.8.3 Composition

The thermoplastic material shall consist of light coloured aggregate, pigment and extender bound together with resin plasticized with oil as necessary, in approximately the following proportions:

Aggregate, including glass beads:	60%
Pigment and extender:	20%
Binder:	20%

The maximum size of the aggregate shall be 2 mm. The softening point of the binder shall be 45°-50°C.

23.8.4 Reflectorization

Reflectorization shall be by solid glass beads to BS 6088 and/or BS EN 1423, which shall make up approximately 20% of the total mix, and shall be treated as part of the aggregate. The glass beads shall be reasonably spherical and free from flaws and of a size suitable for this method of reflectorization, subject to a maximum size of 2 mm.

23.8.5 Application

The application of hot applied thermoplastic material shall be carried out by a purpose made machine in accordance with the manufacturer's instructions and shall have a minimum thickness of 3 mm and a maximum of 6 mm.

The width of the road marking shall be as specified in the current Manual of Road Signs and Markings.

23.9. Barriers

23.9.1 Flexible (Cable) barriers

Dimensions and erection details for cable barriers shall comply with American NCHRP 350 Level 3 Specification.

(a) Materials

(i) Cables for barriers shall have a diameter of 19 mm and comprise 21 wires of galvanized high tensile carbon steel with each of these wires having a tensile strength of approximately one tonne. The cables shall be obtained from a manufacturer approved by the Engineer.

(ii) Posts shall be constructed of cold-rolled steel with a wall thickness of 6 mm to BS EN 10025 (ASTM F 1916) as per the manufacturer's drawings.

(iii) Ancillary components such as end anchors, rigging screws etc, shall be to the manufacturer's drawings.

(b) Erection

Cable barriers shall be erected in accordance with the manufacturer's published instructions and the Drawings. Where there is any conflict, the Drawings shall take precedence.

Posts shall be placed at a spacing of 2 400 mm in sockets provided in concrete blocks (Class C20/25 reinforced with 16mm diameter mild steel bars) measuring 350 mm square and with a depth of 1 000 mm such that the top of the post shall be 680 mm above ground level.

The barrier shall comprise 4 cables with the upper two cables placed in the slot provided in the post for this purpose. The lower 2 cables shall be interwoven on either side of the posts and placed in the lugs welded onto the posts.

All cables shall be attached to anchor blocks measuring 1 250 mm square and 1 000 mm deep and, after attachment, shall be individually tensioned to 22.24 kN by tightening the turnbuckles. Intermediate anchors shall be provided to all cable barriers that are over 1 000 m long. They shall be spaced at approximately equal intervals between the end anchors.

The Contractor shall provide the barrier cables, posts and all ancillary components. On completion of construction of the cable barrier, all spoil material shall be removed and discarded in accordance with the Environmental Management Plan and the site left neatly trimmed.

(c) Tolerances
The cable barriers shall be erected at the instructed or detailed offsets and levels from the pavement centreline and shall be correct within a tolerance of ± 20 mm in line and level.

23.9.2 Semi-rigid (Guardrail) barriers

Dimensions and erection details for guardrails shall be as shown on the Drawings.

(a) Materials

(i) Beams
Beams for guardrails shall be Class A with a Type 1 finish in accordance with AASHTO M 180 and shall be obtained from a manufacturer approved by the Engineer.

(ii) Posts
Posts shall be constructed of steel, timber or concrete (Class C20/25 reinforced with 16 mm diameter mild steel bars) as shown on the Drawings.

(iii) Blocks
Blocks shall be made from well seasoned straight-grained hardwood free from loose knots and shakes other than surface splits not exceeding 3 mm depth. After all cutting and drilling has been completed, the timber shall be impregnated by the vacuum/pressure process with a copper/chrome/arsenic composition preservative in accordance with BS 4072, to achieve an anticipated dry salt retention of 12 kg/m^3.

(b) Erection

Guardrail shall be erected in accordance with the manufacturer's published instructions and the Drawings. Where there is any conflict, the Drawings shall take precedence.

Where posts are placed in excavated holes, the excavation shall have sides which are approximately vertical.

The Contractor shall provide the guardrail with all posts, blocks, nuts, washers and shall repair galvanising, backfill around the posts and remove any surplus material to spoil.

When erection is complete and the section has been approved by the Engineer the nuts shall be spot welded to the guardrail or to the bolt to stop their removal.

Galvanized coating damaged by spot welding or cutting shall be renovated either by the use of low melting point zinc alloy repair rods or powders made specifically for this purpose, or by the use of at least two coats of zinc-rich priming paint to BS 4652.

(c) Tolerances

Guardrails shall be erected at the instructed or detailed offsets and levels from the pavement centreline and shall be correct within a tolerance of ± 20 mm in line and level. In addition adjacent plates shall not vary in line or grade by more than 5 mm measured from a line extended from one plate to the end of the adjacent plate; where the guardrail is on a horizontal or vertical curve the calculated deflection shall be added to this tolerance.

23.9.3 Rigid barriers

(a) Materials

The barriers shall be constructed of concrete (Class C20/25 reinforced with 13 mm diameter mild steel bars) and may be either prefabricated or cast in situ using a sliding shutter or equivalent.

The profile of the barrier shall be the New Jersey shape as illustrated in the Drawings.

(b) Erection

The barrier section shall be placed in excavated trenches such that the top of the bottom vertical face is no more than 75 mm above the adjacent layer surface. The sides of the trenches shall be nearly vertical. Where the sides of the excavations can not be maintained vertical, temporary casings may be used. Any lateral overbreak of the excavation is to be backfilled with concrete (Class NS15)

(c) Tolerances

Barriers shall be erected at the instructed or detailed offsets and levels from the pavement centreline and shall be correct within a tolerance of ± 20 mm in line and level.

23.9.4 Tubular steel pedestrian barrier

(a) General

The component members of the tubular steel pedestrian barrier shall be fabricated from Grade 43A mild steel to BS 7668. The barrier railings shall be built up into the separate units and shop welded with slightly concave fillet welds with smooth ripple and without undercut.

The welding shall be neatly executed and cleaned free from scale, and any surplus or unsightly weld metal shall be ground off.

(b) Fabrication

(i) General
The railings shall be fabricated generally in accordance with BS 5400-6 and shall conform in all respects with the Drawings and this Specification.

(ii) Bending
Bending of the tubular steel sections shall be carried out using a process approved by the Engineer, such that the material itself shall be neither harmed nor subjected to flattening or other distortion.

(iii) Cut Ends
Cut ends, which are not to be welded, shall be cleared of any roughness and burrs to leave a smooth surface for subsequent anti-corrosion protection.

Cut ends, which are to be welded shall be sufficiently compatible with the shape of the seat to which they are to be welded such that in the best fit situation at least 50% of the interface shall be in contact with its seating with no visible gap, and the remainder of the interface shall be separated from its seating by no more than 1.0 mm.

(iv) Assembly
The components of the tubular steel barriers shall be placed in jigs and all welding shall be carried out whilst the component parts are restrained from movement by such approved apparatus.

(v) Welding
All welding operations shall be carried out in accordance with the requirements of BS EN 1011-1, using welding equipment complying with BS 638-4.

(c) Storage on site

The transport to and storage on the site of the tubular steel pedestrian barriers shall be such that the risk of damage to the said items shall be kept to the absolute minimum. In the event of such damage, the item damaged will be rejected and shall be replaced, unless the Engineer, at his sole discretion, shall decide that the item can be repaired. The cost of replacement or repairs shall be borne by the Contractor.

(d) Erection

(i) Installation
The barrier shall be erected in the position shown on the Drawings. It is anticipated that the Contractor will choose to 'box out' adequate space within the concrete bases shown in the Drawing in order that the railings may be inserted after construction of the adjacent kerb line. In this instance the railings shall be grouted into the concrete bases in their final positions using a pouring quality cement grout, which shall be subject to the approval of the Engineer. Should the Contractor adopt any other method of installation he shall so inform the Engineer and shall not commence installation until receiving approval for the proposed method from the Engineer.

(ii) Bolting

All boltholes shall be drilled small and reamed, and shall be clean cut without torn or ragged edges. The final bolt holes shall have a diameter of not more than 2 mm larger than the nominal diameter of the bolts.

The bolts and nuts shall be mild steel complying with BS 3692. Washers shall be in accordance with the appropriate sections of BS 3410 and BS 4320, and shall be specially shaped to profile of the adjacent tubular section.

The nuts shall be tightened to one half-turn beyond the point at which two adjacent tubular sections just touch each other, or as otherwise directed by the Engineer. Upon completion of the tightening of the nut, the nut shall be tack welded to the bolt.

The bolting shall be carried out when the barrier elements have been installed in their final positions and are securely held, but prior to their being permanently fixed into the concrete bases.

(iii) Tolerances

The finished railings shall be true to line and height throughout their length with posts truly vertical.

(e) Metal Coating

Metal coating anti-corrosion protection to the tubular steel pedestrian barriers shall be by either galvanizing or sheradizing.

Surface preparation for application, sampling and testing of metal coatings shall be in accordance with the following standards:

BS EN ISO 1461	Hot-dip galvanizing coatings
BS 4921	Sheradized coatings

Metal coatings shall only be applied by an applicator approved by the Engineer. The finished thickness of metal coatings shall be not less than 150 µm.

(f) Drill holes, surfaces affected by site welding, damaged surfaces

Drill holes, surfaces affected by site welding and surfaces whose coating has been damaged shall be treated using low melting point zinc alloy repair rods, or powders made specifically for the purpose, or by the use of a good quality zinc rich paint to BS 4652, all as approved by the Engineer.

(g) Treatment of nuts, bolts and washers

Nuts, bolts and washers shall receive metal coating in accordance with the foregoing Specification in respect of tubular railings.

23.10. Kerbs

Where shown on the Drawings or as directed by the Engineer the Contractor shall excavate in any materials, provide and place concrete for the haunch, backfill, remove surplus material to spoil, provide, lay and joint precast concrete kerbs, edgings and quadrants.

Precast concrete kerbs, edgings and quadrants shall comply with the requirements of BS EN 1340, and shall be laid in accordance with the Drawings.

The concrete for the haunch shall be concrete Class C20/25, which shall comply with the requirements of Section 18 of this Specification.

For radii of 12 m or less, kerbs of appropriate radius shall be used.

Any 1.0 m length of kerb, edging or quadrant deviating more than 3 mm from line and level at either end shall be made good at the Contractor's expense by lifting and relaying.

23.11. Kilometre Marker Posts

Where shown on the Drawings or directed by the Engineer the Contractor shall excavate in any material, provide and place kilometre marker posts as detailed.

Concrete for backfill to kilometre marker posts shall be Class C20/25 complying with the requirements of Section 18 of this Specification.

23.12. Traffic Safety Measures

23.12.1 Edge Marker Posts

Edge marker posts shall be constructed and erected in accordance with the Drawings. They shall be set out at the outer edge of the shoulder with their tops at a constant height above the edge of the carriageway at such locations as the Engineer instructs. Culvert marker posts shall be erected in accordance with the Drawings at the outer edge of the shoulder on one side of the carriageway for each culvert.

Markers shall be erected and painted with two coats of an approved white paint before the road is opened to traffic and shall be kept clean until completion.

23.12.2 Road studs

Where shown on the Drawings or directed by the Engineer, the Contractor shall provide and place road studs. The road studs shall be provided by an approved supplier and shall conform to BS EN 1463. Prior to installation of the road studs, the Contractor shall provide a sample of the road studs intended for use. Placing of the road studs and their fixing to the road surface by means of an approved epoxy resin shall be in accordance with the manufacturer's specification subject to such amendments to the method as may be required by the Engineer.

Before fixing the road studs, the surface shall be thoroughly cleaned by watering, brooming or compressed air and shall be completely free of any soil, grease, acid or any other material that may be detrimental to the bond between the road studs and the road surface.

The studs shall be protected against impact until the adhesive has hardened and also protected during painting of any lines or application of any surface treatments.

23.12.3 Rumble Strips

Where shown on the Drawings or directed by the Engineer the Contractor shall provide, place, trim, shape and compact to line and level rumble strips to the inside of bends of radius less than 1 000 m and at junctions or where directed by the Engineer.

Rumble strips shall be constructed in asphalt concrete or Concrete Class C20/25 to the dimensions shown on the Drawings or directed by the Engineer.

Rumble strips shall extend across the full width of the lane except that a drainage gap/cyclist gap of 300 mm shall be left on the edge of the road.

23.12.4 Speed humps

Noting that speed humps should not be employed on arterial roads and should be avoided where possible on bus routes, the Contractor shall construct speed humps where shown on the Drawings or directed by the Engineer.

Speed humps shall be round-topped in profile but, where pedestrians cross the road, the trapezoidal or flat-top speed hump is preferred. The length of the speed hump, if round topped, shall be 3.7 m and if trapezoidal for use as a pedestrian crossing, it shall be a minimum of 6.0 m, unless otherwise ordered by the Engineer. The height of the speed hump will be as shown in Table 23.1. The speed hump shall extend across the full width of the road except that a drainage gap 100 to 200 mm wide shall be left at either end of the speed hump. If predominantly traversed by passenger cars, the gradient of the ramps of a trapezoidal speed hump shall be 1:15 relative to the gradient of the road on which it is built and, if consideration is to be given to heavy goods vehicles or buses, the gradient shall be flattened to 1:40 relative to the gradient of the road.

Table 23.1: Heights of speedhumps

Desired maximum speed over hump (km/h)	Height of speed hump (mm)
30	120
40	100
50	80

Trapezoidal speed humps shall be constructed of concrete paving blocks or interlocking road stones bedded in mass concrete and with concrete ramps (haunches), whereas round-topped speed humps could be constructed of asphalt concrete. As an aid to visibility, the speed humps are to be demarcated with reflective paint markings, typically in a chevron or check pattern, and the provision of edge marker posts.

23.13. Trees

Where shown on the Drawings, directed by the Engineer, or required in the Environmental Management Plan, the Contractor shall excavate for, backfill with topsoil, provide, plant, water and protect trees within the Road Reserve, around borrow pits and quarries and elsewhere as directed by the Engineer.

The excavation for each tree shall be 0.6 m deep and 0.6 m diameter backfilled with topsoil provided by the Contractor.

The tree seedlings shall be obtained by the Contractor from the District Forestry Officer of the Forestry Department closest to the Works or, if not available, from an alternative source approved by the Engineer in accordance with the Environmental Management Plan.

The tree seedlings shall be of indigenous varieties recommended by the District Forestry Officer or specified in the Environmental Management Plan and the method of transportation, handling, planting and caring for each tree seedling shall be as directed by the District Forestry Officer.

The Contractor shall water daily each tree seedling for the first four weeks after planting. For a further 12 weeks the Contractor shall water each tree seedling as necessary to ensure that each becomes firmly established.

Should any tree be damaged, uprooted or die during the first 16 weeks after planting the Contractor shall immediately replace the tree with a new tree seedling and shall water and care for it as prescribed in this Clause. Should the replacement tree be damaged, uprooted or die within the first 16 weeks after the planting the same conditions shall apply and the Contractor shall continue to replace trees and water and care for them until the end of the Period of Maintenance.

Any protection works that the Contractor deems necessary to protect trees from damage, uprooting or death shall be provided at the Contractor's expense.

All trees instructed by the Engineer shall be planted by the Contractor prior to the issuing of a Completion Certificate for the whole Works or any part thereof.

SECTION 24

MISCELLANEOUS BRIDGE WORKS

CONTENTS

24. MISCELLANEOUS BRIDGE WORKS

24.1. Scope

This Section covers the provision of miscellaneous equipment and work to bridges and includes water proofing, bridge bearings and their protection against corrosion, movement joints and sealants.

24.2. Waterproofing to Structures

Waterproofing shall be applied to all structural concrete surfaces in contact with fill material or cut soil surfaces and wherever detailed on the Drawings or instructed by the Engineer.

Prior to application the surface shall be clean and completely free from damp, moisture, dust, membrane curing compounds, projecting tying wire and nails.

Waterproofing materials shall consist of either bitumen emulsion or cutback bitumen or bitumen/rubber latex emulsion.

Bitumen emulsion shall comply with the requirements of BS 434, Type A160. Two coats shall be applied, the first coat at a minimum rate of 0.55 litres per square metre. The first coat shall be allowed to dry before the second coat is applied.

Cutback bitumen shall be type MC30 as described in Section 16 of the Specification. Two coats shall be applied, the application rates being as described for bitumen emulsion. The first coat shall be allowed to dry before the second is applied.

Bitumen/rubber latex emulsion shall contain a minimum of 10% rubber. Two coats shall be applied, the application rates being as described for bitumen emulsion. The second coat shall be applied when the first coat is touch-dry. Bitumen/rubber latex emulsion shall not be applied during wet weather and should rain occur and cause damage before the rubber has dried the membrane shall be repaired or replaced as approved by the Engineer at the Contractor's expense.

Where concrete is cast against existing ground the waterproofing membrane shall be single layer polythene sheet 0.75 mm thick laid with minimum laps between sheets of 150 mm.

24.3. Waterstops

Waterstops shall be of the material and form shown on the Drawings. No waterstop material shall be brought onto site until the Contractor has submitted full details of the materials he proposes to use, including samples, and these have been approved by the Engineer. All samples shall be of adequate length for testing.

Waterstops shall be made of material that is resistant to chlorides, sulfates, or other deleterious substances, which may be present in the environment of the Works.

Rubber waterstops may be of natural or synthetic rubber and shall have an elongation at breaking stress of at least 500% at 25°C and shall allow a joint movement of at least 20 mm.

Low modulus waterstops shall be of rubber or PVC as described above but shall have an elongation of at least 200% at 25°C under a tensile stress of 6 N/mm^2 and shall allow a joint movement of at least 50 mm.

Waterstops shall be supplied in lengths as long as possible consistent with ease of handling and construction requirements.

In rubber or plastic materials joints other than butt joints shall be supplied ready made by the manufacturer. Butt joints shall be made on site in accordance with the manufacturer's instructions and with equipment supplied for the purpose by the manufacturer.

Waterstop material shall be stored carefully on Site to avoid damage and contamination with oil, grease or other pollutants. Rubber and plastic waterstops shall be stored in a cool well ventilated place away from direct sunlight.

Rubber and plastic waterstops that are embedded in one side of a joint more than one month before the scheduled date of placing concrete on the other side shall be protected from the sun.

Waterstops shall be firmly fixed in the formwork so that they cannot be displaced during concrete placing and shall be completely free of all dirt, grease, oil, etc, before placing concrete. Where eyelets are provided, these shall be fully wired to the reinforcement and be the only means whereby the waterstop is fixed. In no circumstances shall a waterstop be punctured with nails, etc, as a means of fixing.

Concrete shall be placed carefully round waterstops so as to avoid distortion or displacement and shall be fully compacted. Where waterstops lie in a horizontal or nearly horizontal plane, the Contractor shall ensure that no voids are left on the underside of the waterstop.

Formwork round waterstops shall be carefully removed to avoid damage. If waterstops suffer any damage which cannot be properly repaired in situ, the Engineer may require a section of concrete to be removed and the waterstop replaced.

24.4. Grouting of Pockets and Holes and Underpinning of Baseplates

Pockets and holding-down bolt holes shall be thoroughly cleaned out using compressed air and water jet. Holes drilled by a diamond bit shall be roughened. The pockets and holes shall be filled with grout consisting of cement and clean fresh water mixed in proportion of two parts by mass of cement to one part by mass of water. The pouring of liquid grout shall cease as soon as each hole is filled and any excess grout on the surface of the concrete foundation shall be completely removed and the surface dried off before the next operation proceeds.

The space between the top surface of foundation concrete and the underside of baseplates shall be filled with a special mortar made from 1 part by mass of Portland cement and 1 part of fine aggregate, plus an additive acceptable to the Engineer to counteract shrinkage in proportions recommended by the manufacturer.

The special mortar shall be mixed with the lowest water-cement ratio that will result in a consistency of mix of sufficient workability to enable maximum compaction to be achieved.

The special mortar shall then be well rammed in horizontally below the baseplate and from one edge only until it is extruded from the other three sides. The mortar that has extruded shall then be rammed back to ensure complete support without voids.

Where specified, an approved proprietary free flowing, non shrink cementitious grout shall be used for grouting bolt holes and under base plates. Proprietary grouts shall be prepared and applied strictly in accordance with the manufacturer's recommendations.

24.5. Bridge Bearings

24.5.1 Materials

(a) General

If required by the Engineer, the Contractor shall submit test certificates from an approved independent testing authority to show that the respective materials comply with the specified requirements, or a certificate from the designer or patent holder, certifying that the manufactured item complies with relevant product specifications.

All materials used for the manufacture of the bearings shall, unless otherwise specified, comply with the requirements of BS 5400: Part 9.2

(b) Elastomer

The elastomer used in the manufacture of bridge bearings, shall be either natural rubber complying with BS 1154, or chloroprene rubber complying with BS 2752, for the specified IRHD (International Rubber Hardness Degree) hardness.

(c) Stainless steel plate

The texture of the sliding surface of stainless steel plate used in conjunction with PTFE to form low-friction sliding surfaces, shall be equal to or better than 0.2 μm mean roughness (R_a) in accordance with the requirements of BS 1134.

(d) Bedding Mortar

Bedding mortar shall be composed of an approved sand and cement or epoxy resin, or may consist of an approved proprietary mortar.

The 7-day compressive strength of 150 mm cubes made from sand-cement mortar and cured in accordance with the requirements for concrete cubes, as specified in clause 2.10 shall not be less than 1.5 times the average contact stress under the bearing, or 15 N/mm^2, whichever is the greater.

The cured compressive cube strength of sand-epoxy resin mortar shall not be less than two times the average contact stress under the bearing, or 20 N/mm^2, whichever is the greater.

The strength requirements of proprietary mortars shall comply with the above requirements, as may be relevant.

24.5.2 Elastomeric bearings

(a) General

The following technical data for each elastomeric bearing or group of identical elastomeric bearings will be indicated on the Drawings. This data shall also be provided on drawings prepared by the Contractor for submission to the Engineer.

- (i) The design loads and deformations
- (ii) The overall dimensions, the number and thickness of individual elastomer layers, and the thickness of the steel plates. The steel plates shall be encased in a 3 mm thick elastomer layer.
- (iii) The hardness and type of elastomer

Where alternative bearings are offered by the Contractor, they shall be designed in accordance with the requirements of BS 5400 Part 9.1 for the loadings and deformations shown on the Drawings.

Where a different type of rubber to that specified for the bearings is offered, the bearings shall be re-designed to make provision for the variation in hardness and/or type of rubber.

(b) Inspection and testing

On completion of manufacture of the bearings, the Contractor shall submit bearings selected by the Engineer, or specially manufactured bearings to serve as samples as authorised by the Engineer, to an independent testing authority for testing. The testing facilities of the manufacturer may be used if so approved, on condition that the tests are conducted in the presence of the Engineer, or his nominee.

The Engineer shall determine which tests are to be conducted, and they shall be carried out in accordance with BS 5400 Part 9.2. The bearings shall comply with the requirements specified therein.

Test results and certificates shall be submitted to the Engineer in good time, to permit assessment of the information before the bearings are installed.

Where compression and stiffness tests are conducted on sample bearings or only on a limited number of bearings in a consignment, the stiffness values as determined by the tests shall be within 20% of the theoretical values.

The dimensional tolerances for the bearings shall comply with the requirements of BS 5400 Part 9.2.

24.5.3 Proprietary Bearings

(a) General

This clause covers custom built bearings and bearings manufactured under licence, except elastomeric bearings. Bearings consisting of an assembly of an elastomeric bearing in conjunction with low friction sliding or mechanical components shall fall under this clause.

(b) Drawings for approval

Prior to the manufacture of the bearings, the Contractor shall submit drawings showing the bearing construction and installation details for each type of bearing, for the consideration of the Engineer. The drawings shall provide details of the manufacturer's specification, including design standards, materials, manufacture and technical data, as well as the friction properties based on actual tests conducted on the relevant materials.

The design loads and movements for each bearing will be indicated on the Drawings, and shall also be indicated on the drawings prepared by the Contractor for submission to the Engineer.

(c) Design

The bearings shall be designed in accordance with the requirements and recommendations of BS 5400 Part 9.1. In addition, the maximum pressure on the area of the elastomer shall not exceed 25 MPa, and the edge stress on the concrete or mortar bedding shall not exceed 0.5 times the 28-day cube strength under the serviceability limit state, unless otherwise prescribed by the Engineer,

Bearings will be of dimensions as will fit into the spaces allowed for their installation.

(d) Construction

Unless otherwise specified, the following shall be complied with:

(i) The thickness of the elastomer disc shall not be less than 0.066 times its diameter.

(ii) Only approved lubricants shall be used on the PTFE sliding surfaces.

(iii) The bearing shall be provided with tight-fitting seals to prevent the ingress of dust and deleterious matter onto the moving parts. The seals shall be of an approved type, and sufficiently durable to last in excess of 50 years.

(iv) The assembled bearing shall be supplied with welded or bolted lugs or straps temporarily securing the moving parts against undesirable relative movement before or during installation.

(v) The bearing shall be of such construction as to facilitate removal of the bearing from the installed position without damage to any part of the bearing, or the surrounding material, after the relevant structural member has been raised by 15 mm.

(vi) All exposed steel surfaces, with the exception of stainless steel shall be corrosion protected as recommended by the manufacturer for the relevant exposure condition. Surface preparation prior to the application of the corrosion protection shall also be in accordance with the manufacturer's specification. The method of surface preparation and corrosion protection shall be subject to the Engineer's approval.

(e) Inspection and Testing

The Contractor shall give the Engineer at least 7 days notice prior to final assembly of the bearings, to enable the Engineer, or his nominee, to inspect the bearings at the factory.

The Engineer may require tests to be carried out to verify compliance of the bearing with the Specification and/or its satisfactory performance under the design loads.

Test certificates of all tests conducted shall be submitted to the Engineer.

24.5.4 Storage and Handling

Bearings shall be stored under cover and clear of the ground, away from sunlight, heat, oils and chemicals deleterious to the bearings. The bearings shall not be stacked in a manner or on a surface that will cause distortion of the bearings.

Bearings shall be handled with care to ensure that they are not subjected to impact or any other harmful conditions.

24.5.5 Installation

The concrete surface on which the mortar bedding is to be constructed, shall be chipped back to expose the aggregate and leave a sound irregular surface. Bonding of the mortar bedding to the concrete surface shall be in accordance with the manufacturer's recommendations and the Engineer's instructions.

Bearings shall be installed on a horizontal plane within a tolerance of 1 in 200 in any direction, unless otherwise specified. They shall be in full contact with the concrete and the bedding surface.

In the case of precast members, soffit irregularities and camber shall be accommodated by lowering the member onto a mortar skim placed on top of the bearing. The member shall then be propped until the mortar skim has hardened into a wedge.

Bearings shall be installed to the specified level, alignment and orientation within 5 mm of the position shown on the Drawings, and 3 mm of the specified level.

24.6. Movement Joints and Sealants

24.6.1 Materials

(a) General

All materials used to form, construct and seal permanent joints, as well as all custom built or proprietary expansion joint assemblies shall be subject to the approval of the Engineer.

If required by the Engineer, the Contractor shall submit test certificates issued by an approved, independent testing authority to confirm that the respective materials comply with the specified requirements, or a certificate by the patent holder or designer certifying that the manufactured item complies in all respects with relevant product specifications.

(b) Joint fillers

Joint fillers shall consist of the following materials complying with the relevant specifications listed:

(i) Bitumen-impregnated fibreboard and bitumen-impregnated corkboard - US Federal Specification HH-F-341F or AASHTO M 213.

(ii) Resin impregnated corkboard US Federal Specification HH-F-341F.

(iii) Flexible foams of expanded polyethylene, polyurethane, polyvinylchlorate or polypropylene-AASHTO F 153.

(iv) Rigid forms of expanded polyethylene, polyurethane or polystyrene-BS 4840 or BS 3837.

Other materials may be used if approved by the Engineer, after full specifications and samples have been furnished to him by the Contractor.

(c) Sealants

Sealants shall comprise one of the following, complying with the relevant specifications listed:

(i) Thermoplastic hot poured sealants - US Federal Specification SS-S-156, BS EN 14188 or AASHTO M 173. Sealants shall be of the rubberised bituminous type containing a minimum of 20% natural or synthetic rubber.

(ii) Thermosetting chemically curing sealants – ASTM C 920 or BS EN ISO 11600. The final IRHD hardness of the sealant shall be 20 ± 5

(iii) Silicone sealants – BS EN ISO 11600.

Other sealants may be used if approved by the Engineer, after full specifications and information have been furnished to him by the Contractor.

(d) Waterstops

Waterstops shall comply with the requirements of Clause 24.3.

(e) Accessory material

(i) Primers

Where a primer is to be used in conjunction with the sealant, it shall be of the prescribed proprietary material.

(ii) Bond breakers

Polyethylene tape, coated paper, metal foil or similar material may be used where bond breakers are required.

(iii) Backup material

Backup material shall consist of a compressible material of correct width and shape to ensure that, after installation, it will be in approximately 50% compression and the sealant can be formed to the specified depth.

Backup materials shall be compatible with the sealant used. Material containing bitumen or volatiles shall not be used with thermosetting chemically curing sealants.

(iv) Cover plates

Steel cover plates shall be of Grade 43A steel, which complies with the requirements of BS 7668 or equivalent. Galvanising shall comply with the requirements of BS EN 10326 or equivalent. Anchor bolts shall be of stainless steel Grade 302 S.21, which complies with the requirements of BS EN 10088.

24.6.2 Filled and unfilled joints

(a) General

Wherever polystyrene or similar material susceptible to damage is used for forming joints, it shall be lined with a hard surface on the side to be concreted. The hard surface shall be sufficiently resilient to ensure that the joint and surfaces can be formed free from defects.

(b) Filled joints

Filled joints shall be accurately formed to the dimensions shown and with the filler material specified on the Drawings. The filler shall be secured in position not to displace during concreting or thereafter if the filler is to remain permanently in the joint.

Where removal of the filler is required, it shall be done prior to installation of the proprietary joint.

(c) Unfilled joints

Unfilled joints shall be accurately formed to the dimensions given on the Drawings, and all external corners chamfered or rounded for at least 5 mm. The concrete face against which the fresh concrete is placed shall be treated in good time with an approved bond breaker.

24.6.3 Concrete nosings

Concrete nosings forming the edges of expansion joints shall be constructed as follows:

After the concrete in the structural member has hardened sufficiently, the protruding ends of the reinforcing steel shall be bent flat onto the concrete surface of the formed recess.

Before the asphalt surfacing is laid, the recess shall be filled with well-compacted crusher run, sand or weak mortar. The Contractor shall ensure that the concrete surfaces of the recess and the reinforcing steel are not contaminated with bituminous agents. The asphalt surfacing shall then be laid continuously over the joint.

The asphalt surfacing shall be cut with a diamond saw blade to correspond to the width of the nosing and all material shall be removed from the nosing recess. The concrete surfaces of the recess shall then be roughened to expose the aggregate and leave sound, irregular surfaces. The reinforcing steel shall then be bent, fixed and placed as shown on the Drawings.

The prepared concrete surfaces of the recesses shall be treated with an approved epoxy-resin adhesive, immediately before the concrete nosings are cast. Opposite concrete nosings, separated by a joint filler strip, shall be cast simultaneously in accordance with Subclause 18.19, and compacted by vibrator. The nosing shall be screeded flush with the premix surfacing and be given a Class UF2 surface finish.

The concrete nosing shall be cured with an approved curing compound.

After three days, the gap between the nosings shall be enlarged to the requisite dimensions by cutting both sides with parallel diamond saw blades. The depth of the saw cut shall be such that a ledge is formed along the lower edge of the cut on which the sealer unit can be supported.

The exposed corners of the nosings shall be ground to a 10 mm chamfer.

After the joint has been sealed, the wearing surface of the nosings shall be treated with a bituminous primer to the satisfaction of the Engineer. Unless otherwise specified, traffic shall not be permitted to pass over the joint before the concrete in the nosing has aged for at least 10 days.

Unless otherwise indicated on the Drawings, the concrete used in the construction of the nosings shall be Class C25/30 and shall have a slump of not less than 50 mm and not more than 75 mm.

Concrete nosings shall be constructed under the direct supervision of experienced and skilled personnel.

24.6.4 Asphalt plug type expansion joints

Asphalt plug type expansion joint systems shall be constructed in accordance with the details on the Drawings and the Specification and instructions of the licensees.

24.6.5 Sealing the joints

(a) General

Sealed joints shall be made watertight over the full length of the joint, including the full height of the kerbing, unless otherwise prescribed in the Special Specification.

Unless a waterstop is equipped with an effective watertight interlocking system for joining sections all joints in waterstops shall be bonded or fused to have a tensile strength of at least 50% of that of the unjointed material. At intersections and abrupt changes of direction, waterstops shall be jointed with prefabricated junction pieces.

Restrictions on joint width and on the temperature at the time of installing the sealant or seal will be shown on the Drawings. In the absence of such restrictions on the Drawings, and unless otherwise specified, installation shall be carried out only when the air temperature is less than 30°C.

(b) Preparing the joints

Where required, joints shall be sawn at a suitable time so as to avoid edge spalling or ravelling.

After the temporary filler material has been removed or the excess concrete has been broken out, the inside faces of the joint shall be wire-brushed or sand-blasted to remove all laitance and contaminants. The joint shall then be cleaned and blown out with compressed air to remove all traces of dust. Solvents shall not be used for removing contaminants from the concrete and porous surfaces.

The Contractor shall ensure that primers are applied only to surfaces which are absolutely dry. The primer shall be applied strictly in accordance with the manufacturer's instructions. Unless otherwise specified, the primer shall be applied at an air temperature less than 40°C, and the sealant shall be applied after the curing period of the primer and within the period when the primer remains active.

(c) Sealants

Sealants shall be applied strictly in accordance with the manufacturer's instructions by a person skilled in the use of the particular type of sealant. Trapping of air and the forming of voids in the sealant shall be avoided. The sealant shall be finished to a neat appearance to the specified depth.

The safe heating temperature of thermoplastic sealants shall not exceed the specified pouring temperature by more than 10°C.

Two-part thermosetting chemically curing sealants shall not be applied after expiry of the specified pot-life period which commences once the base and activator of the sealant have been combined.

24.6.6 Proprietary expansion joints

(a) General

The use of any type of expansion joint shall be subject to approval by the Engineer.

(b) Dimensions

The Contractor shall note the overall dimensions of the expansion joints and the limiting dimensions of that portion of the concrete structure which is to accommodate the joints. No alterations to the concrete, which will be visible in the final structure or major re-arrangement of the prestressing anchorages will be permitted in order to accommodate joints of excessive size.

All joints to be installed skew shall be accurately dimensioned to ensure that any irregularities in the installed joint surface are within the specified tolerances for the road surface.

Unless otherwise specified, proprietary expansion joints shall include the complete expansion-joint assembly, traversing the entire roadway, kerbs, sidewalks and median, and shall include the coping and parapet cover plates as well as the drainage system to drain the expansion joint.

(c) Design and manufacture

The expansion joint shall be designed to withstand the movements, displacements and rotations specified on the Drawings in conjunction with the loads described in the code of practice adopted for the design of the structure without exceeding in any member the requirement for serviceability limit state. Any strengthening of the supporting member required to resist forces imparted by the joint to the structure shall be for the Contractor's account.

The specified movements, displacements and rotations shall be withstood without the efficacy or riding quality of the joint being impaired.

The joint shall be vibration free, resistant to mechanical wear and other forms of abrasion, and shall resist corrosion. It shall have good riding characteristics, shall be highly skid resistant, silent, and of watertight construction or have provision for the disposal of water, debris or grit collecting in the joint. It shall be of a construction that will facilitate easy inspection, maintenance and repair.

Apart from stainless steel, all steel surfaces shall be protected against corrosion as recommended by the manufacturer for the relevant exposure condition. Surface preparation prior to application of the corrosion protection shall also be in accordance with the manufacturer’s specification. The method of surface preparation and corrosion protection shall be subject to the Engineer’s approval.

Prior to manufacture of the joints, the Contractor shall submit for approval detail drawings of each expansion joint.

The expansion joints delivered at the site shall be suitably marked to show clearly the sequence and position of installation.

24.6.7 Installing the expansion joints

Proprietary expansion joints shall be installed by approved specialist subcontractors only. Installed proprietary expansion joints shall have a 15 year written guarantee.

No expansion joint or part thereof shall be installed prior to construction of the final surfacing, unless otherwise approved.

The expansion joint shall form an even surface with the road surface on either side and the deviation across and along the expansion joint shall comply with the tolerances specified for the road surface, for surface regularity measured by ordinary straight-edge.

On completion of the installation of the proprietary expansion joints, the Contractor shall submit to the Engineer a certificate from the manufacturer or supplier of the joints certifying acceptance of the installation. Notwithstanding the issuing of such certificate, it shall not relieve the Contractor of his responsibility under the Contract.

24.7. Weepholes

Where shown on the Drawings or directed by the Engineer, the Contractor shall cast weepholes into concrete walls. The Contractor shall provide and place plastic pipe of the diameter shown on the Drawings to form weepholes which shall be firmly held in position during placing of the concrete and shall be cut flush with the face of the concrete. A 500 mm x 500 mm square of suitable approved geotextile (of mass 280 g/m^2) shall be placed, central on the weephole between the concrete wall and the backfill materials.

24.8. Galvanized Coatings

Galvanized coatings on iron and steel shall comply with the following standards as appropriate:-

Galvanized coatings on corrugated sheets	BS 3083
Galvanized coatings on iron and steel	BS EN ISO 1461
Galvanized coatings on steel and strip	BS EN 10326
Galvanized coatings on wire	BS EN 10244

SECTION 25

TIMBER BRIDGE WORKS

CONTENTS

TABLES

25. TIMBER BRIDGE WORKS

25.1. Scope

This Section covers structural timber work for bridges, excluding timber piles.

25.2. Definitions

Regularized timber is timber that has undergone a machine process by which the width and thickness have been made uniform throughout its length.

Processed timber is timber that has been worked on all four faces to provide a planed or other smooth finish.

A connector is a device inserted into a joint to prevent relative movement parallel to the face of the joint.

Joint plates are metal plates placed on each side of a joint through which the joint fasteners are passed.

25.3. Quality of Timber

The timber used in the Permanent Works shall be one of the permitted species listed in the Special Specification or shown on the Drawings. It shall be seasoned to a moisture content at the time of installation in the Works not exceeding the figure shown in the Special Specification.

The timber shall have a grade classification as shown on the Drawings or in the Special Specification when graded in accordance with BS 5756 (HS grade) and shall be free from deterioration caused by decay or insect attack.

Logs shall be free of bark.

25.4. Dimensions

Sawn timber shall, when seasoned, be full to the dimensions shown on the Drawings with adjacent faces at right angles and shall be regularised unless otherwise approved by the Engineer.

Processed timber shall after processing have transverse dimensions not less than the following:

For sawn dimensions up to 100 mm, the sawn dimension less 3 mm.

For sawn dimensions over 100 mm up to and including 150 mm, the sawn dimension less 5 mm.

For sawn dimensions over 150 mm the sawn dimension less 6 mm.

When logs are used for cribwork, no face log shall have a diameter at the small end of less than 250 mm. Tie logs shall not be less than 200 mm at the small end. The face log in the base tier shall not be less than 300 mm at the small end.

All logs for cribwork shall be selected to give as small an amount of taper as possible.

25.5. Preservative Treatment

Timber shall receive the preservative treatment shown in the Special Specification. Before treatment, as much as possible of the required working shall be carried out. When cutting after treatment cannot be avoided, the cut surfaces shall be liberally treated with the preservative used for the timber.

Where no specific type of treatment is called for on the Drawings or in the Special Specification, timber shall be treated with a water borne preservative of either Type CCA (Hexavalent chromium, copper, arsenic) or ACZA (Ammonia, copper, zinc, arsenic). Timber preservatives and treatment methods shall conform to AASHTO M 133. Treatment shall be undertaken in an approved facility in accordance with the Environmental Management Plan by trained personnel with appropriate protective clothing.

25.6. Inspection

The Contractor shall provide all necessary facilities to enable the Engineer to inspect each piece of timber on all four sides on delivery to Site and again immediately prior to installation in the Works. The Contractor shall also provide facilities to inspect the timber before and after the preservation process if the Engineer so requires.

Timber which has suffered bruising, splitting or other damage shall not be used in the Permanent Works.

25.7. Handling and Storage

Timber shall be handled in a manner to prevent any damage and shall not be subjected to excessive stresses. It shall be protected from rain and sun. It shall be stored on a hard dry level base which will not settle unevenly under the weight of the stack. It shall be placed on timber supports that are truly level and spaced so as to avoid undue warping. The supports in the stack shall be located vertically above one another and in such a manner that there is an air space all round.

25.8. Joints in Timber Work

Joints shall be neatly and accurately formed. Meeting faces shall be in contact over the full area without wedges or filling pieces. The faces of butt joints in compression shall be at right angles to the direction of stress. Scarfed joints shall be made so that timbers on each side of the joint are truly in alignment.

Notches shall as far as practicable be formed by cutting towards pre-drilled stress relieving holes.

Timber shall be worked and installed at a moisture content which does not differ by more than three percent from its estimated stable moisture content in the Works.

All joints shall be subject to the approval of the Engineer. Unsatisfactorily formed joints, which in the opinion of the Engineer will affect the structural integrity and/or appearance of the completed structure, shall be dismantled and reformed, if necessary with new timber members and/or fasteners, all to the satisfaction of the Engineer.

25.9. Fastenings

25.9.1 Nails

Nails shall be of the type and gauge shown on the Drawings or listed in the Special Specification and long enough to penetrate at least 90% of the total joint thickness unless clenching is required. They shall not be driven into end splits. The surface finish on nails shall be as stated in the Special Specification.

Whenever necessary to avoid the splitting of timber, holes shall be pre-drilled to a diameter not exceeding 0.8 of the diameter of the nail.

Unless otherwise shown on the Drawings nails shall be driven so that the spacing is not less than that shown in Table 25.1.

Table 25.1: Spacing of Nails and Screws

Direction of Spacing:	Without Pre-drilling	In pre-drilled holes
From end of timber	20 D	10 D
From edge of timber	5 D	5 D
Between nails across grain	10 D	3 D
Between nails along grain	20 D	10 D
NOTE: D is the diameter of the nail and the distances are centre to centre.		

25.9.2 Screws

Screws shall be of the type and gauge shown on the Drawings or listed in the Special Specification and long enough to penetrate at least 90% of the total joint thickness. Screws shall not be placed in end splits. The surface finish on screws shall be as stated in the Special Specification.

Holes for screws shall be pre-drilled to a depth equal to the length of shank and to a diameter equal to that of the shank. The remainder of the hole, if in hardwood, shall be pre- drilled to a diameter equal to 0.9 of that of the root of the thread adjacent to the shank and, if in softwood, to the extent necessary to prevent splitting.

The spacing of screws shall be as set out in Table 25.1.

Screws shall be driven fully home but without excessive crushing of the timber under the head. The thread of the screws may be dipped in grease to ease driving but excessive quantities shall not be used.

Holes for countersunk head screws shall be countersunk sufficiently to enable screw heads to be driven flush. Hexagon headed coach screws shall carry a washer under the head of the same size as that specified for an equivalent bolt.

25.9.3 Bolts

Bolts shall be of the type and diameter shown on the Drawings or listed in the Special Specification and of a length such that when the nut is fully tightened the bolt end extends at least one full thread beyond the nut.

Holes for bolts shall be pre-drilled to the same diameter as the bolt or not more than 1.5 mm larger. The joint members shall be firmly clamped while bolt holes are drilled. The minimum spacing of bolts shall be as set out in Table 25.2 unless the bolt arrangement is detailed on the Drawings. A washer of the type and size shown on the Drawings or listed in the Special Specification shall be placed under both the head and the nut and the nut shall be fully tightened. Bolts, nuts and washers shall be galvanized or sheradized.

Table 25.2: Spacing of Bolts

Direction of Spacing	Distance between centres
(a) Load at right angles to grain	
From end of timber	4 D
From edge of timber	4 D
Between bolts along grain:	
Timber thickness equal to D	2.5 D
Timber thickness 3 times D	5 D
Between bolts across grain	4 D
(b) Load parallel to grain	
From end of timber:	
Tensile loads	7D
Compressive loads	4D
From edge of timber	1.5D
Between bolts along grain	4D
Between bolts across grain	4D
NOTES: (i) In (a) above the distance between bolts along grain for other timber thicknesses may be interpolated. (ii) D is the diameter of the bolt.	

25.9.4 Connectors

Connectors for use in joints shall comply with BS EN 912 and shall be galvanized. The type, size and spacing of connectors shall be as shown on the Drawings.

Connectors shall be accurately positioned so that the associated bolt passes cleanly through the centre hole.

Connectors shall be fully embedded and joint faces drawn into contact by means of screw jacks, clamps or other means acceptable to the Engineer before bolts are inserted. The timber shall not be crushed or otherwise damaged during this process.

In the case of split ring or shear plate connectors the joint faces shall be prepared by grooving with a tool made for the purpose in accordance with BS EN 912.

25.9.5 Joint Plates

Joint plates shall be of mild steel complying with BS EN 10029 and shall be the size and thickness shown on the Drawings.

Joint plates shall be pre-drilled accurately to the required centres. Hole sizes shall be the diameter of the required nail, screw or bolt plus 1.5 mm.

When joint plates are used in conjunction with bolts, the joint members shall be accurately drilled using a jig or drill guide so that joint plates will fit onto the bolts at both sides of the joint. Any residual mis-match shall be corrected by reaming the joint plate.

Plates shall be galvanized after cutting and drilling. Any damage caused to galvanizing during installation shall be repaired by the application of an approved zinc-rich paint.

25.9.6 Drifts

In cribwork each successive tier of logs or timbers shall be driftbolted to the one on which it rests by drifts not less than 20 mm in diameter and of sufficient length to extend through 2 tiers and not less than 100 mm into the third tier. Drifts shall be staggered and not more than 2.5 m apart. All end joints and splices shall be overlapped for 250 mm and driftbolted at the centre.

25.10. Painting

Surfaces which are to receive a painted finish shall be sound, clean and dry and free from oil and grease. Small holes and other fissures shall be filled with a hard waterproof stopping acceptable to the Engineer.

Where timber has previously received preservative treatment, painting shall be delayed until all danger of adverse effects on the paint has passed.

The type of paint to be used, the number of coats and the total film thickness shall be as stated in the Special Specification.

25.11. Action Prior to Handover

Immediately prior to handing over the Works, the Contractor shall check all screwed and bolted joints and shall tighten any screws or bolts which have become loose.

SECTION 26

PILING

CONTENTS

TABLES

26. PILING

26.1. Scope

Foundation piles are load-bearing members made of steel, concrete, timber or a combination of these materials. This section applies to the construction of such piles to be installed by driving, and by boring with or without grouting.

26.2. General

Piling shall conform to the principles contained in BS 8004.

Unless otherwise stated, concrete, reinforcement and formwork shall be in accordance with the requirements in Specification on Concrete for Structures, Clause 18.

In the event that the provisions of other specification clauses cause ambiguity or conflict with the requirement of Specification clauses in this section, the latter shall take precedence unless otherwise approved by the Engineer.

26.3. Setting Out

The Contractor shall be required to employ an experienced Surveyor who will set up the position of the piles as shown in the layout of the detailed design. The Contractor will be responsible for the accuracy of the location and positioning of each pile. The pile positions shall be staked with durable markers. Any errors in setting out and any consequential loss to the Employer will be made good by the Contractor to the satisfaction of the Engineer.

Upon completion of the piling works, the Contractor shall produce as-built Drawings showing the positions of all piles installed. The positions of the piles shall be verified by the Engineer.

26.4. Piling Layout

The piling layout, the minimum pile size and/or bearing capacity and type together with the steel reinforcement and classes of concrete required for concrete piles shall be as detailed and specified on the Drawings unless otherwise specified in the Special Specification.

26.4.1 Alternative design for piling and piling layout

(a) Submission

The priced Schedule of Quantities submitted for alternative designs shall be compiled strictly in accordance with the relevant measurement and payment clauses.

In the event that pay items not defined as above are used, the measurement and payment requirements for such items shall be specified in detail by the Contractor. In the absence of such definitions, or in the case of any ambiguity, the interpretation of the Engineer shall be final and binding.

Except in piling-only Contracts or where otherwise provided in the Special Specifications, the Contractor shall price the Bill of Quantities for the original design irrespective of whether or not an alternative design is offered.

(b) Design

Preliminary calculations for an alternative design shall be submitted with the tender. Such calculations shall give adequate details so as to enable an assessment to be made of the general efficacy of the design and of its principal elements, also of the degree to which the design prescriptions and codes of the Employer are being complied with. The calculations shall be clear and in a logical sequence and shall clearly reflect all the design assumptions.

The critical design-load combinations acting upon the underside and centre of gravity of the pile-capping slab, the maximum permissible set of the pile-capping slab, and technical data required for designing alternative piles and or piling layouts will be indicated on the Drawings.

For alternative design, the Contractor shall submit with the bid a detailed description of the method of analysis used in the design of the piles and pilegroup layouts. The average length of the pile and/or of the piles per group on which the quantities in the Bill of Quantities for the alternative designs are based shall be stated in each case. The type of pile offered shall be defined in terms of size, material, working and breaking load.

The Contractor shall be responsible for and shall bear the cost for redesigning, drafting and submitting the detail drawings for any structural element affected by the alternative pile design.

The Contractor shall submit to the Engineer, at least three months prior to work being commenced, drawings detailing the piling-group layout and piles, incorporating such amendments to his original design as may be required by the Engineer, and drawings detailing the amendments required to the pile-capping slab dimensions and reinforcement as a result of the layout of the piles, all as applicable.

No work of whatsoever nature shall be commenced on the piling until the Drawings have been submitted to and have been approved by the Engineer, in writing. After approval of the Drawings, no departure therefrom shall be made without authorisation by the Engineer.

Where the alternative piles fail in regard to the load test specified in Subclause 26.19, the Contractor shall be responsible for the cost of the work required for improving the piles and pile layout so as to comply with the design requirements.

26.5. Details to be Furnished by the Contractor

In all cases where the choice of the type of pile to be used is left to the Contractor, full particulars, specifications, calculations and drawings of the piles proposed for use by the Contractor shall be submitted with the tender.

The Contractor shall submit the following information to the Engineer, 4 weeks before any piles are driven or holes are formed:

(i) How the piles and casings will be installed or the holes will be formed;

(ii) How the piles and casings will be installed or the holes will be made through identified obstructions;

(iii) The mass of the hammer;

(iv) The set during the last ten blows;

(v) The expected size of the bulbous base, underream, rock socket, etc, if any;

(vi) How concrete or grout is to be placed and compacted in the case of cast in situ piles;

(vii) How reinforcing steel is to be placed and held in place during placing and compacting the concrete in cast in situ piles;

(viii) Details of permanent casing, if any;

(ix) The mix design for the concrete together with an adequate quantity of cement and aggregate to enable the Engineer to conduct the necessary tests.

26.6. Pile Installation, Frames and Equipment

The pile-installation frames and equipment used for driving the piles or forming the holes or for other methods of sinking the piles shall be in a good working condition, capable of safely, speedily and efficiently, installing piles to design requirements at the project site and to the prior approval of the Engineer and shall comply with the relevant legal provisions.

The Contractor shall supply the necessary equipment, gear and instruments required for the prescribed investigations and inspections.

The installation frames shall be so designed as to ensure that piles can be installed in their proper positions and true to line and slope.

26.7. Piling Platforms

Piling platforms shall include the prepared in situ material or artificial islands or any structure (excluding the piling equipment) constructed for gaining access to the position where the pile is to be installed and for carrying out the piling operations.

Structural piling platforms shall be rigid, and floating barges used for piling operations shall afford sufficient stability to enable piles to be properly installed.

On completion of the piling, the Contractor shall remove all the artificial, constructed platforms and reinstate the site to the satisfaction of the Engineer.

26.8. Ground Surface for Founding Piling

Before starting any piling work, the Contractor shall notify the Engineer in good time to ensure that levels of the ground surface be taken in order that an average ground surface from which the piling is to be measured can be established and agreed on by the Engineer and the Contractor. Where foundation piling at a site is preceded by excavation or the construction of fill, the surface from which the piling is to be done shall be formed as near as possible to the underside of the pile-capping slab as directed by the Engineer.

26.9. Types of piles

26.9.1 Cast in situ concrete piles

(a) Reinforcement

Reinforcement shall not be placed in the pile holes until immediately before concreting. Before the reinforcement is placed in position, all mud, water, and any loose or soft material shall be removed from the hole.

Steel reinforcing shall be accurately maintained in position without damage being done to the sides of the hole or the reinforcing itself. Spacers shall be used to keep the reinforcing steel at the required distance from the inside face of the pile casing and wall of the pile hole but shall not cause zones through which aggressive ground water may penetrate to the reinforcement.

Pile reinforcement will not be shown in the bending schedules. Only the number, diameter and type of bars and their arrangement will be shown on the Drawings. The Contractor, with the permission of the Engineer, may replace the bars shown on the Drawings with bars with different diameters and spacing and of different types, on a basis of equivalent strength.

The reinforcement shall be assembled in cages, which shall be sufficiently robust to prevent their permanent deformation during handling. In the case of cast in situ piles, the inner sides of the cages shall be kept open in view of the unrestricted placing of concrete therein.

The longitudinal bars shall project above the cut-off point by the distance shown on the Drawings, or by 40 times the bar diameter if no dimension has been given.

Splicing the reinforcing may be ordered, and the Contractor shall keep available on the site sufficient steel reinforcing so that an additional length of pile reinforcing can be assembled whenever necessary.

The assembly of this additional reinforcing shall be carried out expeditiously and before any concreting of any specific pile commences. If splices have to be provided, the longitudinal bars shall overlap for a distance of 40 bar diameters, or as required by the Engineer.

(b) The concreting of piles

The concreting of the piles shall not be commenced before the Engineer has given his permission therefore. Except in self-supporting pile holes, a temporary or permanent casing shall be installed for the full depth of the hole to prevent lumps of material from falling from the sides of the hole into the concrete. Where concrete is to be placed under the drilling mud, the temporary casing may be omitted, except at the top end of the hole.

The concrete shall be so proportioned as to be of sufficient strength, but shall be sufficiently workable to enable it to be properly placed, and, where self-compacting concrete is not used, it shall be thoroughly compacted by approved means. Extraction of the temporary casing during placement of the concrete shall be such that no damage is caused to the pile and the advancing concrete level is at all times kept considerably above the temporary casing's trailing edge. Concrete shall generally be placed in the dry, but where this is impracticable it shall be placed by tremie.

The requirements of Subclause 18.10.4 together with the following requirements shall apply when concrete is placed under water by tremie:

1. The cement content shall be not less than 400 kg/m^3 and the slump shall be such that the concrete of the specified strength and desired density can be obtained.

2. The hopper and tremie shall be a closed unit which cannot be penetrated by water.

3. The tremie shall be at least 150 mm in diameter for 19.0 mm aggregate and larger for larger aggregates.

4. The concrete shall be so placed as to prevent the mixing of water and concrete. The tremie shall at all times penetrate into the concrete.

5. Placing the concrete in that part of the pile below the water level in the casing shall be done in one operation, and the same method of placing the concrete shall be maintained throughout.

6. All tremies shall be scrupulously cleaned before and after use.

7. Before placing the concrete in the water, the Contractor shall ensure that no silt or other materials have collected at the bottom of the hole, and where drilling mud is used, the Contractor shall ensure that no drilling mud suspension with a relative density exceeding 1.3 has collected at the bottom of the hole.

8. Concrete shall be placed in a manner that will prevent segregation.

26.9.2 Precast concrete piles

The piles shall be of reinforced or prestressed concrete and shall be manufactured, handled, stored and installed in accordance with BS 8004, unless otherwise specified.

(a) Manufacture
The piles may be manufactured in a factory or a casting yard on the site of the Works. The Contractor shall ensure that the factory or casting yard will at all reasonable times be accessible for inspection by the Engineer.

The relevant requirements of Clause 18 shall apply to the concrete work.

Transverse reinforcement shall comply with the requirements of BS 8004.

The piles shall be cast on a rigid horizontal platform in approved moulds. Particular care shall be taken to keep the reinforcement, coupler sockets and pile shoes accurately in position. Adequate provision shall be made for lifting the piles.

Each pile shall be clearly marked with the date of casting, a reference number, and from the tip of the pile at 1.0 m intervals, with distance marks.

Piles shall be cured for a period sufficient to develop the strength required to withstand, without damage to the pile, the stresses caused by handling, transporting, storing and driving. The piles shall not be driven before the concrete in the pile has attained the specified strength.

(b) Handling, transport and storage
Care shall be taken at all stages of lifting, handling and transporting to ensure that the piles are not damaged or cracked.

Piles shall be stored on firm ground which will not settle unequally under the weight of the stack of piles. The piles shall be placed on timber supports that are truly level and spaced so as to avoid undue bending in the piles. The supports in the stack shall be located vertically above one another.

(c) Lengthening of precast piles
Piles shall be lengthened where required by such means and methods as approved by the Engineer. Care shall be taken to ensure that the additional length of pile joined is truly axially in line with the original pile within the tolerance requirements for straightness as follows:

Precast piles up to 3 m length	5 mm
For piles longer than 3 m	1.0 mm per additional metre of pile length

Driving shall not be resumed until the pile extension and any bonding agent used has attained the required strength.

26.9.3 Steel piles

Steel piles shall be of hollow pipe construction or H-section construction.

Hollow steel piles may be filled with cast in situ concrete and, provided that adequate connections are provided between the steel and the concrete with a view to transferring the load, the concrete may be deemed to assist in carrying the load.

Wherever steel piles are used, they shall be given a protective coating of bitumen, coal-tar pitch or synthetic resins to the satisfaction of the Engineer or as specified. The cross-sectional area of the steel shall be adapted to the aggressiveness of the subsurface conditions to compensate for possible reduction in the pile wall thickness caused by abrasion and corrosion during the service life of the pile.

Steel piles shall be used only where permitted by the Engineer.

26.9.4 Timber Piles

Timber piles shall be of pressure treated round timber approved by the Engineer and shall be manufactured, handled and installed in accordance with BS 5268-2, unless otherwise specified.

Tropical hardwoods shall be used for all permanent piles. Softwoods may be used for temporary structures subject to the approval of the Engineer. All timber shall be obtained from approved suppliers who have permission to harvest and sell timber.

(a) Manufacture and testing

The piles may be manufactured in a factory or treated on the site of the Works in accordance with BS 5268-5 and the Environmental Management Plan,, unless otherwise specified.

When required the Engineer will order and the Contractor shall carry out tests on the timber piles in accordance with BS 5268-5, to satisfy him/herself that the timber is fit for the purpose for which it is to be used.

The Contractor shall ensure that the factory or treatment yard will at all reasonable times be accessible for inspection by the Engineer.

The piles shall be treated and stored in a horizontal position and protected from the weather.

Each pile shall clearly be marked with the date of manufacture, date of treatment, type of tree, a reference number, and from the tip of the pile at 1.0 m intervals, with distance marks.

Piles shall be seasoned for a period sufficient to develop the strength required to withstand, without damage to the pile, the stresses caused by handling, transporting, and driving. The piles shall not be driven before they have attained the specified strength.

(b) Handling, transport and storage

Care shall be taken at all stages of lifting, handling and transporting to ensure that the piles are not damaged or cracked.

Piles shall be stored on firm ground that will not settle unevenly under the weight of the stack of piles. The piles shall be placed on timber supports which are truly level and spaced so as to avoid undue bending in the piles. The supports in the stack shall be located vertically above one another.

(c) Lengthening of timber piles

Piles shall be lengthened where required by such means and methods in accordance with BS 5268 or as instructed by the Engineer. Care shall be taken to ensure that the additional length of pile joined is truly axially in line with the original pile within the tolerance required for straightness as follows:

Timber piles up to 3 m length	5 mm
For timber piles longer than 3 m	1.0 mm more per additional metre of pile length

Driving shall not be resumed until the pile extension and any bonding agent has attained the required strength.

26.10. Installing the piles

26.10.1 Driving the piles

(a) Pile-installation frames

Piles and pile casings shall be driven with a gravity hammer, a rapid-action power hammer or by other approved means. Prestressed-concrete piles shall be driven with a hammer with a mass of at least equal to that of the pile. Other piles shall preferably be driven by a hammer with similar mass characteristics. The hammer shall not, during driving operations, damage any permanent component of the pile. Pile driving leaders shall be constructed in such a manner as to afford freedom of movement of the hammer and shall be held in position to ensure adequate support for the pile or pile casing during installation. Inclined leaders shall be used for installing raking piles.

The heads of precast concrete piles shall be protected with packing of resilient material, care being taken to ensure that it is evenly spread and held in place. A helmet shall be placed over the packing, and a dolly of hardwood or other material not thicker than the diameter of the pile shall be placed on top.

Pile driving shall be carried out in accordance with the Environmental Management Plan, with due care being taken to minimize impacts to neighbouring communities, wildlife and aquatic organisms.

(b) Water jetting

The Contractor may employ water jetting to install piles in granular material. Jetting shall be discontinued before the leading end of the pile reaches a depth of 80% of the anticipated final depth or a depth as approved by the Engineer. After jetting, piles or their casings shall be driven to the required depth, level or set. Water jetting shall be carried out in accordance with the Environmental Management Plan, and due care shall be taken by the Contractor to ensure that displaced material does not contaminate water courses.

(c) Installation sequence

Unless otherwise specified or ordered, the sequence for installing the piles shall be left to the Contractor. However, the sequence for driving the piles in a group shall be programmed to minimise the creation of consolidated blocks of ground into which piles cannot be driven or which cause fictitious penetration values. Piling shall generally commence at the centre of the group and be progressively extended to the perimeter piles unless otherwise approved by the Engineer.

The installation of piles shall be undertaken in such a manner that structural damage, distortion or positioning defects will not be caused to previously installed piles or casings.

(d) Heaving of piles

In soils in which the installation of piles may cause previously installed piles to heave, accurate level marks shall be placed on each pile immediately after installation and all piles that have heaved shall be redriven to the required resistance, unless redriving tests on neighbouring piles have shown this to be unnecessary. Piles shall not be concreted neither shall any pile-capping slab be constructed until the piles within a heave-influence zone have been redriven as required.

(e) Bulbous bases

Where required, bulbous (enlarged) bases shall be formed after the driven casing has reached the required depth. The base shall be formed by progressively displacing the surrounding subsoil with concrete placed by the repeated action of a gravity hammer. The size of the base will depend on the compressibility of the surrounding subsoil but shall in no instance have a diameter of less than 1.5 times the diameter of the pile.

(f) Piling alignment

Where the inclination of a precast concrete pile deviates from the correct slope during installation, the pile shall not be forced into the correct position. The slope of the guiding frame shall be adjusted so as to coincide with the actual inclination of the pile to preclude the bending of the pile. Where the verticality or the inclination of the installed pile falls outside the specified tolerances, the pile will be classified as being defective.

26.11. Augering and boring

26.11.1 Auger and bore pile holes

The augering and boring of pile holes shall be carried out as expeditiously as local conditions permit taking due account of services or other restrictions on the site.

Holes shall be cleaned after augering and boring to obtain a clean and level surface. . Care shall be taken to prevent contamination of water bodies. Excess material shall be transported to spoil in accordance with the Environmental Management Plan.

Where indicated by the Engineer, suitable casing shall be installed in those parts of the augered holes where the sides are in danger of caving in before the concreting has been completed.

During extraction of the casing, care shall be taken to avoid lifting the concrete and damaging the pile.

The use of water for augering and boring holes shall not be permitted unless approved by the Engineer. Surface water shall not be allowed to enter the hole.

26.11.2 Underreaming

Where required, the holes shall be enlarged or belled out to form an underream. The earth excavated shall be removed in a manner which will not damage the walls of the hole.

The shape of the underream shall be a truncated cone of which the base diameter depends on the bearing capacity of the founding material, but it shall be not less than twice the shaft diameter. The base angle of the cone between the inclined face and horizontal plane shall be not less than 60°.

Full safety measures shall be enforced to protect workmen working at the bottom of the pile hole.

26.11.3 Bulbous bases

Bulbous bases shall comply with the requirements of Subclause 26.10.1(e).

26.11.4 Inspecting preformed holes

Equipment for inspecting the pile shafts shall be provided and operated in accordance with the latest amendment or edition of the BS 8008 Safety Precautions and Procedures for the Construction and Descent of Machine-Bored Shafts for Piling and Other or similar documents.

Immediately before the reinforcement is to be installed or the concrete placed, the Engineer shall be informed thereof with a view to inspecting the pile holes. When piles are to be underreamed, the excavation shall be inspected twice by the Engineer, firstly to ascertain that suitable founding material has been obtained before underreaming may start, and, secondly, after the underreaming has been completed for approval to be given by the Engineer for casting the pile.

26.12. Rock sockets

Where required, rock sockets to the required dimensions shall be formed in rock formations of adequate strength, quality and thickness for transmitting the specified load.

26.13. Obstructions

26.13.1 Definitions

(a) Identified obstructions

Identified obstructions shall mean any obstruction described on the Drawings or in the Project Specifications and for which provision for payment has been made in the Schedule of Quantities in respect of penetrating the obstructions.

(b) Unidentified obstructions

Where provision has been made in the Schedule of Quantities for penetrating identified obstructions and obstructions not described are encountered, such obstructions shall be classified as unidentified obstructions and the penetration of such obstructions shall be paid for separately subject to the condition that the rate of penetration drops to below that achieved for identified obstructions when the same method and effort are used, or subject to additional methods and effort over and above those required for identified obstructions being required for penetrating the obstruction.

OR

Where no provision has been made in the Schedule of Quantities for penetrating identified obstructions and obstructions are encountered and, after resorting to the methods specified in the submission in terms of Subclause 26.5, it is found to be impossible to form the holes in the proper positions and at the proper inclinations and depths, and the Contractor has to resort to additional methods for forming the pile holes successfully, such obstructions shall be classified as unidentified obstructions.

26.13.2 Classification of materials

For piling, only the following classification of materials shall apply to the identification and description of obstructions.

(a) Matrix

The matrix shall comprise that part of the material that will pass through a sieve with 50 mm x 50 mm openings.

(b) Coarse gravel

Coarse gravel shall comprise that part of the material (stones, pebbles, cobbles, etc) that will pass through a 200 mm x 200 mm opening, but will not pass through a 50 mm x 50 mm opening. The gravel shall be obtained from material with at least a Class R2 hardness, (Table 26.1).

Table 26.1: Rock Classification

Description of hardness			Unconfined compressive strength (N/mm^2)
Class	**Description**	**Field indicator tests**	
R1	Very soft rock	Material crumbles under firm (moderate) blows with the sharp end of geological pick and can be peeled off with a knife; it is too hard to cut a triaxial sample by hand. SPT refusal	1 to 3
R2	Soft rock	Can just be scraped and peeled with a knife, firm blows of the pick point leave indentations 2 mm to 4 mm in specimens	3 to 10
R3	Medium hard rock	Cannot be scraped or peeled with a knife; hand-held specimen can be broken with the hammer end of a geological pick with a single firm blow.	10 to 25
R4	Hard rock	Point load tests shall be conducted for distinguishing between these categories. These results may be verified by means of uniaxial compressive-strength tests.	25 to 70
R5	Very hard rock		70 to 200
R6	Extremely hard rock		> 200

Classification after: "A Guide to Core Logging for Rock Engineering" Bulletin of the Association of Engineering Geologists, Vol. XV, No. 3, 1978

(c) Boulders

Boulders shall mean any rock mass with a hardness of at least Class R2 that will pass through a square opening with dimensions equal to the maximum size boulder specified in the Special Specification.

(d) Rock formation

A rock formation shall be any rock mass with a hardness of at least Class R2 that will not pass through a square opening with dimensions equal to the maximum size boulder specified in the Schedule of Quantities.

Where a boulder is cut through and part of it is left imbedded in the wall of the hole, such boulder obstruction shall be classified as rock formation.

For the identification of rock in terms of this Clause, the classification in Table 26.1 shall apply.

26.13.3 Driven displacement and prefabricated piles

Where obstructions make it difficult to install driven displacement and prefabricated piles in the positions and at the inclinations shown and to the proper lengths by the methods specified in the submission in terms of Subclause 26.5 the Contractor shall resort to additional methods that are suitable for the type of pile. If the successful installation of a pile proves to be impossible after such methods have been tried, the Engineer may order an additional pile or piles to be installed.

All such work and additional piles shall be paid for in accordance with the tendered rates.

26.13.4 Auger and bore pile holes

Where identified or unidentified obstructions are encountered when shaping holes for piles, payment for penetrating the obstructions shall be made against the appropriate pay items.

26.14. Determining pile lengths

The design of the piles and pile groups, and the quantities in the Schedule of Quantities are based on the subsurface data shown on the Drawings.

The Engineer will determine the depth of piles as work proceeds.

Where variations in the subsurface conditions occur as regards the material and height of the water table, the Engineer shall be informed immediately.

If the Contractor is not satisfied that the piles will be capable of carrying the specified loads at the depth determined by the Engineer he may, in consultation with the Engineer, lengthen the piles to reach a suitable founding depth. Where the Engineer and the Contractor cannot agree on the founding depth, the Engineer may require the Contractor to:

(a) undertake additional foundation investigations and/or core drilling in accordance with Subclause 26.18, and/or

(b) install one or more test piles and conduct a load test in accordance with Subclause 26.19. The Engineer will prescribe the positions for each test pile. Test piles shall comply with the specified requirements for piling.

26.15. Piling record

The following data on each pile installed shall be recorded in a form prescribed by the Engineer:

(a) The effort used for driving the pile and the resistance to penetration at founding level.

(b) A description of subsurface material, the presence of ground water and the quality of material on which the pile is founded.

(c) The quality of the materials used in the construction or manufacture of the pile, as well as of the permanent casing if used. The method of placing and compacting the concrete in cast in situ piles.

(d) The method of founding of the piles eg bulbous bases, underreams, rock sockets, etc, and their dimensions.

(e) The maximum working load of the pile.

(f) The length of the pile and the accuracy of installation in respect of position and inclination.

(g) Nominal dimensions and type of pile.

(h) Length and details of any temporary and permanent casings used.

26.16. Stripping the pile heads

Precast piles shall be installed to a level of at least 1.0 m above the cut-off level, and cast in situ piles shall be cast to a level of at least 150 mm above the cut-off level. The excess concrete shall be so stripped off that only sound concrete will project into the pile-capping slab.

Before a pile head is stripped, the cut-off plane shall be marked by cutting a 20 mm deep groove with a grinding machine along the full circumference of the pile.

Concrete demolishing equipment used for the stripping of pile heads shall be such that it causes no damage to the pile shaft. All loose aggregate shall be removed from the cut-off plane.

The concrete shall be so stripped off that the pile below the cut-off level will not be damaged, or, should defective concrete be found in the completed pile, the damaged or defective concrete shall be cut away by the Contractor at his own cost and replaced with new concrete well bonded to the old concrete, or the pile shall be replaced as directed by the Engineer.

The main reinforcement of the piles shall extend at least 40 times the diameters of the reinforcing bar beyond the cut-off level into the pile-capping slab. This reinforcement shall be left straight unless otherwise directed by the Engineer.

The cut-off level for piles shall be the level shown on the Drawings

26.17. Construction of pile-capping slab

The Contractor shall not construct the pile capping slab before the Engineer has confirmed, in writing, that all the relevant load tests have been completed and the piles have been accepted.

26.18. Core drilling and additional sub-surface investigation

The Engineer may instruct core drilling to be done with a view to obtaining cores of the founding formation and/or of the concrete in the completed structural member. In the case of piling, the core drilling may precede the piling or may be done through the completed pile, as specified, or as instructed by the Engineer.

The Contractor shall supply the necessary construction plant on the site for drilling under the above conditions. The plant and techniques used shall be suitable for ensuring 100% core recovery. The diameters, depths and lengths of the cores shall agree with the Specification or the instructions of the Engineer.

The Contractor shall keep accurate records of the drilling, which, together with the cores, shall be handed over to the Engineer. The cores shall be placed in the correct sequence in a clearly identified wooden core box with a lid.

Any additional foundation investigation required shall be carried out in accordance with BS EN 1997-2, unless otherwise agreed to by the Engineer.

26.19. Load Testing of piles

26.19.1 General

The Engineer may order certain selected piles to be load tested. The procedure for loading tests shall comply with the requirements of Subclause 2.19. During the period of testing, driving of other piles which may affect the testing shall cease.

The pile load test procedure, particularly with respect to the number of loading steps, the duration of these steps and the application of load cycles, where applicable, shall be such that conclusions can be drawn about deformation behaviour and rebound of pile foundation from the measurements on the pile.

No working pile shall be used as an anchor pile. Where anchor piles or earth anchors are required for providing reaction, they shall be so placed as to have a minimal effect on the test results.

The Contractor shall provide the complete testing assembly, the necessary plant, equipment, instruments and labour for carrying out the test and for determining accurately the settlement of the piles under each increase or decrease of the load. The test assembly, plant, equipment and instruments used shall be subject to the approval of the Engineer.

Within two days of having completed the tests, the Contractor shall supply the Engineer with the test results. The report shall include; a description of the site, the ground conditions with reference to the ground investigations, the pile type, a description of the test assembly, calibration documents of the load cells, the jacks and gauges, the installation record of the test piles, neatly plotted load against settlement, load against time, and settlement against time graphs. Justification of the reasons for any departure from the above recommendations shall be provided.

26.19.2 Loading

The maximum test load applied shall be equal to twice the specified working load or the ultimate test load, whichever shall be the smaller.

The maximum working load shall be half of the maximum test load or the test load which corresponds with the allowable settlement, whichever shall be the smaller. The allowable settlement shall be as specified on the Drawings.

26.19.3 Ultimate test load

The ultimate test load in the compression-load test shall be the load where settlement suddenly increases disproportionately to the load applied.

The ultimate test load in the tension-load test shall be the load where the upward movement suddenly increases disproportionately to the load applied or the load producing a permanent rise of 10 mm at the top of the pile, whichever is the smaller.

26.20. Defective piles

The test pile and the piles represented by the test pile shall be classified as defective if shown in terms of Subclause 26.19 to have a maximum working load of less than the specified working load, or to exhibit excessive settlement.

Defective piles shall also include piles damaged beyond repair, piles with structural defects, or piles that do not comply with the relevant tolerance requirements.

If required, the defective piles shall be corrected by the Contractor at his own cost, by applying one of the following methods approved by the Engineer:

1. Extracting the pile and replacing it with a new pile.
2. Installing a new pile adjacent to the defective pile.
3. Lengthening the pile to the correct length if defective in length only.
4. Altering the design to fit in with the new conditions caused by the defective pile(s).

26.21. Standing time in respect of pile-installation frames

Standing time shall only be paid for pile-installation frames standing during normal working hours as laid down in the Conditions of Contract for such periods during which the pile-installation work has come to a standstill following an action by the Engineer.

As soon as the pile-installation frames have come to a standstill, the Contractor shall inform the Engineer, in writing, that he intends to claim standing time, and shall also furnish:

(i) Full particulars of the action which gave rise to the Claim

(ii) A list of pile-installation frames in respect of which standing time will be claimed, complete with date and time.

The period in respect of which a claim is lodged shall become operative from the moment when the notice has been handed over to the Engineer and shall continue until the restriction has been removed and normal procedure may be resumed.

26.22. Nuclear integrity

Integrity tests using both the nuclear and neutron method shall be performed on all bored piles. The purpose of these tests is to prove that the technique used in constructing the piles is satisfactory, by checking for necking of concrete in the pile shafts, checking concrete cover to reinforcement and by checking for honeycombing, grout loss and segregation of aggregates.

26.23. Caissons

26.23.1 General

Caissons shall, for the purposes of these Specifications, be hollow concrete vessels which are wholly or partly constructed at a higher level and lowered by internal excavation or kentledge to the desired founding level to form structural bearing members. Caissons may be of circular, rectangular or any other shape and may contain one or more excavation compartments, all as detailed on the Drawings.

Unless otherwise specified hereafter, the provisions of BS 8004 shall apply in regard to the construction of caissons.

26.23.2 Construction and sinking

A firm horizontal base shall be prepared on which the cutting edge of the caisson shall be laid truly horizontally. The level of the base shall be determined and shall be agreed on by the Engineer and the Contractor and shall serve as the ground surface from which the excavation inside the caisson will be measured.

Successive stages of the caisson shall be of convenient height, or as directed by the Engineer, and shall be lined up accurately with the preceding stages.

All precast elements shall have properly constructed joints in accordance with the Drawings to ensure that they fit snugly together.

For in situ phase construction, all construction joints in the walls shall be reinforced and the joints shall be made as specified in Subclause 18.19.

The lowest element of every caisson, which contains the cutting edges, shall be cured for at least four days or shall have reached a strength of at least 50% of the specified strength before sinking is commenced. Subsequent elements shall be cast in sufficient good time to ensure adequate strength for safely resisting the applied forces.

During constructing and sinking, the caissons shall be maintained truly vertically and kept in their correct positions.

The position and inclination of each caisson shall be determined accurately by measurement after every 2 m of sinking, or after sinking through the depth of one element, whichever distance is the smaller.

With a view to eliminating excess friction, the Contractor may use bentonite or a similar lubricant, or a water-jet system.

In multi-compartmented caissons, excavation in any one compartment shall not be taken deeper than 0.6 m below that in any other compartment, except where necessary for correcting deviations.

Cutting edges shall be frequently inspected or probed to locate obstacles, which shall be removed immediately.

The Contractor shall supply all grabs, pumps, diving gear and other plant required for sinking and founding all caissons and shall allow the Engineer to use the diving suit and equipment for inspection purposes.

The Contractor shall employ a competent diver to carry out work under water and shall make provision in the rates tendered for the respective items for this cost.

Where the caisson strikes a hard inclined layer and work has to be carried out below the cutting edge, such work shall be measured and paid for under the relevant items and, where no applicable items exist such work shall be paid for as extra work.

Should the Contractor wish to apply the pneumatic caisson method (with a compressed air chamber) for construction, he shall furnish the Engineer with full details of the plant, equipment and method for approval.

The Contractor shall abide by the requirements for caisson construction in the Environmental Management Plan.

26.23.3 Founding

The material at the founding level, if sloping and/or irregular, shall in so far as is possible be cut to as nearly level a surface as possible until the entire cutting edge is evenly and firmly supported on the material. Subject to the approval of the Engineer, blasting may be used for this purpose. If blasting should be resorted to, only light charges may be used and the caisson shall be protected against damage by suitable cushioning being provided.

Should the sloping surface be of hard rock which cannot be cut or broken by any safe and feasible means, the foundation shall be built up by means of a solid wedge of concrete which fills the entire space between the bedrock surface and the horizontal plane through the cutting edge. This concrete shall be of the same class as that specified on the Drawings or in the Schedule of Quantities for the concrete seal.

The rock or hard material on which the structure is to be founded shall be completely uncovered. The founding surface shall be cleared of all loose material before inspection by the Engineer immediately prior to casting the concrete seal.

No concrete shall be placed in the wedge or the seal before the Engineer has inspected and approved the foundation. For this purpose the Contractor shall adequately dewater the caisson to enable the Engineer to conduct the inspection.

In the event of a caisson not being vertical or in its correct position when it has reached the required depth, or in the event of a caisson being cracked during the sinking process, the Contractor shall at his own cost carry out the necessary remedial work to the satisfaction of the Engineer.

26.23.4 Data

The Contractor shall provide the Engineer with a complete record of the types of material excavated during sinking, together with the level at which each type of the material was found. In addition, a log showing the rate of sinking shall be kept by the Contractor and furnished to the Engineer.

26.23.5 Filling the caissons

(a) Concrete seal

The seal shall be constructed of mass concrete of the class specified and shall be placed in accordance with the dimensions and levels shown on the Drawings or as prescribed by the Engineer.

If this seal cannot be placed in the dry and has to be placed under water, the method of placing this concrete shall be approved by the Engineer. The Contractor shall cease placing the concrete under water when sufficient concrete has been placed to seal the foundation effectively.

After the concrete has been placed, the concrete seal and the head of water over it shall remain undisturbed for a period of at least seven days after which the caisson shall be dewatered by pumping for inspection. If more water is still leaking into the caisson, the process of sealing as specified herein shall be continued until the water level within the caisson does not rise at a rate exceeding 10 mm/h.

The relevant requirements of Subclauses 18.10, 18.11 and 26.9a (ii) shall apply for placing the concrete under water. For concrete placed under water by methods other than by tremie, the cement content shall be 20% more than the quantity required for ordinary concrete of the same mix but shall be not less than 450 kg/m^3 of concrete.

(b) Filling

Subsequent to inspection of the caisson compartments above the concrete seal, the compartments shall be filled with sand. The sand shall be sufficiently wetted to obviate bulking.

The first 2 m of filling above the concrete seal shall be lowered gently into position. The sand may then be poured from the top and compacted sufficiently to prevent settlement while the cover slab concrete is being placed.

The top of the sand fill within the caisson shall be finished off to the level specified below the underside of the caisson cover slab.

The Contractor shall abide by the requirements for caisson construction in the Environmental Management Plan. Particular care shall be taken to prevent pollution of water bodies, specifically in terms of altered pH and turbidity.

26.23.6 Stripping

Where the walls of the caisson have been overbuilt, the concrete shall be stripped to the required level without damage being done to the concrete below the cut-off level. Strippings shall be caught in a suitable catch net and shall be prevented from falling into water.

The longitudinal reinforcement of the caisson shall project above the cut-off level by a distance of at least 40 times the bar diameter.

26.23.7 Concrete screed below the caisson cover slabs

A concrete screed of the specified thickness and class of concrete shall be provided to the level shown on the Drawings over the area covered by the cover slab, including the area within the caissons on top of the sand filling, except where the underside of the cover slab is being formed with formwork.

26.23.8 Environmental consideration

Water quality and marine life shall not be adversely affected in any way during operations.

Where adverse impacts have been indicated in the Environmental Impact Assessment Report and mitigated in the Environmental Management Plan, the Contractor shall carry out such mitigation measures to minimize negative impacts to water quality and marine life.

The Engineer shall approve all methods that the Contractor proposes according to the Environmental Management Plan.

SECTION 27

ROAD LIGHTING

CONTENTS

TABLES

27. ROAD LIGHTING

27.1. Scope

This Section covers the standard requirements for lighting columns, lanterns, wiring and accessories. Installations shall conform to the general requirements of BS 5489.

27.2. General Arrangements

27.2.1 Urban Major Arterials (Wide Reserve)

Applicability: Road widths of 7.3 m, speed limits of 80 km/h and traffic volumes of 4 000 to 10 000 vehicles per day.

Columns shall be positioned in the side footpaths opposite one another at a spacing of 30 to 35 m with outreach bracket arms to give a mounting height of 10 to 12 m. Maximum outreach bracket arm length shall be 2.5 m. Lanterns shall be 400 W mercury or 250 W high pressure sodium cut-off type.

27.2.2 Urban Major Arterials (Narrow Reserve)

Applicability: Road widths of 7.3 m, speed limits of 80 km/h and traffic volumes of 4 000 to 10 000 vehicles per day.

Columns shall be positioned in each side footpath opposite one another and within the central reserve in a staggered arrangement. Spacing of columns in the footpaths shall be 40 to 46 m and columns in the central reserve shall be placed half way between them.

Columns shall have single outreach bracket arms in footpaths and double outreach brackets in the central reserve to give a mounting height of 10 m. Maximum outreach bracket arm length shall be 2.5 m.

Lanterns shall be 400 W mercury or 250 W high pressure sodium cut-off type.

27.2.3 Minor Arterials

Applicability: Road widths of 7.3 m, speed limits of 60 to 70 km/h and traffic volumes of 2 000 to 4 000 vehicles per day.

Columns shall be positioned within the central reserve at a 30.0 m spacing with double outreach bracket arms to give a mounting height of 10 m. Maximum outreach bracket arm length shall be 2.5 m.

The lanterns shall be 400 W mercury or 250 W high pressure sodium cut-off type.

27.2.4 Service Roads and Footpaths

Applicability: Service roads and footpaths associated with arterials.

Columns shall be positioned in the side footpaths to the service roads at a spacing of 40 to 50 m with bracket arms of width one quarter of the height of the columns, which shall be 8 m to 10 m to suit adjacent building heights.

The lanterns shall be 125/250 W mercury or 70/150 W high pressure sodium cut-off type.

27.2.5 Distributor/Collectors

Applicability: Low speed roads with typical widths of 6.4 m and traffic volumes of less than 2 000 vehicles per day.

Columns with an outreach bracket arm shall be positioned in a staggered arrangement with a 27 to 32 m spacing in each side footpath to give a mounting height of 8 m. Maximum outreach bracket arm length shall be 2.0 m.

The lanterns shall be 80/125 W mercury or 70/150 W high pressure sodium semi-cut-off type.

27.2.6 Local Roads

Applicability: Lane widths of 3.2 m and less than 50 vehicles per day.

Columns with outreach bracket arms shall be positioned in one side footpath at a spacing of 36 m to 44 m to suit access paths. Maximum outreach bracket arm length shall be 1.5 m.

The lanterns shall be 80/125 W mercury semi-cut-off type.

27.2.7 General notes

Lamp and lantern specifications in the preceding sections are mandatory.

Stated spacings are mandatory unless the Contractor can show justification for altering the spacing, based at least on brightness and glare analyses and on considerations of flicker frequency at the prevailing traffic rate. The requirements and methods prescribed in BS EN 13201 Parts 2 and 3 shall be the determining factor in deciding whether a specific deviation from these requirements constitutes an acceptable solution.

Power supply considerations shall be taken into account when choosing lamp or lantern power ratings. In general, unless a stable supply can be assured, the lower rating units shall be preferred.

For installation heights above 12 m, mercury vapour lights shall be preferred, while at lower heights the sodium lamps shall be used.

27.3. Control Unit

Each road lighting column shall be provided with a two-piece photo-electric (PE) control unit. The PE relay shall be housed in the base compartment of the column and the remote detector head shall be mounted on the lantern. The wiring between the relay and detector head shall be single or multi core 1.5 mm^2 butyl rubber cables to a 'plug in' terminal block provided in a separate compartment within the lantern. The detector head, with pre-wired tails, shall be connected to the lantern terminal block.

27.4. Columns

Lighting columns shall be of galvanized tubular steel or aluminium or of synthetic materials such as fibreglass. The columns shall be base-plate mounted and supplied with suitable holding down bolts, which shall be installed during construction of concrete foundations by means of a template. Columns shall be complete with spigots and clamps for lantern mounting.

Columns shall be provided with a compartment of adequate size to accommodate a fused cut-out unit, lamp control gear, photo-electric relay and non ferrous gland plate. The compartment shall have an earth stud and a weatherproof, lockable access door with six sets of keys. The entry point to the compartment shall be no less than 2.0 m above ground level.

The compartment shall be provided with a non-hygroscopic hardwood or marine ply or rigid synthetic baseboard on which the equipment shall be mounted. If a synthetic base is used, it shall provide at least a similar level of stiffness and electrical resistance to the specified wood types. Suitable materials include bakelite, polytetraflouroethelene (PTFE) or PVC.

27.5. Lanterns

Lanterns shall be of the totally enclosed type of sound and robust construction, weatherproof and dustproof to IP65 and suitable for side entry and obtained from an approved supplier.

The optical compartment shall be equipped with an adjustable lamp holder, a tubular lamp, reflectors and heat resistant glass or a polycarbonate bowl. The lantern shall be designed for cut-off and semi-cut-off distribution with remote gear. A terminal block shall be provided in the gear compartment of the lantern to which the lantern mounted photo electric detector head tails shall terminate.

27.6. Lamps and Control Gear

Lamps shall be mercury vapour complying with BS EN 60188 or high pressure sodium vapour complying with BS EN 62035 for 240 volt operation.

The lamps shall comprise 70 W, 150 W, 250 W and 400 W ratings with minimum average luminous outputs of 5 750, 13 800/14 300, 25 000 and 47 000 lumens for respective wattages.

The lamp control gear shall comply with BS EN 61347 and BS EN 60923. Ballast chokes shall where possible have voltage tapping steps of 5 and 10%.

The control gear shall be power factor corrected to a minimum of 0.85 lagging to BS EN 61048. It shall have radio and TV interference suppression.

Where applicable, lamps shall be provided with external igniters.

27.7. Cables and Wires

All cables and wires shall be supplied, installed, connected up, tested and commissioned in accordance with the regulations of the Electricity Corporation of Ghana, the Drawings and the following:

27.7.1 Main and Sub Main Distribution Cables

1 000 volt grade multicore, stranded copper conductors, PVC insulated, single wire armoured, PVC sheathed (Black) overall to BS 6346 installed direct in the ground, or in ducts, or cleated to cable tray or concrete service trench walls.

The voltage drop across supply cables shall not exceed the maximum value specified by the Engineer. Such value shall be measured at the lantern head under full-load conditions at a supply voltage within 10% of the maximum rated supply voltage.

27.7.2 Wiring in Columns

300/500 volt grade single core or twin and earth stranded copper conductors, butyl rubber (85°) insulated.

27.7.3 Insulation testing

All completed installations shall be tested with an insulation tester at a voltage of at least 500 volts, and must show an insulation resistance of at least 10 MΩ between earth and ground and between neutral and ground.

27.7.4 Joints in Underground Cables

Underground joints in distribution cables shall not be permitted.

Where joints in underground cables are denoted on the Drawings they shall be provided by means of weatherproof surface turret boxes. They shall be suitable for incoming and outgoing 415 and 240 volt circuit cables as denoted on the Drawings.

27.8. Earthing

The whole of the external lighting installation shall be efficiently bonded back to sub-station earth bars via switchboards, feeder pillars, cable armouring and earth wire of flexible cables as indicated on the Drawings and in accordance with local Regulations.

27.9. Distribution Feeder Pillars

The feeder pillars shall be to IP65 protection and equipped with an incoming isolator and outgoing circuit breakers. The circuit breakers shall be contained within a metal clad distribution board with space for additional spare outgoing ways.

The feeder pillars shall be of similar design to existing feeder pillars and shall be erected on suitable concrete foundations with cable access provided.

27.10. Internal Wiring to Columns (Up to 12 m High Columns)

Cables shall be connected to terminals on terminal blocks mounted adjacent to the cut-out on the backboard in the base compartment of the column. Items of equipment mounted on the columns shall not be connected by loop-in wiring.

Cable tails shall be left sufficiently long to readily reach into the fuse cut-out unit in the base of the columns. One earth lead from the column earth terminal to the earthing point shall be provided at the cut-out position.

Wiring in columns between control gear and lantern shall be by 2.5 mm^2 single or 3 core butyl rubber cables. Where the earth conductor is separate it shall be coloured green.

27.11. Photo Electric Control

Photo electric control at each column shall be by the two piece type. The unit shall comprise a relay with test button and a remote detector head with prewired tails.

The photo electric control shall be pre-calibrated to operate ON at 60 lux and OFF at 120 lux.

27.12. Numbering of Columns

Each column shall be identified by means of a 50 mm x 70 mm non ferrous metal plate, stamped with its number in numerals 25 mm high and fixed to the column 150 mm above access door using blind rivets or stainless cheese head screws. Suitable alternate methods may be used with the approval of the Engineer. The numbering system shall be consistent with the existing numbering system and the Drawings.

27.13. Column Foundations

Columns shall be placed on buried concrete foundations with embedded steel reinforcement.

In all cases, concrete foundations shall be designed for a wind speed of 40 m/sec. Bulk or pedestal-and-flange foundations are allowed. In all cases, concrete shall protrude at least 100 mm above the surrounding terrain.

Concrete shall be class C20/25. Test cubes shall be prepared during casting and evaluated at 28 days to prove the integrity of concrete. Where foundations are not cast in a continuous process and from a single mix, multiple samples shall be taken to prove the integrity of each mixture used at the time of casting.

Contractors shall comply with either of the following specifications. If other foundations geometries or dimensions are to be used, the Contractor shall use a foundation design approved by the Engineer for the purpose, taking account of the actual soil conditions at each site. Such designs may take account of actual anticipated air density and soil conditions, with a mean return of 50 years. The design shall be submitted to and approved by the Engineer before any construction activities based on the design may commence.

27.13.1 Block foundations

Block foundations shall have a constant horizontal cross-section. Any convenient plan view geometry with at least two axes of symmetry (circular, triangular or polygonal plan view) can be used, provided that the following dimensions (Table 27.1) are complied with.

Table 27.1: Dimensions of block foundations

Parameter	12 m Column	18 m Column
Column height (m)	< 12.0	< 18.0
Head load (m^2)	< 0.7	< 0.3
Foundation volume (m^3)	> 1.25	> 2.25
Foundation plan area (m^2)	> 1.80	> 3.25
Foundation plan radius (mm)	> 775	> 1050
Reinforcement depth (mm)	> 600	> 600

Column height is the maximum column height and shall be measured from mean ground level within 1.0 m of the base of the column to the highest point on the column or fixtures.

Foundation volume is the minimum total volume of contiguous reinforced concrete.

Foundation plan area is the minimum cross-sectional area of the foundation block in any plane along its depth.

Foundation plan radius is the minimum radius of the foundation along any radial line from the axis of symmetry of the column. In the case of a rectangular plan view, the minimum radius occurs at right angles to the nearest face of the concrete block.

Reinforcement depth is the minimum depth to which the steel reinforcement bars to which the column is bolted shall penetrate the concrete block. Reinforcement bars shall be of high yield strength steel with a minimum yield strength of 450 N/mm^2 and a minimum diameter of 20 mm. The spacing between adjacent attachment bolts for the tower shall be no less than 300 mm. Double nuts or locknuts shall be used for attachment bolts.

27.13.2 Pedestal-and-flange foundations

In this geometry, a pedestal with a small cross-sectional area protrudes above ground level. A horizontal flange with significantly greater cross-section is buried below ground. Both the concrete itself and the mass of soil above the flange contribute to the resistance to overturning.

This geometry provides an advantage in terms of above-ground profile, especially in the case of narrow separation islands between opposing traffic, but shall not be used in sandy soil, specifically when the bearing strength of the column is below 150 kPa. Granular soils with a density of over 1600 kg/m^3 or cohesive soils described as stiff or very stiff (unconfined compressive strength of at least 150 kPa) are suitable.

Flanges and pedestals shall have a constant horizontal cross-sectional area (no taper). The flange has a significantly greater diameter than the pedestal. Any convenient plan view geometry with at least two axes of symmetry (circular, triangular or polygonal plan view) can be used, provided that the limiting dimensions (Tables 27.2 and 27.3) are complied with. Attachment bolts shall have a minimum diameter of 20 mm. Yield strength shall be at least 450 N/mm^2 and the reinforcement shall protrude into the concrete by at least 1.0 m.

Table 27.2: Dimensions of pedestals: Columns

Parameter	12 m Column	18 m Column
Pedestal height (mm)	> 750	> 750
Pedestal plan area (mm^2)	> 0,55	> 0,55
Minimum radius (mm)	> 370	> 370
Concrete volume (m^3)	> 0,42	> 0,42

Table 27.3: Dimensions of pedestals: Flanges

Parameter	12 m Column	18 m Column
Flange depth (height) (m)	> 0,25	> 0,25
Flange plan area (m^2)	> 2,6	> 6,0
Minimum radius (m)	> 0,85	> 1,25
Concrete volume (m^3)	> 0,65	> 1,50
Burial depth (upper surface) (m)	> 0,65	> 0,65

Pedestal height is the minimum height from the upper surface of the flange to the upper surface of the pedestal.

Plan area is the minimum plan sectional area of the pedestal or flange.

Minimum radius is the minimum horizontal distance from the axis of symmetry of the column to any edge of the pedestal or flange.

Concrete volume is the minimum allowed concrete volume, including reinforcement.

Flange depth is the minimum thickness of the flange at any point within its planform.

Burial depth is the minimum distance between the upper surface of the flange and the ground surface at any point within 2.0 m (horizontally) of the column.

SECTION 28

TRAFFIC SIGNAL CONTROLLERS

CONTENTS

TABLES

28. TRAFFIC SIGNAL CONTROLLERS

28.1. Scope

This Section covers the standard requirements for traffic signal controller installations.

28.2. Classes of Controllers

Three classes of controllers, based on the technology used to implement them are referred to in this section:

(i) Class A: Mechanical timing mechanisms and interlocks.

(ii) Class B: Timing and interlocks using electronic logic.

(iii) Class C: Switchgear controlled by programmable logic devices, including PLCs and microprocessors.

Only Class C controllers shall be used in new installations.

Controllers can also be divided into groups according to their functional mode. The most common modes include:

(i) Vehicle actuated: Phases directly triggered by the presence of vehicles, with or without minimum and maximum phase periods. In some cases, only a single phase may have vehicle actuation (such as a minor road crossing a major traffic route).
(ii) Fixed-time: Pre-planned phases, or possibly a number of plans that get activated at different times.
(iii) Manual: Allowing for control by a traffic officer.
(iv) Centralised control: Used with centralised control algorithms.

28.3. Installation of controllers

Each installation shall be described in the Special Specification. The Special Specification shall contain details of:

(i) The physical layout of the intersection, identifying each signal group and the direction of traffic flow for each phase.

(ii) The timing plans, showing a complete cycle period and all phases, as well as the intersection with all signal groups, flow directions and phases superimposed.

(iii) Details of synchronization with other intersection controllers.

(iv) Details of prohibited sequences.

(v) Functional requirements for the controller, including the number of phases, the timebase accuracy, the communications protocols to be supported and the environmental requirements.

(vi) Minimum and maximum phase times, including the intergreen period, the red extended period and the red, amber and green periods.

(vii) Prohibited phases and phase sequences required to circumvent those prohibited phases.

(viii) The timeout period before automatic reversion during manual operation.

(ix) The physical location of the controller and its connection to the power supply and the traffic signals.

(x) Details of integrity monitoring capability to be included in the controller.

(xi) Details of the physical installation, including cable routes and types as well as the numbering scheme employed to identify individual conductors within the enclosure.

Each installation shall be approved by the Engineer in charge of traffic signals before installation and construction work may commence. Details specified in the Special Specification shall become part of the standards against which the installation shall be approved.

All cabling to and from the controller shall be armoured. Buried cables shall be protected by a suitable environmental insulation sleeve. Exposed cables shall be sleeved with a material that provides suitable UV protection for no less than 10 years from date of installation.

All insulation used on supply lines shall have a rated breakdown voltage of no less than 1 000 VAC rms. Supply voltage shall be nominally between 220 and 250 V rms.

Controllers shall be mounted at a height and in surroundings where the controller will not be damaged by brush or grass fires.

28.4. Controller Characteristics

All traffic signal controllers shall be designed such that incorrect insertion of printed circuit boards shall not be possible, or where such incorrect insertion is possible, it shall not cause any damage to the equipment.

The enclosure shall be IP66 rated, according to the requirements of IEC 60529. All equipment shall be accessible for inspection or maintenance without requiring any disassembly. The entry of cables and wires into the enclosure shall be handled in such a way that compliance with IP66 with respect to waterproofing, dustproofing and access by animals and insects is not compromised.

The enclosure shall be lockable using locks that can be operated with a master key system and include provision for the safe storage of documentation such as logbooks and manuals.

The user interface shall be accessible through a separate lockable door, allowing the operator access to the user interface without exposing the operator to electrical and electronic components or affording access to the programming facilities.

Each controller shall be prominently and permanently marked with the manufacturer's name or trade mark, the model number, its class (A, B or C) and the input supply voltage, frequency and current ranges.

All exposed voltages of over 50 V shall be clearly marked with appropriate high-voltage warning symbols. In a case where a cover is installed over such terminals, the cover shall carry a similar warning that is clearly visibly to any party that may attempt to remove the cover.

All controller documentation shall be provided to the Employer in printed form.

Controllers shall operate from the standard 220 V 50 Hz supply. Supply voltages from 120 V to 300 V and frequencies of 45 to 55 Hz shall not result in abnormal operation. If the supply voltage drops below 80% of nominal operating voltage for less than 50 ms, the controller shall continue normal operations. If the interruption lasts longer than 100 ms, the controller shall shut down. Whenever the controller cannot continue normal operations because of supply voltage variations, it shall shut down. After a controller has been shut down, it shall restart in power-up mode once the power supply is restored.

Controllers shall be powered by power supplies including a transformer that features complete electrical isolation between primary and secondary circuits. Primary and secondary windings shall include a metallic shield, grounded to the earth terminal as described below.

All exposed conductors bearing voltages of greater than 50 V rms shall be suitably insulated. Insulation shall exhibit a breakdown voltage of at least 1 000 V rms for one minute without failure.

Solid-state lamp switching shall be required. Switching systems shall be designed for a life of at least 5 million operations for steady signal groups and 10 million operations for flashing signal groups. For design purposes, a signal group shall be assumed to consist of ten 75 W globes.

The controller shall include lightning protection with a clamping voltage of no higher than 1 000 V. A combination of series and parallel devices may be used, but in any case such devices shall provide protection against 10 successive voltage surges of up to 6 kV (2 µs rise and 50 µs fall time) and current surges of up to 3 kA (10 µs rise and 20 µs fall time). These pulse trains shall be applied between each pair of supply conductors (earth-live, earth-neutral and live-neutral).

All controllers shall be guaranteed to have a Mean Time Between Failures (MTBF) of at least six months, when determined in accordance with IEC 60050-191 and IEC 60300-3.

28.5. Controller Operation

The basic capabilities of the controller shall be described in the Special Specification.

In situations where the traffic signals operate in a dark environment (such as in road sections without street lamp illumination), a dimming facility shall be provided on all signal groups. Dimming may be based on timing, with suitable allowances for differing sunrise and sunset times at different times of year, or on light sensors that sense ambient lighting levels.

All controllers shall have manual access for three purposes:

(i) Programming of timing plans.

(ii) Manual intersection control in the event of malfunction or unusual traffic conditions (e.g. sporting events).

(iii) Diagnostics in the event of malfunctions.

The user interface for manual intersection control shall be accessible from outside the cabinet through a lockable hatch. The controls and displays shall be easily readable from outside in bright sunlight. Suitable illumination shall be provided for operation during darkness.

Manual control shall be subject to minimum and maximum phase times as described in the Special Specification.

Manual control shall not be able to override any prohibited phases as defined in the Special Specification.

The timebase used in a traffic controller shall be stable to within one second per day. Where timing is coordinated with other controllers, the time shall be coordinated to within 1.0 s.

Mains voltage cycles may not be used as a primary timebase, but may be used to coordinate phase changes on adjacent controllers, provided that such controllers are fed from the same supply.

The controller shall support the following ranges for each of the timing parameters (Table 28.1):

Table 28.1: Ranges for timing parameters

Parameter	Minimum	Maximum	Increment
Cycle time		200 s	1 s
All-red	1 s	99 s	1 s
All-red extension	0 s	25 s	1 s
Intergreen	0 s	30 s	1 s
Pedestrian clearance	0 s	30 s	1 s
Minimum green	0 s	30 s	1 s
Maximum green	0 s	100 s	1 s
Green extension	0 s	30 s	100 ms
Manual inactivity timeout	30 s	100 s	5 s
Notes: 1. The “increment” is a maximum figure; finer increments are permissible. 2. Critical parameters such as intergreen period shall be subject to confirmation to prevent inadvertent changes. 3. These figures represent the ranges that the controller shall be able to support. Actual ranges for an intersection are defined in the Site Document.			

Controllers shall have the facility to exclude certain undesirable phase sequences. Such prohibited sequences shall be defined in the Special Specification. When an undesirable phase sequence is requested, either by a vehicle detector or by manual control, the controller shall insert an intermediary phase that will eliminate the undesirable phase sequence.

28.6. Inspections and Testing

Controllers shall be checked for compliance with the general construction, appearance and performance in accordance with the manufacturer’s documentation.

Carry out a mechanical shock test in accordance with IEC 60068-2-29, test Eb, with the controller packaged in its original packaging for shipment.

Check that the supply voltage is within the range specified. Keep the controller turned off. Check that the output voltage of the controller’s power supply is within the range specified in the manufacturer’s documentation.

Check that turning on the power switch causes the signal groups to start in the flashing red state and that turning it off again causes the signal groups to be extinguished.

SECTION 29

MISCELLANEOUS TRAFFIC SIGNAL EQUIPMENT

CONTENTS

TABLES

29. MISCELLANEOUS TRAFFIC SIGNAL EQUIPMENT

29.1. Scope

This Section covers all aspects of traffic signal equipment except controllers. Controllers are covered separately in Section 28.

29.2. Traffic Signal Heads

29.2.1 Head mechanical characteristics

Signal heads shall have a lens diameter of no less than 205 mm and no more than 350 mm, measured in a flat plane directly on the lens or bezel, immediately in front of the lens itself.

Signal heads, including visors and louvres, shall be matt black on all exterior surfaces except optical system lenses. They shall have no sharp edges or corners that can lead to injury to personnel during installation and maintenance. Signal heads shall weigh no more than 7.5 kg per head (e.g. 22.5 kg for a three-head assembly), including visors and backing boards.

All metal components shall be rust-proofed to an extent commensurate with the environment in which the signal head is installed.

Overhead signals and signals mounted against confusing backgrounds (granular or multi-coloured surfaces or bright lights) shall have backing boards with rounded ends with a diameter of at least twice the diameter of the signal head itself. The backing board shall be mounted in a plane parallel to the plane of the lenses and no more than 50 mm behind the plane of the lenses. The backing boards shall be made from a material that does not show appreciable deterioration due to weather exposure and shall be coloured matt black. Multiple heads mounted in a vertically-stacked configuration shall have a single backing board covering at least the areas prescribed above for each of the heads. The backing board shall be mounted in a way that facilitates the removal and replacement of the backing board without interrupting the operation of the traffic light or requiring disassembly of any signal heads or their components.

Masks used to provide symbols (arrows, pedestrian symbols etc.) shall be matt black and shall conform to the curvature of the lens to a tolerance of no more than 6 mm at any point along the lens. Paint used to mask symbols on lenses shall be matt black and thermally stable at the equilibrium design temperature for continuous operation at an ambient temperature of 40°C. Painted masks shall also resist flaking when scratched. When two parallel cuts are made 2 mm apart anywhere through the mask, no flaking shall be evident between or around the cuts.

Each vehicular traffic light shall have a visor with a length of at least 160 mm, measured at right angles from the face of the traffic signal at the highest point of the visor. Visors shall be used on pedestrian lights as detailed in the Special Specification. A visor may be asymmetric if required to facilitate shielding from one direction and visibility from another, such as at roads intersecting at acute angles.

Signal heads shall contain incandescent, fluorescent or LED lighting elements as specified in the Special Specification. Where LEDs are used, the supplier shall provide a statement indicating that the LEDs are not driven at a current higher than their continuous rated current when the head is supplied with its rated supply current.

In LED signal heads, clear (uncoloured) lenses shall be used to minimise the risk of phantom effect from reflected ambient light.

Reflectors shall be designed to minimise the risk of overheating in the filaments. In any case, the reflector shall not reflect energy from the filament back directly towards the filament.
Any traffic signal head shall show no signs of deformation or discoloration after continuous operation for 24 hours at maximum rated voltage and at an ambient temperature of 50°C.

Traffic signal heads shall comply with IP65. Any moisture or dust ingress shall not adversely affect the functioning of the head.

Traffic signal heads shall be clearly marked with indelible markings, with the following information: Manufacturer, model number, batch code to identify manufacturing date, intensity class (high or normal), rated voltage, replacement lamp type and rated input voltage and current.

29.2.2 Head functional characteristics

Light shall not be allowed to pass from one head to another during normal operation. In cases where ambient lighting conditions present a substantial risk of phantom effect (apparent illumination of an unpowered head due to reflection of solar light) additional louvres parallel to the optical axis may be used. Such louvres shall be matt black. Louvres are not recommended on heads containing symbols.

Traffic signal heads shall comply with the chromaticity coordinates (CIE colour model 1931) given in Table 29.1 for all voltage conditions within the normal operating range of the heads:

Table 29.1: Chromaticity coordinates for traffic signal heads

Colour	x	x tolerance	y	y tolerance
Red	0.70	0.03	0.31	0.02
Amber	0.58	0.02	0.40	0.01
Green	0.10	0.05	0.50	0.10

The optical axis of a signal head shall be within 2.5° in azimuth and in the range of 0° to 2.5° down in elevation from the nominal geometric axis.

Low-intensity heads shall comply with the following minimum intensity levels (Table 29.2).

Table 29.2: Intensity levels for low-intensity heads

Elevation below beam axis	**Minimum luminous intensity** as a function of azimuth displacement from beam axis			
	0° to 5°	**10°**	**20°**	**30°**
0°	200 cd		25 cd	15 cd
5°	100 cd	100 cd		
10°	25 cd			
20°	15 cd			15 cd

High-intensity heads shall comply with the following minimum intensity levels (Table 29.3).

Table 29.3: Intensity levels for high-intensity heads

Elevation below beam axis	**Minimum luminous intensity** as a function of azimuth displacement from beam axis			
	0°	**4°**	**10°**	**15°**
0°	600 cd	400 cd	100 cd	50 cd
2°	400 cd	400 cd		
5°	100 cd		100 cd	
10°	50 cd			50 cd

Heads shall comply with the following minimum and maximum brightness levels by day (Table 29.4).

Table 29.4: Head brightness levels by day

Time period	**Category**	**Luminous intensity**	
		Minimum	**Maximum**
Day	Low-intensity	Per tables above	600 cd
	High-intensity	Per tables above	1800 cd
Night	Low-intensity		200 cd (recommended)
	High-intensity		600 cd (recommended)

The amber head shall not reflect more than 20 cd of amber light in a direction of 2° down when the unpowered light is illuminated from 10° above by a light source with the spectral characteristics of Standard Illuminant A (CIE 15.2) at 1 000 lx, all incident and reflective light being in the vertical plane passing through the axis of symmetry of the head. All hoods and louvres shall be installed for the test and the sensor shall be protected against uncoloured light reflections from the lens (using a small surface shield on the lens as required).

29.2.3 Head mounting

Spacing between adjacent signal heads shall be no more than 160% of the lens diameter of those heads, when measured between the centres of the heads.

Traffic signal head mounting assemblies shall be adjustable in azimuth to at least 60° on either side of the nominal direction.

29.2.4 Lamps

Incandescent or fluorescent lamps used in traffic lights shall be of a type freely available in the trade and from at least two manufacturers. The lamps shall be mounted in a way that ensures that the lamp is focussed correctly when fully screwed or clipped into the holder.

The type of lamp and its electrical ratings shall be clearly displayed on each head in a position that is clearly visible during lamp replacement.

29.3. Traffic Signal Supports

Traffic signals shall be mounted on a pole with a diameter of at least 100 mm. The pole shall be painted yellow. Rust-proofing shall be specified in the Special Specification.

Traffic signal supports shall be planted directly into soil, and no concrete foundations shall be used unless specified in the Special Specifications or instructed by the Engineer. If concrete foundations are used and the support is situated within 3 m horizontally of the roadway surface, a frangible coupling within 150 mm of ground level shall be used to ensure that the support will fracture when a horizontal force of 1.5 kN is applied to the support at a height of 1.0 m above average ground level within 1.0 m of the support base.

If specified in the Special Specification, retro-reflective strips shall be between 100 and 200 mm wide and shall be applied in horizontal bands, spaced at intervals equal to the width of the bands themselves. Strips shall only be installed between 1.2 and 2.1 m above mean ground level, measured within 1.0 m of the base of the support.

Span wire assemblies to support signal heads on cables between two or more supports or any bridge or gantry for such purposes shall comply with the requirements of AASHTO LTS 4.

29.4. Other Traffic Signal Equipment

Pedestrian pushbuttons shall comply with IP66. They shall be mounted at a height of between 1.0 and 1.3 m as specified in the Special Specification, and shall be clearly labelled as to their function. A graphic symbol shall be used.

29.5. Cabling

Buried cabling between the traffic signal controller and the signal head shall be armoured and sleeved to withstand burial or shall be mounted in a conduit.

Buried conduit or conduit cast into concrete shall have a cross-sectional interior surface area of at least five times the total cross-sectional area of all cables inside it. All conduits shall be of a type approved for burial or casting into concrete, as the case may be. Metal conduits shall be protected on the inside by a plastic coating (PVC or similar) of at least 1.0 mm. All joints in conduit shall be made with couplings approved for the purpose by the manufacturer. Joints that coincide with expansion joints in structures shall be capable of travel to accommodate design deflections in the expansion joints.

A conduit shall not contain bends totalling more than 360° without the introduction of a pull box. Bends in the conduit shall have a minimum radius in accordance with Table 29.5.

Table 29.5: Minimum radius of bends in conduit

Conduit inner diameter	Minimum inner radius of turns
< 13 mm	8 x inner diameter
13 to 38 mm	6 x inner diameter
> 38 mm	5 x inner diameter

Cabling between a traffic controller and the signal head shall not result in a voltage drop of more than 10% of operating voltage in the case of LED signal heads and 4% in the case of incandescent or fluorescent types.

All cabling and wiring shall be labelled in each signal head, pull box or junction box. The supplier shall provide evidence that labels shall remain readable over the design system lifetime under the envisaged operating conditions of the system.

Where wiring enters or passes through equipment, including supports, signal heads and cabinets, no sharp edges or corners shall be exposed to the wiring in such a way that damage to the insulation or conductors may result.

All exposed metal components of the system shall be permanently grounded to an earth point with an earth resistance of no greater than 25 Ω. Resistance between any exposed metal conductors and the earth connection shall not exceed 100 mΩ. These requirements shall be met both in operational condition and in an opened state, as required for servicing. Earth connections shall not be made through mounting bolts or other structural components.

29.6. Administrative Arrangements

The Contractor shall ensure that all warranties on components and subsystems, including traffic controllers, shall be transferred to the road owner on completion of the installation. This clause shall not be interpreted as implying that any of the Contractor's obligations in terms of contractual guarantees or maintenance contracts are reduced or rescinded.

ANNEXE 1

LIST OF STANDARDS REFERRED TO IN THE SPECIFICATION

Ghana Standards (GS)

GS No	Description	Clause No
22	Specification for Portland cements	2.7 14.3.3 15.3.2 18.3.2 18.17
297	Specification for Sandcrete Blocks	2.16
766	Specification for Extended cements	2.7 14.3.3

Ghana Highway Authority Standards (GHA)

GHA No	Description	Clause No
S1	The determination of reference density for compaction control of cohesive soils and gravels	2.4.2(a), 2.20 Tables 2.1 & 2.8 2.21.6, 3.4.1, 4.4 5.4, 5.5, 5.8 6.13.5, 7.3.2, 7.5 8.5.3, 8.5.4, 8.8 8.9, 8.11, 8.17 8.20, 9.3, 10.4 10.7, 11.4, 11.6 11.7, 11.8 Table 12.2 12.5, 13.3 14.3.1, 14.6.2 14.8.2
S2	The determination of the California Bearing Ratio of cohesive soils and gravels	Table 2.1, 5.2
S3	The determination of reference density for compaction control of graded crushed stone and fine gravels	Table 2.1, 2.20 Table 2.8 13.4.1
S4	The determination of reference density for compaction control of cohesionless sands and fine gravels	Table 2.1, 2.20 13.4.1, 15.5.3

GHA No	Description	Clause No
S5	The determination of the in-place dry density of soil or gravel by the sand replacement method	2.4.2 (c)
S6	Determination of Atterberg limits of soil fines	Tables 2.1, 10.1 & 12.1
S7	Sieve analysis of granular soils	Table 2.1
S9	The determination of the grain size distribution in soil fines by means of a hydrometer	Table 2.1

British Standards (BS)

BS No	Description	Clause No
325	Specification for black cup and countersunk bolts and nuts	22.2.3
381 C	Specification for colours for identification, coding and special purposes	23.6
410-1	Test sieves. Technical requirements and testing. Test sieves of metal wire cloth	5.2
434	Bitumen road emulsions (anionic and cationic). Specification for bitumen road emulsions (2 Parts)	2.13.1, 24.2
598	Sampling and examination of bituminous mixtures for roads and other paved areas (10 Parts)	17.2.5
638	Arc welding power sources, equipment and accessories. (2 Parts)	23.9.4 (b)(v)
812	Testing aggregates (22 Parts)	Tables 2.1 & 2.2 17.3.2 (c) 17.4.2 (c)
873	Road traffic signs and internally illuminated Bollards (5 Parts)	23.4, 23.5, 23.6
1052	Specification for mild steel wire for general engineering purposes	8.17
1088	Marine plywood	19.6.3
1109	Specification for cold forged mild steel rivets for cold closing	22.2.4
1134	Assessment of surface texture	24.5.1 (c)
1154	Natural rubber compounds. Specification	24.5.1 (b)
1305	Specification for batch type concrete mixers	18.6
1377	Methods of test for soils for civil engineering purposes (9 parts)	2.4.1, 2.4.2 (c) Table 2.1
1521	Specification for waterproof building papers	18.10.3
1707	Specification for hot binder distributors for road surface dressing	16.4.6 (a)

BS No	Description	Clause No
1881	Testing concrete (20 Parts)	18.5.2
1924	Stabilized materials for civil engineering purposes (2 Parts)	2.9.1, 2.9.3, Table 2.3 14.6.1, 14.12
2752	Chloroprene rubber compounds. Specification	24.5.1(b)
3083	Specification for hot-dip zinc coated and hot-dip aluminium/zinc coated corrugated steel sheets for general purposes	24.8
3262	Hot-applied thermoplastic road marking materials Specification for application of material to road surfaces	23.8.1.
3410	Specification for metal washers for general engineering purposes	23.9.4 (d)
3506	Specification for unplasticized PVC pipe for industrial uses	8.2.1 (g)(iii)
3692	ISO metric precision hexagon bolts, screws and nuts. Specification	22.2.3 23.9.4(d)(ii)
3837	Expanded polystyrene boards. Boards and blocks manufactured from expandable beads. Requirements and test methods	24.6.1 (b)(iv)
3963	Method for testing the mixing performance of concrete mixers	18.6
4072	Copper/chromium/arsenic preparations for wood preservation	23.9.2 (a) (iii)
4320	Specification for metal washers for general engineering purposes. Metric series	23.9.4 (d) (ii)
4395	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering (2 Parts)	22.2.3
4449	Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification	20.2.1, 20.8
4483	Steel fabric for the reinforcement of concrete. Specification	20.2.2

BS No	Description	Clause No
4486	Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete	21.3.1 (a)
4604	Specification for the use of high strength friction grip bolts in structural steelwork. Metric series (2 Parts)	22.5.4, 22.5.10
4652	Specification for zinc-rich priming paint (organic media)	22.10, 22.11.3 23.9.2 (b) 23.9.4 (f)
4800	Schedule of paint colours for building purposes	23.6, 23.7.2 (a) & (b) 23.8.2 (a) & (b)
4840	Rigid polyurethane (PUR) foam in slab form	24.6.1 (b) (iv)
4872	Specification for approval testing of welders when welding procedure approval is not required (2 Parts)	22.5.8
4921	Specification for sherardized coatings on iron or steel	23.9.4 (e)
5268	Structural use of timber	26.9.4 (a) & (c)
5400	Steel, concrete and composite bridges. (12 Parts)	21.12 23.9.4(b)(i) 24.5.124.5.2 24.5.2 (a) & (b) 24.5.3 (c)
5489	Code of practice for the design of road lighting	27.1
5493	Code of practice for protective coating of iron and steel structures against corrosion	22.8.1, 22.8.2 (b)
5756	Specification for visual strength grading of hardwood	25.3
5896	Specification for high tensile steel wire and strand for the prestressing of concrete	21.3.1 (a)
5911	Concrete pipes and ancillary concrete products (6 Parts)	8.2.1 (a), (c), (g) Table 8.1
5950	Structural use of steelwork in building. (9 Parts)	22.3
6088	Specification for solid glass beads for use with road marking compounds and for other industrial uses	23.7.4 (b) & (c) 23.8.4

BS No	Description	Clause No
6100-2	Glossary of building and civil engineering terms	1.3
6346	Electric cables. PVC insulated, armoured cables for voltages of 600/1000V and 1900/3300 V	27.7.1
6463	Quicklime, hydrated lime and natural calcium carbonate. Methods for physical testing	2.8
6699	Specification for ground granulated blastfurnace slag for use with Portland cement	18.3.2
7354	Code of practice for design of high-voltage open-terminal stations	1.14
7668	Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification	22.2.1 23.9.4 (a) 24.6.1 (e)(iv)
8004	Code of practice for foundations	26.2, 26.9.2 (a) 26.23.1
8008	Safety precautions and procedures for the construction and descent of machine-bored shafts for piling and other purposes	26.11.4
8666	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification	20.4

BRITISH–EUROPEAN-INTERNATIONAL STANDARDS (BS EN ISO)

The following Standards have been adopted from the British Standards Institute (BSI), European Standards (EN) and in some cases from the International Standards Organisation (ISO) and are referred to in the Specification. Other international standards are also included in this section.

BS-EN-ISO No.	Description	Clause No.
BS ISO 31	Quantities and units	List of Symbols
BS EN 39	Loose steel tubes for tube and coupler scaffolds. Technical delivery conditions	22.2.2
BS EN 196	Methods of testing cement	2.7, 18.3.2, 18.5.1
BS EN 197	Cement – Part 1: Composition, specifications and conformity criteria for common cements	2.7, 14.3.3(a) 15.3.2, 18.3.2 Table 18.1, 18.17
BS EN 206	Concrete. Specification, performance, production and conformity	Tables 2.4&18.5 18.5.1, 18.9
BS EN 287	Qualification test of welders	22.5.8
BS EN 450	Fly ash for concrete. Definition, specifications and conformity criteria	18.3.2
BS EN 459	Building lime (3 Parts)	2.8, 14.3.3(b)
BS EN 480	Admixtures for concrete, mortar and grout	18.5.1
BS EN ISO 591	Titanium dioxide pigments for paints. Specifications and methods of test	23.7.2 (a)
BS EN 912	Timber fasteners. Specifications for connections for timber	25.9.4
BS EN 932	Tests for general properties of aggregates	2.5.1, 2.6.1
BS EN 933	Tests for geometrical properties of aggregates	Tables 2.2 & 2.3
BS EN 934	Admixtures for concrete, mortar and grout	18.3.5

BS-EN-ISO No.	Description	Clause No.
BS EN 1008	Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete	2.10.1, 15.3.4 18.3.4
BS EN 1011	Welding. Recommendations for welding of metallic Materials (8 Parts)	21.6, 22.2.5 22.5.8 23.9.4(b)(v)
BS EN 1043	Destructive tests on welds in metallic materials. Hardness testing	22.2.5
BS EN 1097	Tests for mechanical and physical properties of aggregates	Table 2.2
BS EN 1338	Concrete paving blocks. Requirements and test methods	11.8
BS EN 1339	Concrete paving flags. Requirements and test methods	11.3, 11.7
BS EN 1340	Concrete kerb units. Requirements and test methods	23.10
BS EN 1367	Tests for thermal and weathering properties of aggregates	18.3.3
BS EN 1423	Road marking materials. Drop on materials. Glass beads, antiskid aggregates and mixtures of the two	23.7.4 (b) & (c) 23.8.4
BS EN 1436	Road marking materials. Road marking performance for road users	23.7.1
BS EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods	22.5.13 (c) 23.9.4 (e), 24.8
BS EN 1463	Road marking materials. Retroreflecting road studs	23.12.2
BS EN 1744	Tests for chemical properties of aggregates	18.5.1
BS EN 1871	Road marking materials. Physical properties	23.7.1
BS EN 1916	Concrete pipes and fittings, unreinforced, steel fibre and reinforced	8.2.1 (f)
BS EN 1997-2	Eurocode 7. Geotechnical design. Ground investigation and testing	26.18
BS EN 2138	Washers, flat, in steel, cadmium plated	22.2.3
BS EN ISO 8501	Preparation of steel substrates before application	22.9, 22.11.2(a)

of paints and related products

BS-EN-ISO No.	Description	Clause No.
BS EN ISO 8503	Preparation of steel substrates before application of paints and related products. Surface roughness characteristics of blast-cleaned steel substrates (5 Parts)	22.11.2 (a)
BS EN ISO 8504	Preparation of steel substrates before application of paints and related products. Surface preparation methods (3 Parts)	22.11.2 (b)
BS EN 10025	Hot rolled products of non-alloy structural steels	23.9.1 (a) (ii)
BS EN 10029	Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above	25.9.5
BS EN 10088	Stainless steels. List of stainless steels	24.6.1 (e)(iv)
BS EN 10223	Steel wire and wire products for fences (7 Parts)	8.17
BS EN 10244	Steel wire and wire products. Non-ferrous metallic coatings on steel wire (6 parts)	8.17, 23.3 24.8
BS EN 10326	Continuously hot-dip coated strip and sheet of structural steels	22.5.13 (c) 24.6.1(e)(iv) 24.8
BS EN ISO 11600	Building construction. Jointing products. Classification and requirements for sealants	24.6.1 (c) (ii) 24.6.1 (c) (iii)
BS EN 12350	Testing fresh concrete. (7 Parts)	2.10.1, 2.10.2 18.5.3 (i), 18.5.5
BS EN 12390	Testing hardened concrete. (8 Parts)	2.10.1, 2.10.2 15.5.3, 18.5.2 18.5.3 (iv)
BS EN 12504	Testing concrete in structures (4 Parts)	2.10.3 (iii), 15.5.3
BS EN 12620	Aggregates for concrete	2.6.2 (a), 8.10 18.3.3, 18.17 Table 18.2
BS EN 12899	Fixed, vertical road traffic signs. Fixed signs	23.4, 23.5
BS EN ISO 12944	Paints and varnishes. Corrosion protection of steel	22.8.1,

	structures by protective paint systems. General introduction	22.8.2 (b)
BS-EN-ISO No.	**Description**	**Clause No.**
BS EN 13201	Road lighting	27.2.7
BS EN 13391	Mechanical tests for post-tensioning systems	21.3.2
BS EN 14188	Joint fillers and sealants. Specifications for hot applied sealants	24.6.1
BS EN 14399	High-strength structural bolting assemblies for preloading. (6 Parts)	22.2.3
BS EN ISO 14713	Protection against corrosion of iron and steel in structures. Zinc and aluminium coatings. Guidelines	22.8.1, 22.8.2 (b)
BS EN 15167	Ground granulated blast furnace slag for use in concrete, mortar and grout. Definitions, specifications and conformity criteria	18.3.2
BS EN ISO 15611	Specification and qualification of welding procedures for metallic materials	22.5.8(a)
BS EN 60188	High-pressure mercury vapour lamps. Performance specifications	27.6
BS EN 60923	Auxiliaries for lamps. Ballasts for discharge lamps (excluding tubular fluorescent lamps). Performance Requirements	27.6
BS EN 61347	Lamp control gear. General and safety requirements	27.6
BS EN 62035	Discharge lamps (excluding fluorescent lamps). Safety specifications	
BS EN 61048	Auxiliaries for lamps. Capacitors for use in tubular fluorescent and other discharge lamp circuits. General and safety requirements	27.6

AMERICAN STANDARDS

The following American Standards are referred to in the Specification:

ASTM Standards

ASTM No.	**Description**	**Clause No.**
A 123/A 123M	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products	23.3
C 127	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate	18.3.3
C 131	Test method for resistance to degradation of small size course aggregate by abrasion and impact in Los Angeles machine	Table 2.2
C 156	Standard Test Method for Water Retention by Concrete Curing Materials	18.3.6
C 227	Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)	18.3.3
C 289	Test method for potential alkali silica reactivity of aggregates (chemical method)	18.3.3
C 295	Guide for Petrographic Examination of Aggregates for Concrete	18.3.3
C 309	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete	18.3.6
C 494	Standard Specification for Chemical Admixtures for Concrete	18.3.5
C 535	Test method for resistance to degradation of large-size coarse aggregate by abrasion and impact in the Los Angeles machine	Table 2.2
C 702	Standard Practice for Reducing Samples of Aggregate to Testing Size	2.5.1, 2.6.1
C 719	Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)	2.12.3
C 805	Test Method for Rebound Number of Hardened Concrete2.10.1	2.10.1

ASTM No.	Description	Clause No.
C920	Standard Specification for Elastomeric Joint Sealants	24.6.1(c) (ii)
C 939	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)	2.11
C 1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)	18.3.3
D 5	Test method for penetration of Bituminous Materials	2.13.2(a)&(b)
D 6	Test method for loss on heating of oil and asphaltic compounds	2.13.2 (a)
D 36	Test method for softening point of bitumen (ring-and ball apparatus)	2.13.2 (a)
D 70	Test method for specific gravity of semi-solid bituminous materials	2.13.2 (a)
D 92	Test method for flash and fire points by Cleveland open cup tester	2.13.2(a)&(b)
D 95	Test method for water in petroleum products and bituminous materials by distillation	2.13.2(a)&(b)
D 113	Test method for ductility of bituminous Materials	2.13.2(a)&(b)
D 140	Practice for sampling bituminous materials	2.13.1
D 243	Standard test method for residue of specified Penetration	2.13.2 (b)
D 244	Standard Test Methods and Practices for Emulsified Asphalts	2.13.2 (c)
D 402	Test method for distillation of cutback asphaltic (bituminous) products	2.13.2 (b)
D 476	Standard Classification for Dry Pigmentary Titanium Dioxide Products	23.7.2 (a)
D 977	Standard Specification for Emulsified Asphalt	14.3.3 (c) 16.2.2 (d)
D 979	Methods for sampling bituminous paving mixtures	2.14.1, 17.2.13

ASTM No.	Description	Clause No.
D 995	Standard specification for requirements for mixing plants for hot-mixed, hot-laid bituminous paving mixtures	17.2.3 (b)
D 1075	Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures	Table 17.9
D 1188	Test method for bulk specific gravity and density of compacted bituminous mixtures using paraffin-coated specimens	2.14.2
D 1250	Standard guide for the use of the Petroleum measurement tables	16.2.5
D 1310	Standard test method for flash point and fire point of liquids by Tag open-cup apparatus	2.13.2 (b)
D 1461	Standard test method for moisture or volatile distillates in bituminous paving mixtures	2.14.2
D 1754	Standard test method for effect of heat and air on asphaltic materials (thin-film oven test)	2.13.2 (b)
D 1856	Standard test method for recovery of asphalt from solution by Abson method	2.14.2
D 2026	Standard specification for cutback asphalt (slow-curing type)	16.2.2 (c)
D 2027	Standard specification for cutback asphalt (medium-curing type)	16.2.2 (c)
D 2028	Standard specification for cutback asphalt (rapid-curing type)	16.2.2 (c)
D 2041	Standard test method for theoretical maximum specific gravity and density of bituminous paving mixtures	2.14.2
D 2042	Standard test method for solubility of asphalt materials in Trichlorethylene	2.13.2 (a)&(b)
D 2170	Standard test method for kinematic viscosity of asphalts (bitumens)	2.13.2 (b)
D 2172	Standard test method for quantitative extraction of bitumen from bituminous paving mixtures	2.14.2

ASTM No.	Description	Clause No.
D 2489	Standard practice for estimating degree of particle coating of bituminous-aggregate mixtures	2.14.2
D 2726	Standard test method for bulk specific gravity and density non-absorptive compacted bituminous mixtures	2.14.2
D 3142	Standard test method for specific gravity, API gravity or density of cutback asphalts by hydrometer method	2.13.2 (b)
D 3381	Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction	16.2.2 (e) (i) Table 16.1
D 4402	Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer	2.13.2 (a)
D 4759	Standard Practice for Determining the Specification Conformance of Geosynthetics	2.15
D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate	Table 17.2
D 4867	Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures	2.14.2 Table 16.6
D 5360	Standard Practice for Design and Construction of Bituminous Surface Treatments	16.4.6
D 5821	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate	Table 17.2
D 6628	Standard Specification for Colour of Pavement Marking Materials	23.7.2(a)&(b) 23.8.2(a)&(b)
F 1916	Standard Specifications for Selecting Chain Link Barrier Systems With Coated Chain Link Fence Fabric and Round Posts for Detention Applications	23.9.1(a) (ii)

AASHTO Specifications

AASHTO No.	Description	Clause No.
LTS 4	Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals	29.3
M 36	Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains	8.2.2 (a)
M 81	Cutback asphalt (rapid-curing type)	16.2.2 (c)
M 82	Cutback asphalt (medium-curing type)	16.2.2 (c)
M 133	Preservatives and Pressure Treatment Processes for Timber	25.5
M 167	Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches	8.2.2 (b)
M 173	Concrete Joint-Sealer, Hot Poured Elastic Type	24.6.1(c)(i)
M 180	Corrugated sheet steel beams for highway guardrail	23.9.2(a)(i)
M 213	Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)	24.6.1(b)(i)
M 288	Standard Specification for Geotextile: Specification for Highway Applications	5.7(c)
T 21	Organic impurities in sands for concrete	Table 2.2 14.12.2 (c)
T 40	Sampling bituminous materials	2.13.1
T 44	Solubility of bituminous materials	2.13.2(a)&(b)
T 47	Loss on heating of oil and asphaltic compounds	2.13.2
T 48	Flash and fire points by Cleveland open cup	2.13.2(a)&(b)
T 49	Penetration of bituminous materials	2.13.2(a)&(b)
T 51	Ductility of bituminous materials	2.13.2(a)&(b)
T 53	Softening point of bitumen (ring-and-ball apparatus)	2.13.2(a)
T 55	Water in petroleum products and bituminous materials by distillation	2.13.2(a)&(b)

AASHTO No.	Description	Clause No.
T 59	Testing Emulsified Asphalts	2.13.2(c)
T 78	Distillation of cutback asphaltic (bituminous) products	2.13.2(b)
T 79	Flash point with tag open-cup apparatus for use with material having a flash less than 93.3°C (200°F)	2.13.2(b)
T 96	Resistance to abrasion of small size coarse aggregate by abrasion and impact in the Los Angeles machine	Table 2.2
T 110	Moisture or volatile distillates in hot-mix asphalt (HMA)	2.14.2
T 132	Tensile Strength of Hydraulic Cement Mortars	2.12.1
T 164	Quantitative extraction of asphalt binder from Hot-mix asphalt	2.14.2
T 166	Bulk specific gravity of compacted hot-mix Asphalt using saturated surface-dry specimens	2.14.2
T 168	Sampling bituminous paving mixtures	2.14.1, 17.2.13
T 170	Recovery of asphalt from solution by Abson method	2.14.2
T 176	Plastic fines in graded aggregates and soils by use of the sand equivalent test	Tables 2.1 & 2.2 Table 17.2
T 179	Effect of heat and air on asphalt materials (thin-film oven test)	2.13.2(a)
T 182	Coating and stripping of bitumen aggregate mixtures	2.14.2
T 193	The California bearing ratio test	Table 2.3
T 195	Determining degree of particle coating of bituminous-aggregate mixtures	2.14.2
T 198	Standard Method of Test for Splitting Tensile Strength of Cylindrical Concrete Specimens	Table 14.1
T 201	Kinematic viscosity of asphalts (bitumens)	2.13.2 (b)
T 209	Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures	2.14.2

AASHTO No.	Description	Clause No.
T 211	Determination of cement content in cement; treated aggregate by the method of titration	14.12.2(c)
T 228	Specific gravity of semi-solid bituminous materials	2.13.2 (a)&(b)
T 232	Determination of Lime Content in Lime-Treated Soils by Titration	14.12.2(c)
T 238	Density of soil and soil-aggregate in place by nuclear methods (shallow depth)	Table 2.1
T 245	Resistance to plastic flow of bituminous mixtures using Marshall apparatus	2.14.2, 17.3.4
T 275	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens	2.14.2
T 304	Uncompacted Void Content of Fine Aggregate	Table 17.2
T 310	Field Density and Moisture Content by Nuclear Gage	Table 2.3
T 312	Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor	17.3.4
T 316	Determination of Asphalt Binder Using Rotational Viscometer	2.13.2 (a)

OTHER INTERNATIONAL STANDARDS

The following other International Standards are referred to in the Specification:

IEC 60050-191	International Electrotechnical Vocabulary, Chapter 191: Dependability and quality of service.	28.4
IEC 60068	Basic Environmental Testing Procedures Part 2: Tests - Tests Eb and Guidance: Bump	28.6
IEC 60300	Dependability Management, Part 1: Dependability Management Systems	28.4
IEC 60529	Degrees of Protection provided by Enclosures, Amendment 1	28.4
NCHRP 350	Recommended Procedures for the Safety Performance Evaluation of Highway Features	23.1

SABS 1058	Concrete paving blocks	2.16, 11.8 11.10.1(c)
US Federal Specification HH-F-341		
	Filler, Expansion Joint: Bituminous (Asphalt & Tar) and Non-bituminous (Preformed for Concrete)	24.6.1(b)(i&ii)
US Federal Specification SS-S-156		
	Sealer; Cold Application Emulsion Type, for Joints in Concrete	24.6.1(c)(i)

ANNEXE 2

LIST OF REFERENCES TO THE SPECIAL SPECIFICATION

REFERENCES TO THE SPECIAL SPECIFICATION

When compiling the Special Specification, consideration shall be given to the following clauses

1.2	National Specifications
1.3	Roller passes
1.5	Submissions to the Engineer
1.13	Environmental Management
1.18	Progress Photographs
1.21	Facilities for the Engineer and his Staff
1.22	Time for Erection of the Engineer's Staff Houses, Offices and Laboratories
1.24	Provision of Vehicles
1.31.1	Depletion of Water Resources
1.31.3	Protection of Trees
2.4.2 (a)	Standard Methods of Testing
2.17.1	Laboratory Trials
2.20 (h)	Frequency of Testing
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5.7	Rock fill on Swamps and Soft Ground
5.14	Soil Stabilization
6.2	General (Sources of aggregate)
6.4	Provision of Land
6.13.3 (a) & (b)	Plant and Machinery
6.13.4 ((a) & (b vi)	Construction
8.7 (b)	Joints in Concrete Pipes and Pipe Ends
8.15.3	Precast blocks
8.17	Gabions
8.18.6	Masonry Facework fixed to Concrete
8.18.7	Special Stonework including Quoins, Copings, Plinths Voussoirs, etc
8.18.8	Natural Stone
9.3	Improvements to Existing Roads
9.4	Maintenance of Existing Roads
9.8	Signs, Barriers and Lights
11.10.1(c)	Block Paving for Limited Areas: Materials
11.10.2 (a)	Block Paving for Limited Areas: Underlying Pavement Layers
12.7	Mechanical Stabilization
13.2	Definitions (Stone class and nominal size)
13.3 (b i & c i and d))	Material Requirements (graded crushed stone base and subbase)
14.3.2	Material Requirements (crushed materials)
14.3.3 (b)	Material Requirements (lime for stabilization)
15.5.6	Method of Construction (curing of lean concrete)
15.7	Traffic (running over lean concrete)
16.2.2 (e i & v, f)	General (bituminous materials)
16.3.2	Materials for Prime Coat and Tack Coat
16.3.4	Spraying of Prime Coat and Tack Coat
16.4 (2 a & b)	Materials for Primer Seals and Surface Dressing
16.4.3	Rate of Application of Binder and Chippings (Surface Dressing)

16.4.5	Precoated Chippings
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16.5.2 (a)	Material for Sand Seal: Binder
16.5.3	Rate of Application of Binder and Fine Aggregate (Sand Seal)
16.6.3 (d)	Otta Seal: Application of surfacing
16.7.2 (a) (b)	Materials for Slurries
16.7.3	Preparation of the Slurry Mixture
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17.5.2 (a), (b), (c)	Materials for Cold Asphalt
17.5.3	Grading Requirements for Cold Asphalt
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18.5.2	Concrete Quality (Strength concrete)
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22.9	Surface Preparation of Steelwork
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28.5	Controller Operation
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