

Hong Kong Shooting
Association

**Proposed Shooting
Range at Pillar Point**

Specifications for Civil
Engineering Works

ARUP

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**GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS**

**SECTION |
EARTHWORKS**

SECTION I

EARTHWORKS

GENERAL

<i>Reclamation</i>	6.01	Reclamation shall comply with Section 21 except as stated in this Section.
<i>Trip-ticket System</i>	6.02	The disposal of construction and demolition materials generated from the Contract shall comply with the Trip-ticket System promulgated by the Environment, Transport and Works Bureau.

GLOSSARY OF TERMS

<i>Areas of fill</i>	6.03	Areas of fill are areas within the Site, including areas in embankments, platforms and slopes and in excavations for structures, pits and trenches, in which fill material is deposited and compacted as part of the permanent work.
<i>Earthworks final surface</i>	6.04	Earthworks final surface is the surface to which the work included in Section 6 is finished.
<i>Inert construction and demolition material</i>	6.05	Inert construction and demolition material shall mean rock, rubble, earth, soil, concrete, asphalt, brick, tile and masonry generated from construction and demolition works.
<i>Earthworks material</i>	6.06	Earthworks material may consist of soil, rock, or inert construction and demolition material on or below the Site at the commencement of the Contract, or which is imported to the Site to carry out the Works.
<i>Formation</i>	6.07	Formation is that part of the earthworks final surface on which a pavement, structure or utility, is constructed, or on which the blinding or bedding for a pavement, structure or utility is placed.
<i>Intermediate areas of fill</i>	6.08	Intermediate areas of fill are areas of fill which are stated in the Contract as such, and in which fill material is deposited and compacted directly into shallow water or onto naturally occurring soft ground.

MATERIALS

<i>Fill material</i>	6.09	<p>(1) Fill material shall consist of naturally occurring or processed material, or inert construction and demolition material, which at the time of deposition is capable of being compacted in accordance with the specified requirements to form stable areas of fill.</p> <p>(2) Fill material shall not contain any of the following:</p> <p>(a) Material susceptible to volume change, including marine mud, soil with a liquid limit exceeding 65% or a plasticity index exceeding 35%, swelling clays and collapsible soils,</p>
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- (b) Peat, vegetation, timber, organic, soluble or perishable material,
 - (c) Dangerous or toxic material or material susceptible to combustion, and
 - (d) Metal, rubber, plastic or synthetic material.
- (3) The different types of fill material shall have the particle size distributions within the ranges stated in Table 6.1.
- (4) Special fill material shall consist of material which has a liquid limit not exceeding 45%, a plasticity index not exceeding 20% and a coefficient of uniformity exceeding 50.
- (5) Granular fill material shall consist of clean, hard and durable material including recycled aggregates, rock and concrete.
- (6) Rock fill material shall consist of pieces of concrete or hard and durable rock of which the maximum size shall not be greater than three times the minimum dimension of individual pieces and in the opinion of the Engineer not more than 30% by mass is discoloured or shows evidence of decomposition.
- (7) The soluble sulphate content of fill material placed within 500 mm of concrete, cement bound material or cementitious material shall not exceed 1.9 grams of sulphate, expressed as SO_3 , per litre.
- (8) The total sulphate content, expressed as SO_3 , of fill material placed within 500 mm of metalwork shall not exceed 0.5% by mass.
- (9) Well-graded material shall consist of material that has a coefficient of uniformity exceeding 10.
- (10) Uniform-graded material shall consist of material that has a coefficient of uniformity of 10 or less.

Table 6.1: Particle size distributions of fill material

Type of fill material	Percentage by mass passing					
	Size		BS test sieve			
	400 mm	200 mm	75 mm	20 mm	600 μ m	63 μ m
Fine fill material	-	-	100	-	-	-
General fill material	-	100	75-100	-	-	-
Special fill material	-	-	100	-	-	0-45
Granular fill material	-	-	100	-	0-5	-
Rock fill material (Grade 200)	-	100	20-75	0-50	-	-
Rock fill material (Grade 400)	100	20-75	10-30	0-25	-	-

SUBMISSIONS

Particulars of earthworks

6.10

(1) The following particulars of the proposed materials and methods of construction for earthworks shall be submitted to the Engineer:

- (a) Details of construction plant and haulage vehicles,
- (b) Methods of excavation and of deposition and compaction of fill material,
- (c) Use of different types of excavated material and sources of imported fill material,
- (d) Arrangements for stockpiling, sorting and separating excavated material, earthworks material and fill material, and for reusing and disposing of such materials,
- (e) Methods of controlling the moisture content of fill material,
- (f) Methods of controlling surface water and groundwater and of protecting earthworks and earthworks material from damage due to water and from weather conditions which may affect the earthworks or earthworks material,
- (g) Methods of monitoring groundwater levels, and
- (h) Methods of monitoring the ground and structures for movements.

(2) The particulars shall be submitted to the Engineer at least 14 days before the relevant work starts.

Particulars of blasting 6.11

(1) The following particulars of the proposed blasting procedures shall be submitted to the Engineer:

- (a) Any conditions or restrictions imposed by the Commissioner of Mines, including copies of applications, licences, permits and correspondence,
- (b) Names, qualifications and experience of the persons responsible for the design and supervision of blasting operations,
- (c) Location, diameter, inclination and depth of holes to be charged with explosive,
- (d) Type and total mass of explosive to be used and its mass and distribution in each hole,
- (e) Dimensions of stemming and decking,
- (f) Initiation sequence, delay periods and mass of explosive per delay,
- (g) Burden and bench height,
- (h) Ratio of diameter of explosive to diameter of hole,
- (i) Arrangements for and methods of instrumentation and monitoring the effects of blasting,
- (j) Details of velocity seismographs, including manufacturer's literature,
- (k) Method of controlled blasting,
- (l) Details of blasting trials, and
- (m) Protective measures.

(2) The particulars, other than particulars relating to blasting trials, shall be submitted to the Engineer at least 48 hours before the relevant blasting starts. Particulars relating to blasting trials shall be submitted to the Engineer at least 14 days before the blasting trials are carried out.

GENERAL EARTHWORKS REQUIREMENTS

Ownership of earthworks material

6.12

(1) Earthworks material within the Site at the commencement of the Contract shall remain the property of the Employer except as stated in Clause 6.12(2).

(2) Earthworks material that needs to be disposed of by the Contractor shall become the property of the Contractor when it is removed from the Site and shall be disposed of in tips provided by the Contractor, unless otherwise stated in the Contract.

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| <i>Temporary Works for earthworks</i> | 6.13 | <p>(1) The design of Temporary Works associated with earthworks, including temporary slopes, stockpiles and drainage, shall be such that the risk of failure is not more than that which would be adopted if the Temporary Works were to be permanent. Allowance may be made in the design of the Temporary Works for the shorter design life and for the risk to persons and property and the surface water and groundwater conditions that are likely to occur during construction.</p> <p>(2) The Contractor shall provide details to the Engineer to demonstrate that the design of Temporary Works has been considered and incorporated measures, which minimise excavation of materials.</p> |
| <i>Handling and storage of earthworks material</i> | 6.14 | <p>(1) Earthworks material shall not be handled or stored in a manner which will result in segregation, deterioration, erosion or instability of the material.</p> <p>(2) Different types of earthworks material shall be kept separate from each other. Earthworks material that is suitable for use as fill material shall be maintained in a suitable condition and shall not be contaminated.</p> <p>(3) Material handling and storage areas shall be levelled and well drained. Stockpiles of material shall be sprayed with water or a dust suppression chemical to minimize dust generation.</p> |
| <i>Protection from water and weather</i> | 6.15 | <p>(1) Earthworks after site clearance, excavation or filling and earthworks material after excavation shall be kept free of water and shall be protected from damage due to water and from exposure to weather conditions which may affect the earthworks or earthworks material. The measures to be taken shall include the following:</p> <ul style="list-style-type: none"> (a) As stated in Clauses 1.19 and 1.20. (b) Surfaces shall be maintained in a stable condition and shall be formed to falls to shed water and to prevent ponding. (c) The area of exposed surfaces shall be kept to a minimum. <p>(2) Excavations for structures, pits and trenches shall not be carried out on or adjacent to slopes unless measures are taken to drain the excavation and to prevent water from the excavation entering the slope.</p> |
| <i>Earthworks material allowed to become unsuitable or to deteriorate</i> | 6.16 | <p>(1) Earthworks material which has been used, or is required for use, in the permanent work and which is allowed to become unsuitable such that in the opinion of the Engineer it no longer complies with the specified requirements for that type of material shall be replaced or dealt with by methods agreed by the Engineer.</p> <p>(2) Earthworks material which is not stated in the Contract to be excavated and which the Contractor causes or allows to deteriorate such that in the opinion of the Engineer the permanent work will be affected shall be replaced or dealt with by methods agreed by the Engineer.</p> <p>(3) Material provided to replace earthworks material, which has been allowed to become unsuitable, or which the Contractor causes or allows to deteriorate, shall be an equivalent material approved by the Engineer. The replacement material shall have the same volume after compaction as the material replaced.</p> <p>(4) The material that is to be replaced shall be disposed of by the Contractor.</p> |

<i>Additional excavation and stabilisation</i>	6.17	<p>(1) Earthworks material which is not stated in the Contract to be excavated but which in the opinion of the Engineer has inadequate strength, durability or stability shall be dealt with by additional excavation or filling as stated in Clause 6.17(2) or by stabilisation as stated in Clause 6.17(3) or by other methods instructed by the Engineer.</p> <p>(2) Additional excavation shall be carried out and the resulting voids shall be dealt with as follows:</p> <ul style="list-style-type: none"> (a) General fill material, fine fill material or special fill material shall be deposited and compacted below areas of fill and below formations other than in rock. (b) Grade 10 concrete shall be placed and compacted below formations in rock. (c) Granular fill material shall be deposited below standing water. <p>(3) Stabilisation shall be carried out using rock fill material (Grade 400) deposited directly into the original unstable material and compacted to form a stable foundation on which to construct the subsequent work.</p>
<i>Removal of earthworks material</i>	6.18	<p>Earthworks material that is required for use in the permanent work as fill material shall not be removed from the Site unless permitted by the Engineer. The Contractor shall notify the Engineer before any earthworks material is removed from the Site.</p>

EXCAVATION

<i>Disposal of excavated material</i>	6.19	<p>(1) The Contractor shall take measures to sort and separate excavated material on site for use in the permanent works as required in the environmental protection measures unless otherwise stated in the Contract. Excavated material, which in the opinion of the Engineer cannot be selected, processed or mixed in a practical manner to make it suitable for use in the permanent works, as fill material shall be disposed of by the Contractor unless otherwise stated in the Contract.</p> <p>(2) Excavated material that is surplus to the requirements of the permanent work shall be disposed of by the Contractor unless otherwise stated in the Contract. The Contractor shall, unless otherwise stated in the Contract, take all practical measures to sort and separate the surplus material according to its nature before disposal as required in the environmental protection measures and dispose of the material off-site using the Trip-ticket System.</p>
<i>Use of excavated material</i>	6.20	<p>(1) Excavated material required for use in the permanent work which is capable of being selected, processed and mixed to make it suitable for use as fill material shall not be used for any other purposes unless permitted by the Engineer.</p> <p>(2) Excavated material that is required for use in the permanent work as fill material and which the Engineer permits to be removed from the Site or used for other purposes shall be replaced by an equivalent material approved by the Engineer. The replacement material shall have the same volume after compaction as the material replaced.</p>

<i>Obstructions in excavations</i>	6.21	<p>(1) The Contractor shall inform the Engineer without delay of the nature and location of any unforeseen obstruction encountered during excavation.</p> <p>(2) Boulders that intersect the earthworks final surface or formation shall be dealt with as excavation proceeds by methods agreed by the Engineer. Boulders shall not be left protruding unless permitted by the Engineer.</p>
<i>Excavation</i>	6.22	<p>(1) Temporary supports or other methods shall be used to maintain excavations in a stable condition and to prevent settlement of structures or utilities due to excavation or dewatering.</p> <p>(2) Construction plant or other vehicles shall not be operated or parked adjacent to excavations and earthworks material or other materials shall not be placed adjacent to excavations unless this has been allowed for in the design of the Temporary Works for the support of the excavation.</p>
<i>Excavations adjacent to structures and utilities</i>	6.23	<p>(1) Excavations shall be carried out by hand adjacent to utilities that are known, proven or suspected to exist.</p> <p>(2) Unless otherwise permitted by the Engineer excavations next to structures shall be carried out by hand.</p>
<i>Excavations for structures, pits and trenches</i>	6.24	<p>(1) Excavations for structures, pits and trenches shall be the minimum size necessary to construct the permanent work. The sides of excavations shall be vertical unless otherwise permitted by the Engineer.</p> <p>(2) The length of trench excavation left open at any one time shall not exceed that agreed by the Engineer.</p> <p>(3) Unless permitted by the Engineer, trenches for utilities in fill areas shall not be excavated until the fill material has been deposited and compacted up to the earthworks final surface or formation or up to 1 m above the top of the utility, whichever is lower.</p>

BLASTING TRIALS

<i>Blasting trials</i>	6.25	<p>(1) Blasting trials shall be carried out for each proposed blasting procedure to demonstrate that:</p> <ul style="list-style-type: none"> (a) The procedure is safe, (b) The resulting ground vibrations at locations stated in the Contract or instructed by the Engineer can be satisfactorily predicted, recorded and are within acceptable limits, and shall not adversely affect the safety and stability of adjoining structures, installations, slopes and land, and (c) The specified tolerances for earthworks final surfaces and formations can be achieved. <p>(2) Blasting trials shall be completed at least 7 days before the related blasting starts.</p>
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(3) Blasting trials shall be carried out in accordance with the trial procedure submitted to and agreed by the Engineer. The location and size of blasting trials shall be as agreed by the Engineer.

<i>Controlled blasting trials</i>	6.26	Blasting trials for pre-splitting and other methods of controlled blasting shall be carried out to form a face at least 6 m wide by 6 m high. The blasting trials shall be carried out on rock which has similar properties to that of the earthworks final surface and which is at least 6 m away from the earthworks final surface.
<i>Results of blasting trials</i>	6.27	If in the opinion of the Engineer any aspect of the proposed blasting procedure as demonstrated by blasting trials is unsatisfactory, particulars of proposed changes to the procedure shall be submitted to the Engineer. Further blasting trials shall be carried out until the procedure is satisfactory.
<i>Commencement of blasting</i>	6.28	Blasting shall not proceed until in the opinion of the Engineer the procedure as demonstrated by the relevant blasting trials is satisfactory.
<i>Changes in blasting procedure</i>	6.29	Unless permitted by the Engineer, the satisfactory blasting procedure shall not be changed. Further blasting trials shall be carried out to demonstrate proposed changes to the procedure unless otherwise permitted by the Engineer.

BLASTING

<i>Statutory requirements for blasting</i>	6.30	Blasting operations and the supply, transportation, storage, use and disposal of explosives shall be in accordance with conditions and restrictions imposed by the Commissioner of Mines. The Contractor shall make all arrangements with and obtain all licences and permits from the Commissioner of Mines in connection with blasting operations.
<i>Recording vibrations due to blasting</i>	6.31	<p>(1) Measurements of vibrations due to blasting shall be taken at locations stated in the Contract or instructed by the Engineer at all times when blasting is carried out. Records of the vibrations shall be kept by the Contractor on the Site and a copy provided for the Engineer. Arrangements for installing instruments and taking measurements both inside and outside the Site shall be made by the Contractor.</p> <p>(2) Vibrations due to blasting shall be measured in terms of peak particle velocity, peak particle acceleration and vibrational amplitude. The peak values shall be taken as the maximum resultant calculated by vector summation of the three components of velocity and amplitude respectively, measured as instantaneously as the resolution of the recording instrument permits.</p> <p>(3) Measurements shall be made with velocity seismographs of a type agreed by the Engineer. Seismographs shall be capable of:</p> <ul style="list-style-type: none"> (a) Recording vibrations in terms of peak particle velocity and vibrational amplitude over a frequency of 0 – 200 Hz in three mutually perpendicular directions, and (b) Producing a permanent record of vibrations by tracing an ultra-violet light beam on sensitised paper, or by other methods agreed by the Engineer.

- (4) The accuracy of seismographs shall be checked before blasting trials are carried out and at regular intervals agreed by the Engineer.
- Preparatory work for blasting*** 6.32 Before assessments of blasting safety precautions are made, all vegetation, overburden and soft or loose material shall be removed to expose the rock that is to be blasted.
- Notification of blasting*** 6.33 The Contractor shall notify the Engineer by not later than noon of the previous day of his intention to bring any explosives to the Site or to carry out any blasting.
- Storage of explosives*** 6.34 Explosives and detonators shall not be stored on the Site overnight unless permitted by the Commissioner of Mines. Explosives and detonators which are not used by the end of each day shall be disposed of as stipulated by the Commissioner of Mines.
- Restrictions on blasting times*** 6.35 Blasting shall not be carried out at the following times:
- (a) On General Holidays,
 - (b) Before 8:30 a.m. or after 5:30 p.m. on any day,
 - (c) Unless permitted by the Commissioner of Mines, when a Hong Kong Observatory thunderstorm warning is in force, and
 - (d) Unless permitted by the Commissioner of Mines, when strong wind signal or storm signal No. 3 or higher is hoisted.
- Blasting*** 6.36
- (1) Unless otherwise permitted by the Commissioner of Mines, screens and other protective covers shall be erected to prevent the projection of flying fragments of material resulting from blasting. The screens shall be constructed using wire mesh securely supported on steel frames. The nominal diameter of the wire shall be at least 3.5 mm and the wire mesh size shall not exceed 25 mm.
 - (2) Unless permitted by the Commissioner of Mines, plaster blasting shall not be used.
 - (3) Unless otherwise permitted by the Commissioner of Mines blast holes shall be stemmed and decked using free-flowing granular material. Charges shall be covered with thick gunny sacking and 2 m by 2 m squares of steel fabric reinforcement weighed down with filled sandbags. Surface detonating cords, knots, detonating relay conductors and initiating detonators shall be covered with a 300 mm thickness of sand or soil.
 - (4) Unless permitted by the Commissioner of Mines electrical detonators shall not be used within 60 m of overhead power lines. The use of electrical detonators in the vicinity of static or mobile radio transmitters shall comply with BS 6657.
 - (5) Unless otherwise permitted by the Commissioner of Mines delay blasting with millisecond delays shall be used for all blasting, except as stated in Clause 6.37(5).
 - (6) Unless permitted by the Engineer blasting shall not be carried out within a distance of:

- (a) 60 m from water retaining structures or water tunnels, and
- (b) 6 m from water mains or other water supply structures or installations.

(7) Unless permitted by the Engineer the vibrations at structures and installations due to blasting measured in terms of peak particle velocity and vibrational amplitude shall not exceed the values stated in Table 6.2.

(8) Unless otherwise permitted by the Engineer, the vibration at adjoining slopes and land due to blasting measured in terms of peak particle acceleration and peak particle velocity shall not exceed the values stated in the Contract.

Table 6.2: Restrictions on peak particle velocity and vibrational amplitude

Type of structure or Installation	Peak particle velocity (mm/s)	Vibrational amplitude (mm)
Water retaining structures Water tunnels	13	0.1
Water mains Other structures and pipes	25	0.2

Controlled blasting

6.37

(1) Earthworks final surfaces which are to be formed by blasting and which slope at a gradient exceeding 2 vertical to 1 horizontal and exceed 3 m in height shall be formed by pre-splitting. Other methods of controlled blasting shall not be used unless permitted by the Engineer.

(2) Pre-splitting and other methods of controlled blasting shall be carried out in such a manner that the rock mass is cleanly split on the required plane to within the specified tolerances and such that rock outside the earthworks final surface is not shattered or loosened.

(3) Faces formed by pre-splitting or other methods of controlled blasting shall not exceed 15 m in height in any one blasting operation unless permitted by the Engineer.

(4) If an earthworks final surface is to be formed by pre-splitting or other methods of controlled blasting:

- (a) Other blast holes shall be located at a sufficient distance from the earthworks final surface to avoid damaging the surface, and
- (b) The row of blast holes nearest to that surface shall be parallel to the row of pre-splitting holes.

(5) Pre-splitting shall consist of a single row of holes drilled at the appropriate inclination along the line of the earthworks final surface. The holes shall be loaded with explosives not exceeding half the diameter of the hole. The explosives shall be detonated simultaneously or with the minimum amount of delay necessary to reduce ground vibrations.

(6) Holes for pre-splitting shall be at least 50 mm diameter and the ratio of the distance between the centre of the holes and the diameter of the hole shall not exceed 10. The holes shall be within a distance of 0.015 times the length of the hole from their designed position.

(7) Holes for pre-splitting shall not be drilled into the sub-grade below berm levels. Rock that remains in position on berms after blasting shall be removed by methods other than blasting.

DEPOSITION OF FILL MATERIAL

<i>Types of fill material</i>	6.38	Unless otherwise stated in the Contract, areas of fill shall be formed of general fill material.
<i>Sources of fill material</i>	6.39	Except in public filling area as stated in Clause 6.58, fill material shall be obtained from excavation within the Site. If there is insufficient fill material of the required types within the Site, imported fill material shall be provided by the Contractor from sources outside the Site.
<i>Surface preparation for fill material</i>	6.40	<p>Except as stated in Clause 6.56, surfaces on which fill material is to be deposited shall be prepared after site clearance in accordance with the following requirements:</p> <ul style="list-style-type: none"> (a) Topsoil, grass, and other organic matter shall be removed. (b) Soft spots, boulders and other materials, which in the opinion of the Engineer are unsuitable or unstable, shall be removed. (c) Watercourses shall be diverted as stated in the Contract. (d) Benches shall be cut and sub-soil drainage systems installed as stated in the Contract. (e) Voids shall be dealt with as stated in the Contract or instructed by the Engineer. (f) Surfaces other than rock shall be scarified to a depth of 200 mm and compacted to the same standard as the fill material that is to be deposited.
<i>Commencement of deposition of fill material</i>	6.41	The permission of the Engineer shall be obtained before deposition of fill material starts in any area of fill.
<i>Haulage of fill material</i>	6.42	Haulage of fill material to an area of fill shall proceed only when the compaction plant operating at the area to be filled is sufficient to achieve the specified requirements for relative compaction of the fill material.
<i>Deposition of fill material</i>	6.43	<p>(1) Fill material obtained from excavations within the Site shall be deposited in its final location as soon as practicable after it has been excavated.</p> <p>(2) Fill material shall be deposited in layers of a thickness appropriate to the compaction method to be used. In deposition of fill material, the Contractor shall ensure that a good bond is achieved between layers of fill, and unless otherwise directed by the Engineer, no material shall be placed</p>

on previously compacted layers unless the surface has been scarified or otherwise broken up and, if necessary, watered.

(3) Unless otherwise permitted by the Engineer, layers of fill material shall be horizontal, except for any gradient required for drainage, and the thickness of each layer shall be uniform over the area to be filled. The fill material shall be brought up from the bottom in uniform horizontal layers, with the top of each layer graded to enable surface water to drain readily.

(4) Except in excavations for structures, pits and trenches, if the difference in level between adjacent areas to be filled exceeds 1 m, the edge of the higher area shall be benched before fill material is placed against it.

(5) Execution of the Works shall be controlled in such a manner that any compaction of the fill material resulting from the passage of construction plant or haulage vehicles is uniform.

(6) Except as stated in Clause 6.56, fill material shall not be deposited by end-tipping, by pushing loose material down slope faces or by other methods which may result in segregation or inadequate compaction of the fill material.

Overfilling

6.44

In areas of fill formed of material other than rock fill material, earthworks final surfaces sloping at a gradient exceeding 1 vertical to 3 horizontal shall be formed by overfilling and cutting back after compaction. Over-filling shall extend beyond the earthworks final surface by a horizontal distance of 0.5 m or three times the thickness of the compacted layer, whichever is greater.

Deposition of fill material adjacent to structures and utilities

6.45

(1) Except as stated in Clause 6.45(4), fill material deposited within 0.5m of a structure or utility shall be fine fill material unless otherwise stated in the Contract. In addition, the material may contain up to 5% by weight of fresh, slightly decomposed or moderately decomposed rock fragments of up to 200 mm provided that these do not cause any damage to structures, nor do they interfere with the compaction requirements.

(2) Fill material shall not be deposited adjacent to or above structures or utilities until the construction of the structure or utility is sufficiently advanced to accept the imposed forces without disturbance or damage.

(3) Fill material shall be deposited evenly on all sides of structures and utilities and in such a manner that the structure or utility is not disturbed or damaged.

(4) Unless otherwise stated in the Contract, fill material around water, sewage and drainage pipes which are laid as part of the permanent work shall be special fill material. They shall be deposited in layers not exceeding 100 mm thick to a level of 300 mm above the top of the pipe. The fill material shall be deposited in such a manner that the layer on one side of the pipe is not more than 100 mm higher than the layer on the other side.

<i>Deposition of rock fill material</i>	6.46	<p>(1) The final compacted thickness of each layer of rock fill material shall exceed 1.5 times and shall not exceed twice the nominal Grade size of the rock fill material.</p> <p>(2) The surface voids of each layer of rock fill material shall be filled with fragments of rock before the next layer is deposited. The final surface of rock fill material shall also be blinded with fine fill material.</p>
<i>Deposition of fill material in excavations for structures, pits and trenches</i>	6.47	If sheet piling, timbering or other temporary supports to excavations for structures, pits and trenches are not to be left in place, the sheet piling, timbering or supports shall be removed as deposition of fill material proceeds. The supports shall be removed in such a manner that the stability of the adjacent ground is maintained and the compacted fill material is not disturbed.

COMPACTION OF FILL MATERIAL

<i>Compaction of fill material</i>	6.48	<p>(1) Fill material in areas of fill shall be compacted in layers to a stable condition as soon as practicable after deposition and in a manner appropriate to the location and to the material to be compacted.</p> <p>(2) The permission of the Engineer shall be obtained before the next layer is deposited on each layer of compacted fill material.</p> <p>(3) Except as stated in Clauses 6.50(2), 6.52(1), 6.54(2), 6.57 and 6.66, fill material shall be compacted to obtain a relative compaction of at least 95% throughout unless otherwise stated in the Contract.</p>
<i>Moisture content of fill material</i>	6.49	Fill material other than rock fill material and material as stated in Clause 6.52(1) shall be at optimum moisture content during compaction. The tolerance on the optimum moisture content percentage shall be $\pm 3\%$, provided that the fill material is still capable of being compacted in accordance with the specified requirements to form stable areas of fill. All necessary measures shall be taken to achieve and maintain the specified moisture content.
<i>Compaction of fill material adjacent to structures and utilities</i>	6.50	<p>(1) Fill material shall be compacted in such a manner that structures or utilities are not disturbed or damaged.</p> <p>(2) Fill material around water, sewage and drainage pipes, which are constructed as part of the permanent work, shall be compacted by hand-rammers or manually operated power equipment. Fill material within 300 mm above the top of sewage and drainage pipes shall be compacted to obtain a relative compaction of at least 85% throughout.</p>
<i>Compaction of rock fill material</i>	6.51	<p>(1) Every layer of rock fill material shall be compacted by at least eight passes of a vibrating roller or by other equivalent compaction method approved by the Engineer. The final surface of rock fill material shall be compacted by at least two additional passes of a vibrating roller or by other equivalent compaction method approved by the Engineer.</p> <p>(2) Vibratory rollers used for the compaction of rock fill material shall have a static load per 100 mm width of roll of at least 2 kN for layers with a compacted thickness not exceeding 500 mm and at least 4 kN for layers with a compacted thickness exceeding 500 mm.</p>

*Compaction of
general fill material
with a large portion of
coarse material*

6.52

(1) For general fill material of which less than 90% passes a 20 mm BS test sieve, it is difficult to determine of the moisture content and maximum dry density according to Clauses 6.75(2), 6.75(3), 6.78(2), 6.81(5) and 6.81(6). This type of material shall be compacted to the requirements of Clauses 6.52(2), 6.52(3) and 6.52(4).

(2) Each horizontal layer of general fill material shall be spread and levelled with a thickness not less than 1.5 times of the maximum size of the general fill material and not exceeding the maximum depth of compacted layer in accordance with Table 6.2A. If there is a presence of over-sized coarse material in the general fill, the over-sized coarse material shall be removed or broken down to sizes acceptable to the Engineer. Each layer shall be systematically compacted by a vibratory roller with the stipulated minimum number of passes corresponding to the minimum static load per 100 mm width of the roller.

(3) The number of passes of the roller shall only be counted when the roller is travelled on the material to be compacted at a speed of not more than 2 km per hour with full vibration. Plant other than a vibratory roller carrying out material spreading or providing some preliminary compaction, to assist the use of heavier plant, shall be disregarded in counting the number of passes.

(4) Variation from the method or the use of plant different from that specified in Clause 6.52(2) will be permitted only if the Contractor demonstrates at site trials that equivalent compaction is achieved by the alternative method or plant. The procedure to be adopted for these site trials shall be agreed with and approved by the Engineer.

(5) Without prejudice to the provision of the Conditions of Contract and in order that the Engineer may take proper provision for the supervision of compaction in the permanent work, the Contractor shall, not less than 24 hours before he proposes to carry out compaction processes, apply in writing to the Engineer for permission to do so.

(6) When materials of widely divergent grading are used in embankments and fill areas, they shall be spread and compacted in separate clearly defined areas.

(7) If more than one class of material is being used in such a way that in the opinion of the Engineer, it is not practicable to define the areas in which each class occurs, compaction plant shall be operated as if only the material that requires the greatest compaction effort is being compacted.

Table 6.2A: Compaction requirement for general fill material with a large portion of coarse material

Force per 100 mm width	Well-graded material		Uniform-graded material	
(kN)	Maximum depth of compacted layer (mm)	Minimum no. of passes	Maximum depth of compacted layer (mm)	Minimum no. of passes
0.25 – 0.45			150	16
0.46 – 0.70			150	12
0.71 – 1.25	125	12	150	10
1.26 – 1.75	150	8	200	10
1.76 – 2.30	150	4	225	10
2.31 – 2.80	175	4	250	10
2.81 – 3.50	200	4	275	8
3.51 – 4.20	225	4	300	8
4.21 – 4.90	250	4	300	8

COMPLETION OF EARTHWORK SURFACES

Completion of earthwork final surfaces

- 6.53 (1) Earthwork final surfaces shall be completed to a stable condition as soon as practicable after excavation or after deposition and compaction of fill material has been completed. The subsequent permanent work or surface protection shall be carried out as soon as practicable after the earthworks final surface has been completed.
- (2) Earthworks final surfaces shall be completed to smooth alignments without abrupt irregularities unless otherwise stated in the Contract.

Completion of formations

- 6.54 (1) Formations above structures or utilities shall be completed after construction of the structure or utility.
- (2) Except in excavations in rock and in areas of fill formed of rock fill material or fill material as stated in Clause 6.52(1), formations shall be compacted to obtain a relative compaction of at least 98% to a depth of 200 mm below the formation.
- (3) Unless otherwise permitted by the Engineer, proof rolling shall be carried out on formations. The formation shall be rolled in the presence of the Engineer by at least two passes of a non-vibrating rubber tyred roller. The roller shall have a static load per 100 mm width of roll of at least 4 kN and shall travel at a speed not exceeding 2 km/h. Any defect in the formation which is revealed during proof rolling by deformation of the formation which in the opinion of the Engineer is excessive shall be made good as instructed by the Engineer.
- (4) After all other formation work and testing have been completed and damage caused by testing reinstated, formations for pavements shall be rolled with one pass of a smooth steel-wheeled non-vibrating roller. The roller shall have a load per 100 mm width of roll of at least 2 kN.
- (5) Unless otherwise permitted by the Engineer, formation surfaces that will not be immediately covered by the subsequent permanent works shall be protected by methods agreed by the Engineer.

<i>Protection of earthwork final surfaces and formations</i>	6.55	<p>(1) Earthwork final surfaces and formations shall be maintained in a stable condition and shall be protected from damage due to water or other causes and from exposure to conditions which may adversely affect the surface.</p> <p>(2) Formation shall not be used by construction plant or vehicles other than those which, in the opinion of the Engineer, are essential to construct the subsequent work.</p>
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INTERMEDIATE AREAS OF FILL

<i>Deposition of fill material in intermediate areas of fill</i>	6.56	Fill material may be deposited in intermediate areas of fill by end-tipping or by pushing into position until, in the opinion of the Engineer, it is sufficient to form a stable foundation on which to construct the subsequent work.
<i>Compaction of fill material in intermediate areas of fill</i>	6.57	<p>Fill material in intermediate areas of fill up to the level stated in Clause 6.56 shall be compacted to a degree, which in the opinion of the Engineer is practicable. Except as stated in Clause 6.52(1), fill material above the level stated in Clause 6.56 shall be compacted to obtain a relative compaction of at least:</p> <ul style="list-style-type: none"> (a) 90% throughout, (b) 95% within 1.5 m of earthworks final surfaces and formations, and (c) 98% within 200 mm of formations.

EARTHWORKS IN PUBLIC FILLING AREA

<i>Public filling area</i>	6.58	Public filling area shall mean any area or portion of earthworks/reclamation works to receive inert construction and demolition material, and other materials disposed of by the public as stated in the Contract.
<i>Public fill</i>	6.59	Public fill shall mean inert construction and demolition material that is disposed of at a public filling area.
<i>Combined reception and exit offices</i>	6.60	<p>(1) Combined reception and exit offices for the operation of a public filling area shall be provided at the location shown on the Drawings.</p> <p>(2) The Contractor shall design and provide the combined reception and exit office in accordance with the schematic layout shown on the Drawings. The combined reception and exit office shall comply with the following requirements:</p> <ul style="list-style-type: none"> (a) Each shall consist of two floors and shall be constructed on a 1300mm high raised hollow platform. The upper floor is an inspection cabin, which shall be designed to withstand at least 5kPa live load and equipped with staircases and guard railings.

- (b) Windows of sliding type with locks and security bars shall be provided at the sides to enable a clear view of the approaching traffic. All windows shall be provided with venetian blinds.
 - (c) Collision barriers, collision bollards, separation barriers, red/green light type automatic signaling system and drop-bars shall be provided as shown on the Drawings.
 - (d) An overhead water-spraying system shall be installed at each of the reception hallways. It shall consist of groups of nozzles and shall be supported firmly with posts standing on the ground. Each overhead water-spraying system shall be capable of emitting 100 litres of water in 30 seconds.
 - (e) The roof and all walls shall be fully lined, well insulated, waterproof and painted.
 - (f) All doors shall have secure and efficient locks.
 - (g) A surveillance system shall be installed in each combined reception and exit office at locations agreed by the Engineer. The surveillance system shall consist of closed circuit digital colour video camera, closed circuit video duplex multiplexer and the accessories with schedule as stated in the Contract. The surveillance system shall be operated in accordance with Clause 6.60(3).
 - (h) Weighbridge system shall be installed at each combined reception and exit office at locations as agreed with the Engineer to measure and record the weight of each and every dump truck using the public filling area. The weighbridge system shall be calibrated by a suitable method and at frequency as agreed with the Engineer.
- (3) The surveillance system shall be operated as follows: -
- (a) The camera of the surveillance system shall allow continuous recording and close surveillance of activities within the public filling area during the operation hours.
 - (b) Images captured by the cameras shall be continuously recorded by DVD recorders. Each recorded DVD shall be kept for at least 6 months. The Contractor shall insert and replace the DVD for the surveillance system so as to ensure the continuous recording of the operation activities.
 - (c) The position and angle of each camera of the surveillance system shall be as instructed by the Engineer. The Contractor shall be responsible for any relocation and/or adjustment required.
- (4) Detailed proposals for the combined reception and exit offices shall be submitted by the Contractor to the Engineer for approval within 14 days of the date for commencement of the Works. The proposal shall include locations, layouts, associated facilities and construction details.

(5) Within 28 days of the date of approval by the Engineer, the Contractor shall complete the construction of the combined reception and exit offices that shall be ready for occupation and operation.

(6) The combined reception and exit offices shall be maintained in a clean, stable and secure condition daily.

(7) Equipment provided for the use of the Engineer shall be maintained in a clean and serviceable condition and all consumables shall be replenished as instructed by the Engineer.

(8) The permission of the Engineer shall be obtained before the combined reception and exit office or equipment is removed. The combined reception and exit office or equipment which are to be left in position or become the property of the Employer after completion of the Works shall be repaired, repainted and serviced as instructed by the Engineer.

***Reception areas,
queuing areas and
access roads***

6.61

(1) Reception areas, queuing areas and access roads shall be provided in accordance with the Drawings.

(2) The Contractor shall operate and maintain reception areas, queuing areas and access roads complying with the following requirements:

(a) The riding surfaces shall be kept in good condition without excessive bumps and depressions,

(b) The surfaces shall be kept in wet condition so as to minimize dust generation,

(c) The surfaces shall be kept free of grease, debris and the like, and

(d) Measures shall be taken to prevent ponding and flooding.

***Management of dump
truck movements***

6.62

(1) The Contractor shall manage entry to and exit from the public filling area to:

(a) Maintain orderly traffic conditions at the reception areas, queuing areas and access roads.

(b) Ensure all dump trucks are inspected and weighed at the combined reception and exit offices before and after deposition. In the event that the materials carried by a dump truck are inspected as not acceptable, the Contractor shall direct the dump truck to leave the Site as instructed by the Engineer, and

(c) Direct dump trucks to the designated deposition point for deposition.

(2) The maximum speed of dump trucks within the public filling area shall be restricted to 10km per hour.

Upon instruction by the Engineer, the Contractor shall within three hours tow away any broken down dump truck from an operation area to a safe area within the Site as agreed with the Engineer so as not to disrupt the operation of the public filling area.

(3) The Contractor shall supply and erect temporary traffic signs, including speed limit signs, for directing dump trucks and traffic diversion within the public filling area.

Temporary haul roads and drains 6.63

(1) The Contractor shall provide and maintain temporary haul roads and drains to suit the programme of deposition and shall remove all temporary drainage systems after the Works. Lighting facilities shall be provided along the temporary haul roads and at each deposition point to ensure safe operation.

(2) The Contractor shall design the temporary haul roads and drains to ensure good riding condition and safety. All temporary haul roads shall be paved with granular material. The Contractor shall submit the details of the proposed temporary haul roads and drains to the Engineer for agreement 14 days before implementation or commencement of associated work whichever is earlier.

(3) The Contractor shall grade, regulate and compact all temporary haul roads as instructed by the Engineer to prevent undulation.

Handling and storage of wet soil 6.64

(1) Public fill may consist of wet soil. Wet soil may be any naturally occurring or processed material, which at the time of deposition is unable to be compacted in accordance with the specified requirements to form a stable area of fill.

(2) The Contractor shall plan the Works by allowing stockpiling space as agreed with the Engineer for handling wet soil. The Contractor shall process the wet soil received including mixing it with public fill to make it suitable for compaction and use in the Works. The processed material shall be handled and stored in accordance with Clause 6.14. The proposed method of processing and mixing shall be agreed with the Engineer at least 7 days before any processing and mixing starts.

Deposition of public fill 6.65

Clauses 6.43(2), 6.43(3), 6.43(4), 6.43(5), 6.43(6), 6.44, and 6.56 shall apply to deposition of public fill.

Compaction of public fill 6.66

(1) In addition to Clauses 6.48(1), 6.48(2) and 6.50(1), public fill shall be compacted to the requirements of Clauses 6.66(2), 6.66(3) and 6.66(4). The Contractor shall submit the proposed method of compaction including the proposed compaction plant, thickness of compacted layer and minimum number of passes to the Engineer for approval at least 7 days before any compaction starts.

(2) Each horizontal layer of public fill shall be spread and levelled with a thickness not exceeding the maximum depth of a compacted layer in accordance with Table 6.2B. Each layer shall be systematically compacted by the compaction plant with the minimum number of passes approved by the Engineer.

(3) Definitions and requirements associated with Table 6.2B are as follows:

(a) Where combinations of different types or categories of plant are used, the compaction requirements shall be:

- The depth of layer shall be that for the type of plant requiring the least depth of layer: and

- The number of passes shall be that for the type of plant requiring the greatest number of passes.
- (b) The number of passes of the roller shall only be counted when the roller is travelled on the materials to be compacted at a speed of not more than 2 km per hour with full vibration where appropriate.
- (c) The plant other than the approved compaction plant by the Engineer as stated in Clause 6.66(1) to carry out material spreading or to provide some preliminary compaction only to assist the use of heavier plant shall be disregarded in counting the number of passes.
- (d) The force per 100 mm width is the total weight on the roll divided by the total roll width. Where a smooth-wheeled roller has more than one axle the machine will be assessed on the basis of the axle giving the highest value of force per 100 mm width.
- (e) Wheel load is the total weight of the roller divided by the number of wheels.
- (f) Vibratory rollers are machines having means of applying mechanical vibration to one or more rolls.
 - The requirements for vibratory rollers are based on the use of the lowest gear on a self-propelled machine and a towing speed of 1800 - 2400 m/hour for a towed machine. If higher gears or speed are used, an increased number of passes shall be provided in proportion to the increase in speed of travel.
 - Vibratory rollers operating without their vibration mechanism in use will be classified as smooth-wheeled rollers.
 - Vibratory rollers shall only be operated with their vibration mechanism operating at the frequency of vibration recommended by the manufacturers. All such rollers shall be equipped with a device automatically indicating the frequency at which the mechanism is operating.
- (g) Vibrating-plate compactors are machines having a base-plate to which a source of vibration consisting of one or two eccentrically weighted shafts is attached.
 - The static pressure under the plate of a vibrating-plate compactor is calculated by dividing the total weight of the machine in working order by the area in contact with compacted material.
 - Vibrating-plate compactors shall be operated at the frequency of vibration recommended by the manufacturer. They shall normally be operated at travelling speeds of

less than 900 m/hour but, if higher speeds are necessary, the number of passes shall be increased in proportion to the increase in speed of travel.

- (h) Vibro-tampers are machines in which an engine-driven reciprocating mechanism acts on a spring system, through which oscillations are set up in a base-plate.
- (i) Power rammers are machines that are actuated by explosions in an internal combustion cylinder, each explosion being controlled manually by the operator.

(4) Variation from the methods or the use of plant different from that specified in Clause 6.66(2) will be permitted only if the Contractor demonstrates by site trials that equivalent compaction effect is achieved by the alternative method or plant. The procedure to be adopted for these site trials shall be agreed with and approved by the Engineer.

(5) Without prejudice to the provision of the Conditions of Contract and in order for the Engineer to make proper provision for the supervision of compaction in the permanent work, the Contractor shall, not less than 24 hours before he proposes to carry out compaction processes, apply in writing to the Engineer for permission to do so.

Table 6.2B: Compaction requirement

Type of compaction plant	Category	Maximum depth of compacted layer (mm)	Minimum no. of passes
Smooth-wheel roller	Force per <u>100 mm width</u> 2.1 – 2.6 kN	125	10
	2.61 – 5.2 kN	125	8
	More than 5.2 kN	150	8
Grid-roller	Force per <u>100 mm width</u> 5.3 – 7.8 kN	125	12
	More than 7.8 kN	150	12
Pneumatic-tyre roller	<u>Wheel load</u> 2 - 2.5 tonnes	125	12
	2.6 - 4 tonnes	125	10
	4 - 6 tonnes	125	10
	6 - 8 tonnes	150	8
	8 - 12 tonnes	150	8
	More than 12 tonnes	175	6
Vibratory roller	Force per <u>100 mm width</u> 0.71 – 1.25 kN	100	12
	1.26 – 1.75 kN	125	8
	1.76 – 2.3 kN	150	4
	2.31 – 2.8 kN	175	4
	2.81 – 3.5 kN	200	4
	3.51 – 4.2 kN	225	4
	4.21 – 4.9 kN	250	4
Vibratory-plate compactor	Static pressure under <u>base plate (kN/m²)</u> 13.8 - 17.2	100	6
	17.3 - 20.7	150	6
	More than 20.7	200	6
Vibro-tamper	<u>Mass (kg)</u> 50 – 65	100	3
	66 – 75	125	3
	More than 75	150	3
Power rammer	<u>Mass (Kg)</u> 100	150	6
	More than 500	275	12

*Use of fill material
adjacent to structures
and utilities in public
filling area*

6.67

Fill material shall be used adjacent to structures and utilities in public filling areas as stated in the Contract. Fill material shall comply with Clause 6.09. The use of fill material shall comply with Clauses 6.45, 6.47 and 6.50.

TOLERANCES

***Tolerances:
earthworks final
surfaces and
formations***

6.68

(1) Earthworks final surfaces and formations shall be within the tolerances of the specified lines and levels stated in Table 6.3. The tolerances for formations do not apply to pipes or preformed structures that require to be supported over their complete length or area.

(2) In excavation, a positive tolerance refers to insufficient excavation and a negative tolerance refers to excess excavation. In areas of fill, a positive tolerance refers to excess fill material and a negative tolerance refers to insufficient fill material.

Table 6.3: Tolerances for earthworks final surfaces and formations

Type of surface	Method of forming surface	Tolerance (mm)	
		+	-
Formations for structures and utilities	Excavation except in rock	0	25
	Excavation in rock	0	150
	Deposition and compaction of fill material	0	25
Formations for pavements, including carriageways, footways, cycletracks, paved areas, aircraft pavements and railway trackbeds.	Excavation except in rock	0	50
	Excavation in rock	0	150
	Deposition and compaction of fill material	0	50
Earthworks final surfaces other than formations, with a gradient not exceeding 1 vertical to 10 horizontal	Excavation except in rock	0	100
	Excavation in rock	0	200
	Deposition and compaction of fill material	0	100
Other earthworks final Surfaces	Excavation except in rock	100	100
	Excavation in rock	100	200
	Deposition and compaction of fill material	100	100

TESTING: FILL MATERIAL - GENERAL REQUIREMENTS

- Batch: fill material** 6.69 A batch of fill material is any quantity of fill material of the same type and which in the opinion of the Engineer has similar properties throughout. For the purpose of testing for moisture content and relative compaction a batch shall, in addition to the above, be fill material which is deposited in a single layer in any area of fill presented by the Contractor for testing on one occasion.
- Samples: fill material** 6.70 (1) Each sample of fill material shall consist of at least four increments taken from different parts of the batch. The increments shall be combined and thoroughly mixed and shall then be divided by quartering or by using a riffle box to obtain specimens of an appropriate size to carry out the individual tests.
- (2) The size of samples of fill material other than rock fill material shall be in accordance with Geospec 3, Clauses 2.5.1, 4.2 and Table 2.1. Each sample of rock fill material of Grade size not exceeding 200 shall have a mass of at least 250 kg and each sample of rock fill material of Grade size exceeding 200 shall have a mass of at least 1000 kg.

TESTING: FILL MATERIAL - PARTICLE SIZE DISTRIBUTION, LIQUID LIMIT, PLASTICITY INDEX, COEFFICIENT OF UNIFORMITY AND SULPHATE CONTENT

- Samples: particle size distribution, liquid limit, plasticity index, coefficient of uniformity, sulphate content** 6.71 Samples of fill material to be tested for particle size distribution, liquid limit, plasticity index, coefficient of uniformity and sulphate content shall be delivered at least 14 days, or such shorter period agreed by the Engineer, before deposition of the fill material starts. The number of samples to be provided from each batch shall be as stated in Table 6.4.

Table 6.4: Number of samples to be tested for particle size distribution, liquid limit, plasticity index, coefficient of uniformity, sulphate content, optimum moisture content and maximum dry density

Description	Size of batch	No. of samples per batch
Special fill material	0 - 3,000 m ³	3
	Exceeding 3,000 m ³	1 for each 1,000 m ³ or part thereof
Fill material other than special fill material	0 - 15,000 m ³	3
	Exceeding 15,000 m ³	1 for each 5,000 m ³ or part thereof

Testing: *particle size distribution, liquid limit, plasticity index, coefficient of uniformity, sulphate content* 6.72

(1) Each sample of fill material taken as stated in Clause 6.71 shall be tested to determine the particle size distribution. In the case of special fill material, testing shall include calculation of the coefficient of uniformity as stated in Clause 6.72(4). Unless otherwise agreed by the Engineer, each sample of fill material other than rock fill material shall be tested to determine the liquid limit and the plasticity index of that portion of the fill material passing a 425µm BS test sieve. Each sample of fill material, which will be deposited within 500 mm of concrete, cement, bound material, cementitious material or metalwork shall be tested to determine the soluble sulphate content.

(2) The method of testing shall be in accordance with the following:

Particle size distribution	: Clause 6.72(3)
Liquid limit	: Test Method 6.1 of Geospec 3
Plasticity index	: Test Method 6.1 of Geospec 3
Soluble sulphate content	: Test Method 9.3 of Geospec 3
Total sulphate content	: Test Method 9.3 of Geospec 3

(3) The particle size distribution of fill material passing a 75 mm BS test sieve shall be determined in accordance with Geospec 3, Test Method 8.1 or 8.2, whichever as instructed by the Engineer. The size of particles of fill material, which do not pass a 75 mm BS test sieve, shall be taken as the largest dimension measured in any plane.

(4) The coefficient of uniformity (Cu) shall be calculated from the equation:

$$Cu = D_{60}/D_{10}$$

where:

- D₆₀ and D₁₀ are the equivalent sieve sizes in millimetres, interpolated from the particle size distribution curve, through which 60% and 10% of the fill material would pass respectively.

Non-compliance: *particle size distribution, liquid limit, plasticity index, coefficient of uniformity, sulphate content* 6.73

(1) If the result of any test for soluble sulphate content of fill material does not comply with the specified requirements for soluble sulphate content, each sample shall be tested to determine the total sulphate content.

(2) If the result of any test for particle size distribution, liquid limit, plasticity index, coefficient of uniformity or total sulphate content of fill material does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be as stated in Table 6.4.

TESTING: FILL MATERIAL - OPTIMUM MOISTURE CONTENT AND MAXIMUM DRY DENSITY

<i>Samples: optimum moisture content, maximum dry density</i>	6.74	<p>(1) Samples of fill material to be tested for optimum moisture content and maximum dry density shall be delivered at least 72 hours, or such shorter period agreed by the Engineer, before deposition of the fill material starts. The number of samples to be provided from each batch shall be as stated in Table 6.4.</p> <p>(2) The Contractor shall inform the Engineer of the exact location in which the fill material from which each sample is taken is to be deposited.</p> <p>(3) Samples to be tested for optimum moisture content and maximum dry density shall also be taken after the fill material has been deposited in its final position, at intervals of not more than 28 days.</p> <p>(4) Samples shall not be provided from:</p> <ul style="list-style-type: none"> (a) Fill material including rock fill material which contains an insufficient proportion of particles passing a 20 mm BS test sieve to permit determination of the moisture content and maximum dry density, and (b) Fill material that is to be deposited as stated in Clause 6.56.
<i>Testing: optimum moisture content, maximum dry density</i>	6.75	<p>(1) Each sample of fill material taken as stated in Clause 6.74 shall be tested to determine the optimum moisture content and the maximum dry density.</p> <p>(2) The method of testing shall be in accordance with Geospec 3, Test Method 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7 or 10.8, whichever is instructed by the Engineer.</p> <p>(3) If agreed by the Engineer, the Hilf method stated in Appendix 6.3 may be used instead of the methods stipulated in Clause 6.75(2) to determine the optimum moisture content and maximum dry density.</p> <p>(4) If in the opinion of the Engineer there is any undue discrepancy between the results of tests for optimum moisture content of fill material using methods stipulated in Clause 6.75(2) and the results of tests using the Hilf method, the results of tests using methods stipulated in Clause 6.75(2) shall prevail.</p>
<i>Consistency: optimum moisture content, maximum dry density</i>	6.76	<p>If the result of any test for optimum moisture content or maximum dry density of fill material indicates that the batch contains material which in the opinion of the Engineer, differs to such an extent that subsequent tests for relative compaction may be affected, the batch shall be divided into smaller batches. Each of the smaller batches shall comprise material with similar properties throughout. Additional samples shall be provided from each of the smaller batches and additional tests for optimum moisture content and maximum dry density shall be carried out. The number of additional samples shall be as stated in Table 6.4.</p>

TESTING: FILL MATERIAL - MOISTURE CONTENT:***Samples:
moisture content***

- 6.77 (1) Samples of fill material to be tested for moisture content shall be taken during deposition and compaction of fill material and shall be delivered not more than 1 hour after the fill material has been deposited in its final position.
- (2) The number of samples to be provided from each batch shall be as stated in Table 6.5. Samples shall not be provided if, in accordance with Clause 6.74(4)(a) or (b), the optimum moisture content has not been determined.

***Testing:
moisture content***

- 6.78 (1) Each sample of fill material taken as stated in Clause 6.77 shall be tested to determine the moisture content.
- (2) The method of testing shall be in accordance with one of the following methods:
- (a) Method 1 : Geospec 3, Test Method 5.1 or 5.2, whichever is instructed by the Engineer
 - (b) Method 2 : Microwave oven drying method as stated in Appendix 6.2.

Method 1 shall be used unless otherwise agreed by the Engineer.

***Compliance criteria:
moisture content***

- 6.79 If in the opinion of the Engineer there is any undue discrepancy between the results of tests for moisture content of fill material using Method 1 and the results of tests using Method 2 in Clause 6.78, the results of tests using Method 1 shall prevail.

***Non-compliance:
moisture content***

- 6.80 If the result of any test for moisture content of fill material differs from the optimum moisture content by more than the specified amount and if instructed by the Engineer, the moisture content of the whole of the batch of fill material shall be adjusted. Additional samples shall be provided from the same batch and additional tests for moisture content shall be carried out. The number of additional samples shall be as stated in Table 6.5.

Table 6.5: Number of samples to be tested for moisture content and number of tests for relative compaction

Description	Size of area of fill in batch	No. of samples/No. of tests per batch
Areas of fill in excavations for structures, pits and trenches and on formations	0 - 100 m ²	3
	100 - 500 m ²	2 for each 100 m ² or part thereof
	exceeding 500 m ²	1 for each 100 m ² or part thereof
Other areas of fill	0 - 1 ha	4 for each 1000 m ² or part thereof
	1 - 10 ha	3 for each 1000 m ² or part thereof
	exceeding 10 ha	2 for each 1000 m ² or part thereof

TESTING: FILL MATERIAL - RELATIVE COMPACTION

Testing: relative compaction

6.81

(1) Unless otherwise agreed by the Engineer, each batch of fill material shall be tested to determine the relative compaction. Tests shall be carried out after the fill material has been deposited and compacted in its final position. The number of tests on each batch shall be as stated in Table 6.5. Tests shall not be carried out on:

- (a) Fill material including rock fill material which contains an insufficient proportion of particles passing a 20 mm BS test sieve to permit determination of the relative compaction, and
- (b) Fill material that has been deposited as stated in Clause 6.56.

(2) Tests shall be carried out at positions, which in the opinion of the Engineer are representative of the batch of compacted fill material as a whole.

(3) Testing will be carried out by the Engineer.

(4) The relative compaction of fill material shall be determined in accordance with one of the following methods:

- (a) Method 1: Geospec 3, Test Method 11.4

$$RC = IDD/MDD \times 100\%$$

where:

- IDD is the in-situ dry density determined as stated in Clause 6.81(5)
- MDD is the maximum dry density determined as stated in Clause 6.75(2)

- (b) Method 2: The relative compaction (RC) shall be calculated from the equation:

$$RC = IBD/MCBD \times 100\%$$

where:

- IBD is the in-situ bulk density determined as stated in Clause 6.81(5)
- MCBD is the maximum converted bulk density determined by the Hilf method as stated in Appendix 6.3

Method 1 shall be used unless otherwise permitted by the Engineer.

(5) The in-situ bulk density and the in-situ dry density of fill material shall be determined in accordance with one of the following methods:

- (a) Method 1 : Geospec 3, Test Method 11.1 or 11.2
- (b) Method 2: Nuclear densometer method as stated in
Geospec 3, Test Method 11.3

Method 1 shall be used unless otherwise permitted by the Engineer.

(6) The maximum converted bulk density of fill material of which more than 5% is retained on a BS 20 mm test sieve, shall be adjusted as stated in Appendix 6.4.

<i>Compliance criterion:</i> <i>relative compaction</i>	6.82	If in the opinion of the Engineer there is any undue discrepancy between the results of tests for relative compaction of fill material using Method 1 and the results of tests using Method 2 in Clause 6.81, the results of tests using Method 1 shall prevail.
<i>Non-compliance:</i> <i>relative compaction</i>	6.83	If the result of any test for relative compaction of fill material does not comply with the specified requirements for relative compaction, additional tests for relative compaction shall be carried out on the same batch. The number of additional tests shall be as stated in Table 6.5.

APPENDIX 6.1

TEST METHODS FOR FILL MATERIAL

- General** 6.1.1 The definitions, terms, abbreviations symbols, and grouping of materials stated in BS 1377 shall apply except as stated in Clauses 6.1.2 and 6.1.3.
- Terms and symbols** 6.1.2 Terms used in the GS, and in BS 1377 are identified in the GS by the abbreviations and symbols stated in Table 6.1.1.

Table 6.1.1: Abbreviations and Symbols

Abbreviation/ Symbol	Term
BD	Bulk density
CBD	Converted bulk density
DD	Dry density
IBD	In-situ bulk density
IDD	In-situ dry density
MDD	Maximum dry density
MCBD	Maximum converted bulk density
RC	Relative compaction
W	Moisture content
w_i	In-situ moisture content
w_o	Optimum moisture content

- Grouping of material** 6.1.3
- (1) Fine-grained material is material of which at least 90% passes a 2 mm BS test sieve.
 - (2) Medium-grained material is material of which at least 90% passes a 20 mm BS test sieve and more than 10% is retained on a 2 mm BS test sieve.
-

APPENDIX 6.2

DETERMINATION OF THE MOISTURE CONTENT OF FINE GRAINED AND MEDIUM GRAINED MATERIAL BY THE MICROWAVE OVEN DRYING METHOD

<i>Scope</i>	6.2.1	This method covers the determination of the moisture content of fine-grained and medium-grained material as a percentage of the mass of the dry material.
<i>Apparatus</i>	6.2.2	<p>The following apparatus is required:</p> <ul style="list-style-type: none"> (a) A microwave oven with a timer and an adjustable power setting. (b) An airtight container of microwave safe and non-reflective material. (c) A balance readable and accurate to 0.01g. (d) A desiccator containing anhydrous silica gel.
<i>Procedure</i>	6.2.3	<p>The procedure shall be as follows:</p> <ul style="list-style-type: none"> (a) The container shall be cleaned, dried and weighed to the nearest 0.01g (m_1). (b) A specimen shall be crumbled and placed loosely in the container and the lid shall be replaced. Each specimen of fine-grained material shall be at least 30 g and each specimen of medium-grained material shall be at least 300 g. Specimens of medium-grained material may be tested in several parts each less than 300 g and the results aggregated. (c) The container and contents shall be weighed to the nearest 0.01g (m_2). (d) The lid of the specimen container shall be removed and the container with its lid and contents shall be placed in the microwave oven and dried. The specimen shall be considered to be dry when, after an initial drying period, successive weighings at intervals of 1 minute produce results that are the same to the nearest 0.01g. Alternatively, the oven may be set to an appropriate time and power setting to dry the specimen as determined by calibration of the oven on soil of a similar type. (e) After drying, the container and contents shall be removed from the microwave oven and placed in the desiccator to cool. (f) The lid shall be replaced and the container and contents shall be weighed to the nearest 0.01g (m_3).

Calculation

- 6.2.4 The moisture content of the material (w) shall be calculated as a percentage of the dry mass of the material from the equation:

$$w = (m_2 - m_3)/(m_3 - m_1) \times 100\%$$

where:

- m_1 is the mass of the container (g)
- m_2 is the mass of the container and contents before drying (g)
- m_3 is the mass of the container and contents after drying (g)

Reporting of results

- 6.2.5 The following shall be reported:

- (a) Source and identification of the soil.
 - (b) The moisture content of the material to the nearest 0.1%.
 - (c) That the test method used was in accordance with this Specification.
-

APPENDIX 6.3

DETERMINATION OF THE MAXIMUM CONVERTED BULK DENSITY BY THE HILF METHOD

- | | | |
|------------------|-------|--|
| <i>Scope</i> | 6.3.1 | This method covers the determination of the maximum converted bulk density and the difference between the optimum moisture content and the in-situ moisture content of a material by relating the converted bulk density and the moisture added. |
| <i>Apparatus</i> | 6.3.2 | <p>The following apparatus is required:</p> <ul style="list-style-type: none"> (a) Apparatus in accordance with Geospec 3, Test Method 10.1 or 10.2, whichever as instructed by the Engineer. (b) Apparatus for determination of the moisture content in accordance with either Geospec 3, Test Method 5.1 or 5.2 or Appendix 6.2, whichever as instructed by the Engineer. (c) Apparatus to extract specimens from the mould. (d) Apparatus, such as a warm air blower, for rapid drying of the material. |
| <i>Procedure</i> | 6.3.3 | <p>The procedure shall be as follows:</p> <ul style="list-style-type: none"> (a) A sample of material shall be taken immediately after completing the in-situ bulk density test at the same location as the test. The sample shall be obtained by digging to the same depth as that of the in-situ bulk density test, keeping the sides of the excavation vertical and the bottom flat and level. The size of the sample shall be sufficient to yield a minimum of 10 kg after screening over a 20 mm BS test sieve. (b) The sample shall be weighed to the nearest 0.01 g. (c) The sample shall be screened over a 20 mm BS test sieve, ensuring that moisture loss is kept to a minimum and that any free moisture appearing in the containers is worked back into the sample. (d) The amount retained on the sieve shall be weighed to the nearest 0.01 g and expressed as a percentage of the mass of the sample. If the percentage exceeds 5%, an adjustment for coarse material shall be made in accordance with Appendix 6.4. If the percentage does not exceed 5%, no adjustment is required. (e) The material to be tested shall be thoroughly mixed and divided by quartering or by using a riffle box to obtain a minimum of four specimens of at least 2500 g each, ensuring that moisture loss is kept to a minimum. Alternatively, if it has previously been ascertained that the material is not susceptible to crushing, a single specimen of at least 2500 g may be used for repeat testing. |

- (f) Each specimen shall be weighed to the nearest 0.01 g and the result shall be taken as the mass of the specimen at the in-situ moisture content.
- (g) Each specimen and any remaining material shall be placed in separate moisture-tight containers and the containers sealed.
- (h) The converted bulk density of at least three specimens shall be plotted against the amount of water added or removed as a percentage of the mass of the specimen at the in-situ moisture content (z) on a graph as shown in Civil Engineering and Development Department Standard Drawing No. C2006, in accordance with the procedure stated in Clause 6.3.3(i) to (o).
- (i) The first point on the graph shall be obtained as follows:
 - A specimen shall be compacted at its in-situ moisture content in accordance with Geospec 3, Test Method 10.1, Clause 10.1.5 or Test Method 10.2, Clause 10.2.5, whichever is instructed by the Engineer.
 - A diametrical slice of approximately 400 g to 500 g shall be cut from the specimen along its entire length. The in-situ moisture content of the slice (w_i) shall be determined in accordance with either Geospec 3, Test Method 5.1 or 5.2 or Appendix 6.2, whichever as instructed by the Engineer.
 - The bulk density (BD_1) shall be calculated as stated in Clause 6.3.4(1) and plotted on the 0% ordinate of the graph as the converted bulk density (CBD_1).
- (j) The second point on the graph shall be obtained as follows:
 - A second specimen shall be examined and, if the in-situ moisture content obviously exceeds the optimum moisture content, the procedure stated in Clause 6.3.3(k) shall be followed.
 - The moisture content of the specimen shall be increased by adding an amount of water equal to 2% of the mass of the specimen. The specimen shall be thoroughly mixed and compacted in accordance with the method stipulated in Clause 6.3.3(i).
 - The bulk density (BD_2) shall be calculated as stated in Clause 6.3.4(1), adjusted to converted bulk density (CBD_2) as stated in Clause 6.3.4(2) and plotted on the +2% ordinate of the graph.

- (k) If the in-situ moisture content of the second specimen obviously exceeds the optimum moisture content, the specimen shall be dried until the amount of water removed is approximately 2% of the mass of the specimen and cooled. The specimen shall be thoroughly mixed and compacted in accordance with the method stipulated in Clause 6.3.3(i). The amount of water removed shall be determined. The bulk density (BD₂) shall be calculated as stated in Clause 6.3.4(1), adjusted to converted bulk density (CBD₂) as stated in Clause 6.3.4(2) and plotted on the negative ordinate of the graph at a point which corresponds to the amount of water removed.
- (l) The third point on the graph shall be obtained as follows:
- If the plotted value of CBD₂ is equal to or greater than the plotted-value of CBD₁, the moisture content of a third specimen shall be increased by adding an amount of water equal to 4% of the mass of the specimen. Alternatively, if the procedure stated in Clause 6.3.3(k) has been followed, the specimen shall be dried until the amount of water removed is approximately 4% of the mass of the specimen after cooling.
 - If the plotted value of CBD₂ is less than the plotted value of CBD₁, the third specimen shall be dried until the amount of water removed is approximately 2% of the mass of the specimen after cooling. Alternatively, if the procedure stated in Clause 6.3.3(k) has been followed, the moisture content shall be increased by adding an amount of water equal to 2% of the mass of the specimen.
 - The specimen shall be thoroughly mixed and compacted in accordance with the method stipulated in Clause 6.3.3(i). The amount of water removed shall be determined.
 - The bulk density (BD₃) shall be calculated as stated in Clause 6.3.4(1), adjusted to converted bulk density (CBD₃) as stated in Clause 6.3.4(2) and plotted on the graph at a point which corresponds to the amount of water added or removed.
- (m) If the centre point of the three points plotted is lower than one of the other two points, or is higher than one point and equal to the other, an additional point or points shall be obtained by proceeding in 2% increments or decrements as appropriate.
- (n) If it is apparent that the moisture condition of the material is such that a total of five points will not result in the determination of the optimum moisture content, increments and decrements of 3% moisture content may be adopted for the entire procedure.
- (o) A smooth approximately parabolic curve shall be drawn to the plotted points. The peak value of the curve shall be determined as the maximum converted bulk density (MCBD).

- (p) The amount of water added or removed as a percentage of the mass of the specimen at the in-situ moisture content corresponding to the maximum converted bulk density shall be determined (z_m).
- (q) The value of the moisture correction curve passing through the peak value of the plotted parabolic curve shall be determined (z_c). If there is no moisture correction curve passing through the peak value of the curve, a moisture correction curve shall be drawn through the peak by interpolating to the nearest 0.1%.

Calculation

- 6.3.4 (1) The bulk density (BD) shall be calculated from the equation:

$$BD = (m_2 - m_1)/V \quad \text{Mg/m}^3$$

where:

- m_1 is the mass of the mould and base (g)
- m_2 is the mass of the mould, base and wet material (g)
- V is the volume of the mould (mL)

- (2) The converted bulk density (CBD) shall be calculated from the equation:

$$CBD = BD/(1+z/100) \quad \text{Mg/m}^3$$

where:

- z is the amount of water added or removed as a percentage of the mass of the specimen at the in-situ moisture content
- z is negative for values below the in-situ moisture content

- (3) The difference between the optimum moisture content (w_o) and the in-situ moisture content (w_i) of the material shall be calculated from the equation:

$$w_o - w_i = z_m + z_c \quad \%$$

where:

- z_m is the amount of water added or removed as a percentage of the mass of the specimen at the in-situ moisture content corresponding to the maximum converted bulk density (%)
- z_c is the value of the moisture correction curve passing through the peak value of the plotted parabolic curve (%)

- (4) The optimum moisture content (w_o) shall be calculated from the equation:

$$w_o = w_i + (1 + w_i/100) z_m \quad \%$$

where:

- w_i is the in-situ moisture content of the material (%)

(5) The maximum dry density (MDD) shall be calculated from the equation:

$$\text{MDD} = \text{MCBD} / (1 + w_i/100) \quad \text{Mg/m}^3$$

where:

- MCB D is the maximum converted bulk density of the material (Mg/m^3)

(6) The relative compaction (RC), if required, shall be calculated from the equation:

$$\text{RC} = \text{IBD} / \text{MCBD} \times 100\%$$

where:

- IBD is the in-situ bulk density of the material determined in accordance with Geospec 3, Test Method 11.1 or 11.2 as appropriate to the grain size of the material

Reporting of results

6.3.5 The following shall be reported:

- (a) Source and identification of the soil.
- (b) The graph showing the plotted points and the parabolic curve passing through them.
- (c) The maximum converted bulk density to the nearest 0.01 Mg/m^3 .
- (d) The optimum moisture content to the nearest 0.1% .
- (e) The maximum dry density to the nearest 0.01 Mg/m^3 .
- (f) The relative compaction to the nearest 0.1% , if determined.
- (g) The percentage retained on the 20 mm BS test sieve and the percentage retained on the 37.5 mm BS test sieve to the nearest 1% , if applicable.
- (h) Whether the test was carried out using individual specimens or repeat testing of a single specimen.
- (i) Whether a manual or an automatic compaction rammer was used.
- (j) That the test method used was in accordance with this Specification.

APPENDIX 6.4

ADJUSTMENT OF THE MAXIMUM CONVERTED BULK DENSITY FOR THE DETERMINATION OF THE RELATIVE COMPACTION

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|------------------|-------|--|
| <i>Scope</i> | 6.4.1 | This method covers the adjustment of the maximum converted bulk density determined in accordance with Appendix 6.3 for the determination of the relative compaction of a material containing more than 5% of the mass of the material at the in-situ moisture content retained on a 20 mm BS test sieve. |
| <i>Apparatus</i> | 6.4.2 | <p>The following apparatus is required:</p> <ul style="list-style-type: none"> (a) Apparatus in accordance with Appendix 6.3. (b) A 20 mm and a 37.5 mm BS test sieve. (c) A mould with collar as used for determination of the California Bearing Ratio (CBR mould). (d) An extrusion device as used for determination of the California Bearing Ratio. |
| <i>Procedure</i> | 6.4.3 | <p>The procedure shall be as follows:</p> <ul style="list-style-type: none"> (a) If the amount of material retained on the 20 mm BS test sieve exceeds 5% and does not exceed 20%, the material passing the sieve shall be compacted in accordance with Appendix 6.3. The maximum converted bulk density (MCBD₂₀) shall be determined and adjusted as stated in Clause 6.4.4. (b) If the amount of material retained on the 20 mm BS test sieve exceeds 20%, the retained material shall be screened over the 37.5 mm BS test sieve. The procedure stated in either Clause 6.4.3(c) or Clause 6.4.3(d) as appropriate shall be followed. (c) If the amount of material retained on the 37.5 mm BS test sieve does not exceed 5%, the procedure stated in Clause 6.4.3(e) shall be followed. (d) If the amount of material retained on the 37.5 mm BS test sieve exceeds 5% and does not exceed 20%, the retained material shall be replaced with an equal mass of material which is of a similar nature and which is retained on a 20 mm BS test sieve but passes a 37.5 mm BS test sieve. The procedure stated in Clause 6.4.3(e) shall be followed. (e) The procedure stated in Appendix 6.3 shall be followed except that the material shall be compacted into the CBR mould and each layer shall be subjected to 62 blows of the rammer. |

Calculation

- 6.4.4 The maximum converted bulk density (MCBD) shall be calculated from the equation:

where:

- $MCBD_{20}$ is the maximum converted bulk density of the material passing the 20 mm BS test sieve (Mg/m^3)
- z is the amount of water added as a percentage of the mass of the specimen at the in-situ moisture content corresponding to the maximum converted bulk density (%)

Reporting of results

- 6.4.5 The following shall be reported:

- (a) The source and identification of the soil.
 - (b) The results in accordance with Appendix 6.3.
 - (c) The mass of the original material not passing the 20 mm and 37.5 mm BS test sieve as a percentage of the mass of the material at the in-situ moisture content to the nearest 0.1%.
 - (d) The type of mould used.
 - (e) The number of blows per layer.
 - (f) Whether the specific gravity was measured or assumed and, if measured, the method used.
 - (g) That the test method used was in accordance with this Specification, and the results have been adjusted in accordance with this Appendix.
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**GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS**

**SECTION 2
CARRIAGEWAYS: SUB-BASE MATERIAL AND
BITUMINOUS MATERIALS**

SECTION 2

CARRIAGEWAYS: SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

GLOSSARY OF TERMS

<i>Nominal maximum aggregate size</i>	9.01	Nominal maximum aggregate size is the smallest BS sieve size for which the upper limit of the percentage of the aggregate by mass passing is 100%.
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MATERIALS

<i>Sub-base material using virgin material</i>	9.02	Sub-base material shall be crushed rock and shall have the properties stated in Table 9.1. Sub-base material passing the 425 µm BS test sieve, when tested in accordance with Clause 9.46(4) shall be non-plastic.
<i>Recycled sub-base material in lieu of virgin material</i>	9.03	<p>(1) Recycled sub-base material shall be crushed rock, crushed concrete or clean crushed inert demolition material and may contain up to 12.5 % by mass of natural sand which passes the 5mm BS test sieve. The material shall lie within the grading limits of Table 9.1, and not be gap graded.</p> <p>(2) The material shall have a 10 % fines value of 50 KN or more when tested in accordance with Clause 9.47(3).</p> <p>(3) The material passing the 425µm BS test sieve shall be non-plastic when tested in accordance with Clause 9.47(4).</p> <p>(4) The aggregate shall be considered suitable if it has a soundness value greater than 65.</p> <p>(5) The material shall have a water-soluble sulphate content of less than 1.9g of sulphate (expressed as SO₃) per litre, if used within 500mm of cement-bound material, concrete pavements, concrete structures or concrete products.</p> <p>(6) The material shall have a minimum laboratory California Bearing Ratio (CBR) value of 30% or such other higher value as specified by the Engineer.</p> <p>(7) The material shall not contain quantities of contaminants in excess of the percentages given in Table 9.2 unless otherwise approved by the Engineer.</p> <p>(8) Notwithstanding the above sub-clauses, the Contractor may propose for the Engineer's approval the use of virgin aggregates in lieu of recycled aggregates in the sub-base material when there is a shortage of supply of recycled aggregates.</p>

Table 9.1: Properties of sub-base material

Properties	BS test sieve	Percentage by mass passing
Particle size distribution	75 mm	100
	37.5 mm	85 - 100
	20 mm	60 - 85
	10 mm	40 - 70
	5 mm	25 - 45
	600 µm	8 - 22
	75 µm	0 - 10
Ten percent fines value		> 50 kN

Table 9.2 : Allowable contamination of recycled sub-base material

Sub-base type	Type of contamination			
	Maximum sulphate content By mass	Maximum metals content By mass	Maximum foreign material content e.g. glass, soft material etc. By mass	Maximum organic material content (by mass)
Recycled sub-base	1%	1%	1%	0.5%

Aggregates for bituminous materials

- 9.04 (1) Coarse aggregate for bituminous materials shall be crushed rock all retained on a 5 mm BS test sieve and shall have the properties stated in Table 9.3.
- (2) Fine aggregate for bituminous materials shall be crushed rock, river sand or a mixture of crushed rock and river sand all passing 5 mm BS test sieve. The water absorption of fine aggregate shall not exceed 2.0%.
- (3) For the purpose of mix design, the combined grading of aggregates for bituminous materials shall be such that the particle size distribution lies within the limits stated in Table 9.4 for the relevant bituminous material.

Table 9.3: Properties of coarse aggregate for bituminous materials

Properties	Nominal maximum aggregate size (mm)			
	37.5	28	20	10
Flakiness index	≤ 25.0%	≤ 26.0%	≤ 27.0%	≤ 30.0%
Ten percent fines value	> 100 kN			
Water absorption	≤ 2.0%			

Table 9.4: Design limits for particle size distribution and bitumen content for bituminous materials

Properties		Type of bituminous material					
		Roadbase (recipe mix)	Base course		Wearing course		Friction course
Nominal maximum aggregate size (mm)		37.5	37.5	28	20	10	10
Particle size distribution	BS test sieve	Percentage by mass passing					
	50 mm	100	100	-	-	-	-
	37.5 mm	90 - 100	91 - 100	100	-	-	-
	28 mm	70 - 94	70 - 94	91 - 100	100	-	-
	20 mm	62 - 84	62 - 84	85 - 95	91 - 100	-	-
	14 mm	-	55 - 76	72 - 87	78 - 90	100	100
	10 mm	49 - 67	49 - 67	55 - 75	68 - 84	87 - 100	85 - 100
	5 mm	37 - 55	37 - 55	35 - 53	54 - 72	62 - 80	20 - 40
	2.36 mm	27 - 43	27 - 43	25 - 40	42 - 58	42 - 58	5 - 15
	1.18 mm	-	20 - 35	15 - 30	34 - 48	34 - 48	-
	600 µm	13 - 28	13 - 28	12 - 24	24 - 38	24 - 38	-
	300 µm	7 - 21	7 - 21	8 - 18	16 - 28	16 - 28	-
	150 µm	-	4 - 14	5 - 12	8 - 18	8 - 18	-
	75 µm	2 - 8	2 - 8	3 - 6	4 - 8	4 - 8	2 - 6
Bitumen content as percentage of total mass including binder	min.	3.0	4.0	4.5	5.0	6.0	4.5
	max.	4.0	4.5	5.0	5.5	7.0	5.5

Filler for bituminous materials 9.05

(1) Filler for bituminous materials shall be crushed rock filler, PC, PFAC, PFA or hydrated lime. Filler shall be free-flowing and dry before addition to the bituminous mixture.

(2) Filler for bituminous friction course material shall contain hydrated lime. The amount of hydrated lime, expressed as a percentage by mass of the total aggregates, shall be at least 1.5%.

(3) PC and PFAC shall comply with BS EN 197-1.

(4) PFA shall comply with BS 3892: Part 1 except that the criterion for maximum water requirement shall not apply.

(5) Crushed rock filler and hydrated lime shall comply with ASTM D 242.

<i>Bitumen</i>	9.06	Bitumen for bituminous materials shall comply with ASTM D 946, Grade 60-70 and shall have a softening point exceeding 44°C and less than 55°C. The wax content of the bitumen shall comply with requirements for Grade A specified in JTG F40-2004. Unless otherwise permitted by the Engineer, blending or mixing of bitumen shall be carried out at a refinery approved by the Engineer.
		Amd 2/2007
<i>Bituminous emulsion</i>	9.07	Bituminous emulsion shall be anionic bituminous emulsion complying with BS 434: Part 1, Table 1, Class A1-40 or cationic bituminous emulsion complying with BS 434: Part 1, Table 2, Class K1-40.
<i>Bituminous priming material</i>	9.08	Bituminous priming material shall be medium curing-grade cutback bitumen complying with ASTM D 2027, Table 1, Class MC-30.

DESIGN OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

<i>Design procedure for sub-base material and bituminous materials</i>	9.09	<p>(1) Sub-base material and bituminous roadbase materials shall be recipe mixes. Laboratory design mixes other than those for sub-base material and bituminous roadbase materials shall be made and tested as part of the design procedure at a laboratory approved by the Engineer.</p> <p>(2) Unless otherwise permitted by the Engineer, mix designs and associated tests shall be carried out by the Contractor in the presence of the Engineer. The Contractor shall notify the Engineer at least 7 days, or such shorter period agreed by the Engineer, before carrying out the mix designs.</p> <p>(3) Subject to the approval of the Engineer, the Contractor may use bituminous roadbase material incorporating reclaimed asphalt pavement (RAP) for carriageway works. The specific requirements are as follows: -</p> <p style="padding-left: 40px;">(a) Roadbase incorporating RAP shall be designed, manufactured, laid and tested in accordance with the requirements for roadbase using non-recycled materials or otherwise specified by the Engineer.</p> <p style="padding-left: 40px;">(b) The RAP shall comply with the following:</p> <p style="padding-left: 80px;">(i) RAP shall be obtained from milling or excavation of existing bituminous pavements, and return loads from site and offcuts from bituminous layer joint preparation. Return loads can include bituminous materials rejected from site. RAP shall be crushed and screened as necessary such that the maximum particle size is not greater than the nominal maximum aggregate size of the bituminous roadbase materials being produced and a reasonably well-graded and consistent mixture can be produced.</p> <p style="padding-left: 80px;">(ii) RAP shall be free of foreign materials such as unbound granular sub-base, broken concrete, or other contaminants.</p> <p style="padding-left: 80px;">(iii) RAP shall be stored in separate stockpiles before use. RAP that has been stockpiled for some time shall be reprocessed.</p>
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where necessary, to ensure that it is in a free-flowing state at the time of use.

- (iv) The maximum amount of RAP allowable in the bituminous roadbase material shall be 15% by mass of the total mix. Separate mix designs shall be required for roadbase materials incorporating RAP.

Design of bituminous materials

9.10

(1) Bituminous materials shall consist of coarse and fine aggregates complying with Clause 9.04, filler complying with Clause 9.05 and bitumen complying with Clause 9.06. The different types of bituminous materials shall have particle size distributions and bitumen contents within the limits stated in Table 9.4.

(2) Subject to the Engineer's approval, the Contractor may use bituminous wearing course and base course materials incorporating reclaimed asphalt pavement (RAP) for carriageway works. The RAP shall comply with the requirements specified in Clause 9.09(3). Wearing course and base course materials incorporating RAP shall be designed, manufactured, laid and tested in accordance with the requirements for these materials using non-recycled materials or otherwise specified by the Engineer.

Amd 1/2007

(3) The properties of the different types of bituminous materials shall be as stated in Table 9.5.

(4) Bituminous materials of all aggregate sizes, other than bituminous roadbase material, shall be designed in accordance with the Marshall Method of Mix Design stated in The Asphalt Institute Handbook 'MS-2 Mix Design Methods for Asphalt Concrete and other Hot-mix Types, Sixth Edition (1997)' with modifications only if agreed by the Engineer. The compaction standard shall be 75 blows per side. The maximum amount of RAP allowable in the bituminous wearing course and base course materials shall be 15% by mass of the total mix. Separate mix designs shall be required for these materials incorporating RAP.

Amd 1/2007

(5) Design procedures for bituminous friction course material shall be as stated in Clause 9.10(4) except that the mixing and compaction temperatures shall be consistent with bitumen viscosities of 900 ± 100 centistokes and 2000 ± 200 centistokes respectively.

Table 9.5: Properties of designed bituminous materials

Properties	Type of bituminous material				
	Base course		Wearing course		Friction course
	Nominal maximum aggregate size (mm)				
	37.5	28	20	10	10
Minimum Marshall stability (kN)	10.0		10.0		-
Maximum flow value (mm)	4.0		4.0		-
Minimum voids in mineral aggregate as a percentage of total bulk volume	12.5	13.0	14.0	16.0	25.0
Air voids in mix as a percentage of total bulk volume	3.0	- 5.0	3.0	- 5.0	18.0 - 25.0

SUBMISSIONS

Particulars of filler and bitumen for bituminous materials

9.11

(1) The following particulars of the proposed filler and bitumen for bituminous materials shall be submitted to the Engineer:

- (a) A certificate from the manufacturer for each type of filler showing the manufacturer's name, the date and place of manufacture and showing that the filler complies with the requirements stated in the Contract and including results of tests for particle size distribution, and
- (b) A certificate from the manufacturer for bitumen showing the manufacturer's name, the date and place of manufacture and showing that the bitumen complies with the requirements stated in the Contract, including a temperature-viscosity relationship for the bitumen, and including results of tests for:
 - Relative density
 - Softening point
 - Penetration
 - Ductility
 - Retained penetration after thin film oven test
 - Solubility
 - Viscosity
 - Loss on heating

- Wax.

Amd 2/2007

(2) The particulars, including certificates, shall be submitted to the Engineer at the time stated in Clause 9.12(3).

(3) Further certificates showing that the materials comply with the specification shall be submitted at intervals agreed by the Engineer.

***Particulars of mixes
for sub-base material
and bituminous
materials***

9.12

(1) The following particulars of sub-base material and bituminous roadbase materials shall be submitted to the Engineer:

- (a) Source and type of aggregates,
- (b) Grading details in tabular and graphical form, and
- (c) Details of each mixing plant proposed,

(2) The following particulars of bituminous materials shall also be submitted to the Engineer:

- (a) Certified copies of work sheets for mix designs, which shall include the relative density of the mixed aggregates,
- (b) Source of bitumen, and
- (c) If requested by the Engineer, past test records of the same mix produced in the same plant.

(3) The particulars shall be submitted to the Engineer at least 21 days before:

- (a) Trial areas are constructed, or
- (b) The mix is placed in the permanent work if trial areas are not required.

***Particulars of recycled
sub-base material***

9.13

(1) The following particulars of recycled sub-base material if used in lieu of virgin material shall be submitted to the Engineer:

- (a) Details of the recycling plant, and test results for:
 - Ten percent fines value
 - Soundness value
 - CBR value
 - Content of contaminant in percentage by mass
 - Water-soluble sulphate content
 - Organic material content, and
- (b) Grading details in tabular and graphical form

***Particulars of supplier
of sub-base material
and bituminous***

9.14

The name of the supplier and the location of each plant from which the Contractor proposes to obtain sub-base material and bituminous materials shall be submitted to the Engineer at the time stated in Clause 9.12(3).

<i>Particulars of methods of laying and compacting sub-bases and bituminous materials</i>	9.15	<p>(1) The following particulars of the proposed methods of laying and compacting sub-bases and bituminous materials shall be submitted to the Engineer:</p> <ul style="list-style-type: none"> (a) Details of construction plant, and (b) Programme and rate of working. <p>(2) The particulars shall be submitted to the Engineer at the time stated in Clause 9.12(3).</p>
<i>Samples of sub-base material, aggregate, filler and bitumen</i>	9.16	One sample of each type of sub-base material and one sample of each type of aggregate, filler and bitumen for bituminous material shall be submitted to the Engineer at the same time as particulars are submitted.

TRIALS

<i>Trial areas</i>	9.17	<p>(1) Trial areas of each type and layer of bituminous materials shall be constructed to demonstrate that the proposed materials, mixes, methods of production and methods of construction are capable of producing a carriageway that complies with the specified requirements. Unless otherwise stated in the Contract, the trial areas shall be constructed as part of the permanent carriageway at locations agreed by the Engineer. The width of each trial area shall be at least one lane of carriageway, and the length shall be at least 60 m.</p> <p>(2) Trial areas shall be constructed using the materials, mixes, methods of production and methods of construction submitted to the Engineer. Materials shall be delivered in not less than two loads.</p> <p>(3) The Contractor shall inform the Engineer 48 hours, or such shorter period agreed by the Engineer, before constructing trial areas.</p> <p>(4) The permission of the Engineer shall be obtained before each layer of material is placed in the trial area.</p> <p>(5) The Engineer shall be given sufficient time to determine whether the specified requirements have been produced in the trial area before further material of the same type is placed in the permanent carriageway.</p> <p>(6) Trial areas shall be protected from damage and shall be left in position unless the Engineer instructs their removal. Trial areas which form part of the permanent carriageway and which comply with the specified requirements shall not be removed.</p>
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Table 9.6: Sampling and testing bituminous materials

Type of material	Properties	Methods of sampling	Methods of testing
Bituminous base course and wearing course material	Particle size distribution	Clause 9.55	Clause 9.56
	Bitumen content	Clause 9.55	Clause 9.56
	Rice's specific gravity	Clause 9.55	Clause 9.56
	Void content	Clause 9.62	Clause 9.63
Bituminous friction course material	Particle size distribution	Clause 9.59	Clause 9.60
	Bitumen content	Clause 9.59	Clause 9.60
	Texture depth and permeability	-	Clause 9.66

- Samples: trial areas** 9.18 (1) One sample of bituminous materials, excluding bituminous roadbase materials, shall be provided from each mix used in trial areas. The method of sampling shall be as stated in Table 9.6.
- (2) Ten cores shall be cut from each layer of base course and wearing course in trial areas. The method of taking cores shall be as stated in Clause 9.62.
- Testing: trial areas** 9.19 (1) Each sample of bituminous material taken as stated in Clause 9.18, shall be tested to determine the properties stated in Table 9.6. The method of testing shall be as stated in Table 9.6.
- (2) If the layer is to form part of the permanent work, each layer of bituminous material in trial areas, excluding bituminous roadbase material, shall be tested as stated in Clause 9.40 to determine the level of the surface.
- (3) The layer which is to be the final layer of the carriageway in each trial area shall be tested as stated in Clauses 9.42 and 9.43 to determine the surface regularity, if the layer is to form part of the permanent work.
- (4) The layer of friction course in each trial area shall be tested as stated in Clauses 9.66 to 9.68 to determine the texture depth and permeability.
- (5) Cores shall be tested as stated in Clauses 9.62 to 9.65 to determine the compacted layer thickness and air void content.
- Compliance criteria: trial areas** 9.20 The properties of the materials, the levels of the surface, compaction, surface regularity, texture depth and permeability of bituminous materials laid in the trial areas shall comply with the specified requirements for the permanent carriageway.
- Non-compliance: trial areas** 9.21 (1) If the result of any test on trial areas does not comply with the specified requirements for trial areas, particulars of proposed changes to the materials, mixes, methods of production or methods of construction shall be submitted to the Engineer. Further trial areas shall be constructed until the result of every test on trial areas complies with the specified requirements for the trial areas.

(2) Unless otherwise permitted by the Engineer, trial areas or parts of trial areas, which do not comply with the specified requirements for the trial area, shall be removed.

Approved mix for bituminous materials other than bituminous roadbase material

- 9.22 (1) A mix for bituminous materials other than bituminous roadbase material that complies with the specified requirements for designed mixes and for trial areas shall become an approved mix.
- (2) The approved gradation envelope for bituminous materials other than bituminous roadbase material shall be the gradation envelope found by applying the tolerances stated in Table 9.7 to the particle size distribution of the approved mix.
- (3) The approved bitumen content range for bituminous materials other than bituminous roadbase material shall be the bitumen content range formed by applying a tolerance of $\pm 0.5\%$ to the bitumen content of the approved mix.

Table 9.7: Tolerances for particle size distribution from approved mix

BS test sieve	Tolerance of particle size distribution in percentage by mass of total mix passing BS test sieve			
	Nominal maximum aggregate size (mm)			
	37.5	28	20	10
50 mm	0	-	-	-
37.5 mm	± 4	0	-	-
28 mm	± 7	± 4	0	-
20 mm	± 7	± 7	± 4	-
14 mm	± 7	± 7	± 7	0
10 mm	± 7	± 7	± 7	± 4
5 mm	± 7	± 7	± 7	± 7
2.36 mm	± 7	± 7	± 7	± 7
1.18 mm	± 7	± 7	± 7	± 7
600 μm	± 5	± 5	± 5	± 5
300 μm	± 5	± 5	± 5	± 5
150 μm	± 3	± 3	± 3	± 3
75 μm	± 2	± 2	± 2	± 2

Commencement of placing bituminous materials

- 9.23 Bituminous material shall not be placed in the permanent works until the Engineer has approved the mix.

Changes in materials and methods of construction

- 9.24 Unless permitted by the Engineer, the materials and methods of production used in producing the approved mixes and the methods of construction used in trial areas shall not be changed.

HANDLING, STORAGE AND TRANSPORT OF MATERIALS

<i>Handling and storage of sub-base material and bituminous materials</i>	9.25	<p>(1) Cement and PFA shall be stored as stated in Clause 16.33.</p> <p>(2) Material handling and storage areas shall be levelled and well drained. Sub-base material and bituminous materials shall not be handled or stored in a manner which will result in mixing of the different types and sizes or in segregation or contamination of the materials. Measures to protect the materials from the effects of weather shall be submitted to the Engineer for approval.</p> <p>(3) Unless otherwise permitted by the Engineer, bituminous materials shall not be stored in heated surge bins for more than 12 hours or in transport vehicles for more than 3 hours.</p> <p>(4) Bituminous friction course material shall not be stored in surge bins for more than 30 minutes.</p>
<i>Transport of sub-base material and bituminous materials</i>	9.26	<p>(1) Sub-base material and bituminous materials shall be protected by covers while being transported and before laying. Covers for bituminous materials shall be heavy canvas or a similar insulating material. The covers shall completely cover the material and shall be securely fixed to minimize loss of heat and to protect the materials from contamination by dust or other deleterious material.</p> <p>(2) Sub-base material and bituminous materials shall be transported in clean vehicles with smooth trays and sides.</p> <p>(3) The trays of vehicles transporting bituminous materials may be lubricated with soap solution or light oil sprayed on the trays. Vehicles transporting bituminous friction course material shall not be lubricated with light oil.</p>

MIXING OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

<i>Mixing of sub-base material and bituminous materials</i>	9.27	<p>Mixing of sub-base material and mixing of bituminous materials shall be carried out before delivery to the Site at mixing plants approved by the Engineer. The plants shall be designed and operated to produce uniform mixes that comply with the specified requirements.</p>
<i>Mixing plant for bituminous materials</i>	9.28	<p>(1) The mixing plant for bituminous materials shall have at least four separate cold-feed bins for preliminary cold batching of the coarse and fine aggregates, and a rotary drum dryer, which will continuously agitate the aggregates during the heating and drying processes. After passing through the dryer, the aggregates shall be screened into at least four hot storage bins before mixing.</p> <p>(2) Bitumen heating and storage tanks shall be fitted with circulating pumps to ensure an even temperature throughout the tanks.</p>

(3) The mixing plant shall be provided with sampling devices to enable samples of hot aggregates, filler and bitumen to be taken before mixing.

(4) Insulated surge bins, if fitted to the mixing plant, shall be designed and operated to prevent segregation occurring in the mix. Heating devices fitted to surge bins shall be capable of maintaining the temperature of the mix to within the specified limits.

(5) Measuring and weighing equipment shall be maintained in a clean, serviceable condition. The equipment shall be set to zero daily and calibrated before mixes for the permanent work are produced, and at regular intervals not exceeding 6 months.

(6) Alternative methods of mixing bituminous materials may be used with the approval of the Engineer.

Mixing bituminous materials

9.29

(1) Aggregates and filler for bituminous materials shall be measured to an accuracy of $\pm 3.0\%$ by mass. The aggregate moisture content after drying shall not exceed 0.4% by mass.

(2) Mixing of bituminous materials shall continue after the addition of all constituents for such period as is necessary to ensure that the aggregates and filler are uniformly coated with bitumen.

(3) Bituminous materials shall comply with the temperature requirements as stated in Table 9.8 during and after mixing.

Table 9.8: Temperature requirements for bituminous materials

Type of bituminous material		Roadbase, base course and wearing course	Friction course
Aggregate temperature at mixing (°C)	Min.	130	115
	Max.	175	135
Binder temperature at mixing (°C)	Min.	135	115
	Max.	165	165
Bituminous mixture temperature after mixing (°C)	Min.	130	115
	Max.	165	135
Bituminous mixture temperature at laying (°C)	Min.	-	110
	Max.	-	135
Bituminous mixture temperature at start of compaction (°C)	Min.	-	85

PRELIMINARY WORK

Installation of utilities

9.30

(1) Pipes, cables, manholes, chambers, gullies and other utilities below carriageways shall be completed and fill material shall be deposited and compacted in trenches before the carriageway is constructed. Openings to manholes, chambers and gullies shall be protected with temporary covers or by other methods agreed by the Engineer.

(2) Covers, frames and other hardware which will prevent continuous laying of bituminous materials for roadbase and base course shall not be fixed in position until such work is complete.

(3) After the penultimate layer of bituminous material has been laid and compacted, the layers of asphalt shall be cut out, temporary covers shall be removed and the permanent covers, frames and other hardware shall be installed.

(4) Finishing around covers, frames and other hardware shall be carried out using bituminous material of the same type as that in the adjacent surface unless otherwise permitted by the Engineer. The material shall be compacted in layers not exceeding 50 mm thick using hand rammers or mechanical equipment up to the underside of the wearing course or friction course.

LAYING AND COMPACTION OF SUB-BASE MATERIAL

Laying and compaction of sub-base material using virgin material

- 9.31 (1) Sub-base material shall be laid and compacted in a manner that will not result in segregation of the material and at a moisture content that allows the compaction stated in Clause 9.31(6) to be achieved. The moisture content shall not be less than 2%.
- (2) Sub-base material shall be laid in layers in such a manner that the compacted thickness of each layer will not exceed 225 mm. If the specified final compacted thickness of the sub-base exceeds 225 mm, the material shall be laid in two or more layers. The minimum thickness of each layer shall be 100 mm and, if the layers are of unequal thickness, the lowest layer shall be the thickest.
- (3) Each layer of sub-base material shall be evenly spread immediately after placing in position and shall be compacted immediately after spreading.
- (4) The minimum compaction plant to be used for compaction of sub-base material shall be of the type as stated in Clause 9.36(1).
- (5) The permission of the Engineer shall be obtained before the next layer is placed on each layer of compacted sub-base material.
- (6) Sub-base material shall be compacted to obtain a relative compaction of at least 95% maximum dry density throughout.
- (7) The surface of each layer of sub-base shall be maintained in a compacted condition until the next layer of sub-base material or roadbase material is laid. The surface shall not be disturbed by construction plant or other vehicles, and shall be free of ridges, cracks, loose material, pot-holes, ruts or other defects.

*Laying and
compaction of recycled
sub-base material in
lieu of virgin material*

9.32

(1) Recycled sub-base material shall be laid and compacted in a manner which will not result in segregation of the material and at a moisture content which allows the compaction stated in Clause 9.32(7) to be achieved. The moisture content shall not be less than 2%.

(2) The recycled sub-base shall consist of an upper layer of virgin sub-base material overlying a layer of recycled sub-base material. The ratio of the thickness of the recycled sub-base layer to that of the virgin sub-base layer shall be approximately 6 to 4. During laying and compaction, the thickness of each of these two layers shall take into account the layer thickness requirements given in sub-clause (3) below.

(3) Recycled sub-base material shall be laid in layers in such a manner that the compacted thickness of each layer will not exceed 225 mm. If the specified final compacted thickness of the sub-base exceeds 225 mm, the material shall be laid in two or more layers. The minimum thickness of each layer shall be 100 mm and, if the layers are of unequal thickness, the lowest layer shall be the thickest.

(4) Each layer of recycled sub-base material shall be evenly spread immediately after placing in position and shall be compacted immediately after spreading.

(5) The minimum compaction plant to be used for compaction of recycled sub-base material shall be as stated in Clause 9.36(1).

(6) The permission of the Engineer shall be obtained before the next layer is placed on each layer of compacted recycled sub-base material.

(7) Recycled sub-base material shall be compacted to obtain a relative compaction of at least 95% maximum dry density throughout.

(8) The surface of each layer of recycled sub-base shall be maintained in a compacted condition until the next layer of sub-base material or roadbase material is laid. The surface shall not be disturbed by construction plant or other vehicles, and shall be free of ridges, cracks, loose material, pot-holes, ruts or other defects.

LAYING AND COMPACTION OF BITUMINOUS MATERIALS

*Laying and
compaction of
bituminous materials*

9.33

(1) Bituminous materials shall not be laid during periods of wet weather or when ponding water is present on the underlying surface unless in the opinion of the Engineer the works will not be adversely affected.

(2) Bituminous wearing course material shall not be laid when the ambient air temperature is below 8°C and bituminous friction course material shall not be laid when the ambient air temperature is below 10°C. Temperatures shall be measured in the shade near to the surface on which laying is to be carried out.

(3) Surfaces on which bituminous materials are laid shall be clean and free of mud, grit and other deleterious material.

(4) If instructed by the Engineer, a tack coat of bituminous emulsion shall be applied to surfaces on or against which bituminous materials will be laid. The tack coat shall be evenly applied at a rate of between 0.4 L/m² and 0.6 L/m² using a spray machine complying with BS 434: Part 2. Bituminous materials shall not be laid until the tack coat has cured. construction plant and other vehicles necessary shall only run on the tack coat as necessary to lay the bituminous materials.

(5) If approved by the Engineer, surfaces of existing carriageways may be regulated before the overlying bituminous material is laid. Bituminous regulating course material shall be a material approved by the Engineer complying with the requirements for the 10 mm nominal maximum aggregate size wearing course material as specified in Table 9.4. Regulating course material shall be laid by paving machines unless laying by manual methods is instructed by the Engineer.

(6) Bituminous materials shall comply with the temperature requirements as stated in Table 9.8 during laying and compaction.

Laying bituminous materials by paving machine

9.34

(1) Unless otherwise permitted by the Engineer, bituminous materials shall be placed and spread using a self-propelled paving machine with a screw auger and attached screed capable of spreading and laying the material to the full width required. The paving machine shall be capable of giving initial compaction to the material and finishing it to a level suitable for subsequent compaction.

(2) Paving machines may be fitted with cut-off shoes or extensions to limit or extend the width of the screed. Screed extensions shall not be used unless the screw auger is extended in accordance with the manufacturer's recommendations. The surface texture produced by paving machines shall be free of segregation and pushing or dragging marks.

(3) Bituminous materials laid by paving machines shall be placed directly from the vehicles transporting the material into the hopper of the paving machine. Delivery of materials to the paving machine and laying of the materials shall be at a uniform rate appropriate to the capacity of the paving machine and compaction plant.

(4) If any delay in laying operations occurs, the paving machine shall be removed, the uncompacted cold material shall be removed and a transverse joint shall be formed as stated in Clause 9.37.

(5) Paving machines working in echelon shall be as close as practicable. The machines shall be not more than 30 m apart unless a longitudinal joint is formed as stated in Clause 9.37.

(6) Manual placing of materials on freshly laid surfaces shall only be used for the purpose of locally correcting levels as paving operations proceed, before compaction by rolling is commenced.

Laying bituminous materials by manual methods

9.35

Bituminous materials shall be laid by manual methods only if in the opinion of the Engineer the use of a paving machine is impracticable. If approved by the Engineer, bituminous materials may be laid by manual methods:

(a) In courses of irregular shape and varying thickness,

- (b) In confined locations,
- (c) Adjacent to expansion joints, covers, frames and other hardware, and
- (d) In reinstatements to trenches.

***Compaction of
bituminous materials
and sub-base material***

- 9.36 (1) The minimum compaction plant to be used to compact bituminous roadbase, base course, regulating course, wearing course and sub-base material shall be:
- (a) A smooth three-wheeled steel-wheeled roller with a mass of between 6 t and 12 t, or a vibratory tandem steel-wheeled roller with an effective mass of between 6 t and 12 t, and

A smooth pneumatic-tyre roller with a mass of between 12 t and 25 t, and with not less than seven overlapping wheels which have tyres that are capable of having pressures varying between 300 MPa and 800 MPa, and

Suitable mechanical rammers and hand-tools, or
 - (b) Other types of rollers, vibrating plates and rammers approved by the Engineer, or other similar plant approved by the Engineer, necessary to produce the required degree of compaction.
- (2) Bituminous roadbase, base course, regulating course and wearing course materials shall be initially rolled using a steel-wheeled roller operated in a longitudinal direction along the carriageway with the driving wheels nearest the paving machine.
- (3) All roller marks shall be removed from the surface of bituminous roadbase, base course and wearing course materials using either a smooth-wheeled dead-weight roller or a smooth-wheeled vibratory roller in non-vibrating mode.
- (4) Bituminous friction course material shall be compacted using rollers as stated in Clause 9.36(1)(a) without the application of vibration. Rollers shall not have an excessive film of water over the front and rear wheels. Bituminous friction course material shall be compacted until all roller marks are removed and compaction is complete.
- (5) Rollers shall not be parked on newly laid or compacted bituminous materials.
- (6) Bituminous materials immediately adjacent to kerbs, covers, frames and other hardware where rollers cannot operate effectively shall be compacted using hand-operated mechanical compaction plant.

***Joints in bituminous
materials***

- 9.37 (1) The screed of the paving machine shall overlap previously laid strips of bituminous material by at least 50 mm and shall be sufficiently high that compaction will produce a smooth dense flush joint. Bituminous materials overlapping the previously laid strip shall be pushed back to the edge of the previously laid strip and the excess material shall be removed.

- (2) Longitudinal joints in friction course or wearing course shall be formed coincident with the specified position of the lane-markings unless otherwise permitted by the Engineer.
- (3) A prepared joint shall be formed between hot bituminous material and cold material or existing bituminous material which is at a temperature below the minimum specified laying temperature.
- (4) The distance between prepared longitudinal joints in different layers shall be at least 150 mm and the distance between prepared transverse joints in different layers shall be at least 500 mm.
- (5) Prepared joints in base course and wearing course shall be formed by cutting back the face of the cold material or existing bituminous material for a minimum distance of twice the depth of the layer or 100 mm, whichever is greater. A vertical face shall be cut for the full depth of the layer. All loosened materials shall be removed and the face shall be coated with bituminous emulsion. The bituminous emulsion shall not be applied beyond the edges of the joint. The hot bituminous materials shall be laid and compacted against the coated face with a joint formed as stated in this clause.
- (6) Unless otherwise permitted by the Engineer friction course joints shall not be coated with bituminous emulsion.

PROTECTION OF SURFACES OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

*Protection of surfaces
of sub-base material
and bituminous
materials*

9.38

- (1) The surface of each layer of sub-base material and bituminous materials shall be kept clean and free of deleterious material. If instructed by the Engineer, bituminous priming coat shall be applied to the final surface of the sub-base layer at a rate of between 0.9 L/m² and 1.1 L/m².
- (2) Layers of carriageways under construction shall not be used by construction plant or vehicles other than those which in the opinion of the Engineer are essential to construct the work.
- (3) Unless otherwise permitted by the Engineer, bituminous courses shall not be used by construction plant or other vehicles until 6 hours after the material has been laid and compacted.

TOLERANCES

*Tolerances:
alignment of
carriageway*

9.39

The line of the edges of carriageways shall be within 25 mm of the specified line, except at the edges of structures where it shall be within 6 mm.

- Tolerances: level of carriageway** 9.40
- (1) The levels of the surface of each layer of sub-base, roadbase, base course, wearing course and friction course shall be determined on a grid at 10 m centres in the longitudinal direction and at 2 m centres in the transverse direction.
 - (2) The level of the surface of each layer of sub-base, roadbase, base course, wearing course and friction course shall be within the tolerances stated in Table 9.9.
 - (3) The difference in level of the surface of wearing course and friction course across joints shall not exceed 3 mm.
 - (4) The combination of permitted tolerances in levels shall not result in a reduction in the thickness of the pavement, excluding the sub-base, of more than 15 mm from the specified thickness nor a reduction in the thickness of the bituminous wearing course or friction course of more than 5 mm from the specified thickness.

Table 9.9: Tolerances in level

Type of surface	Permitted tolerance in level (mm)	
Sub-base	+ 10	- 20
Roadbase course	+ 8	- 15
Base course	± 6	
Wearing course		
Friction course		

- Tolerances: covers, frames and other hardware** 9.41
- The level of covers, frames and other hardware shall be not lower than, and shall not be more than 5 mm higher than the surface of the carriageway. The level of gully gratings shall not be higher than, and shall not be more than 5 mm lower than, the surface of the carriageway.

TESTING: SURFACE REGULARITY

- Testing: surface regularity** 9.42
- The surface regularity of the final layer of the pavement shall be determined as stated in Clause 10.55.
- Compliance criteria: surface regularity** 9.43
- The results of tests for surface regularity shall comply with Clause 10.56.

TESTING: SUB-BASE MATERIAL

- Batch: sub-base material** 9.44
- A batch of sub-base material is a quantity not exceeding 250 m³ of sub-base material of the same type and same mix produced at the same mixing plant, and delivered to the Site at any one time.

***Samples:
sub-base material***

- 9.45 (1) Unless otherwise permitted by the Engineer, one sample of each type of sub-base material shall be provided from each batch of sub-base material delivered to the Site.
- (2) The size of each sample shall be at least 50 kg. The method of sampling shall be in accordance with BS 812: Part 102.

***Testing:
sub-base material
using virgin material***

- 9.46 (1) Each sample of sub-base material shall be tested to determine the particle size distribution, ten percent fines value, maximum dry density, optimum moisture content and plasticity index of the portion passing a 425µm BS test sieve.
- (2) The method of testing for particle size distribution shall be in accordance with BS 812: Part 103.1.
- (3) The method of testing for ten percent fines value shall be in accordance with BS 812: Part 111, except that the sample shall be soaked in water at room temperature for 24 hours and shall not be oven-dried before testing.
- (4) The method of testing for plasticity index shall be in accordance with Geospec 3, Test Method 6.1, except that sample preparation shall be by wet sieving the material over a 425 µm BS test sieve.
- (5) The method for testing for maximum dry density and optimum moisture content shall be in accordance with Geospec 3, Test Method 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7 or 10.8, and Appendix 6.4 of this Specification, whichever as instructed by the Engineer.

***Testing:
Recycled sub-base
material in lieu of
virgin material***

- 9.47 (1) Each sample of recycled sub-base material shall be tested to determine the particle size distribution, 10 % fines value, maximum dry density, optimum moisture content, plasticity index of the portion passing a 425µm BS test sieve, CBR value, soundness value, water-soluble sulphate content and percentage of contaminants as defined in Table 9.2.
- (2) The method of testing for particle size distribution shall be in accordance with BS 812:Part 103.1.
- (3) The method of testing for 10 % fines value shall be in accordance with BS 812:Part 111, except that the sample shall be soaked in water at room temperature for 24 hours and shall not be oven-dried before testing.
- (4) The method of testing for plasticity index shall be in accordance with Geospec 3, Test Method 6.1, except that sample preparation shall be by wet sieving the material over a 425 µm BS test sieve.
- (5) The method for testing for maximum dry density and optimum moisture content shall be in accordance with Geospec 3, Test Method 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7 or 10.8, and Appendix 6.4 of this Specification, whichever as instructed by the Engineer.
- (6) Soundness value shall be determined in accordance with BS 812:Part 121.

(7) Water-soluble sulphate content shall be determined in accordance with BS 1377: Part 3.

(8) The maximum organic material content shall be determined in accordance with BS1377: Part3.

(9) The maximum metals and foreign material content shall be determined in accordance with the following procedure:

By means of the sampling procedure detailed in BS812: Part101, a sample shall be obtained of the aggregate containing at least 500 particles. The particles shall then be sorted manually into the following separate fractions:

- (i) Concrete and dense or normal weight aggregates.
- (ii) Brick, mortar, lightweight block and lightweight aggregate.
- (iii) Asphalt, bitumen, tar and mixtures of these materials with aggregate.
- (iv) Wood.
- (v) Glass.
- (vi) Metal.
- (vii) Other foreign material such as clay lumps and plastics

Because of the adherence of dust, it may be necessary to wash or break some particles to make a positive identification. The resulting fractions shall be weighed and expressed as a percentage of the total weight of material.

Notes:

(a) Lightweight block material - This should be noted as a separate category if more than 1% by volume (approx. 5 pieces in 500).

(b) Ultra-lightweight material (e.g. insulation) - This should be noted if more than 1% by volume (5 pieces in 500).

(10) CBR value shall be determined in accordance with BS1377:Part 4 with surcharge discs. The material shall be tested at the density and moisture content likely to develop in equilibrium pavement conditions, which shall be taken as being the density relating to a uniform air voids content of 5% and the optimum moisture content determined in compliance with BS 5835:Part 1:1980.

TESTING: RELATIVE COMPACTION OF SUB-BASE

*Testing:
relative compaction of
sub-base*

9.48

(1) Each area of sub-base which contains sub-base material of the same type and same mix produced at the same mixing plant and which is laid and compacted in a single layer in one day shall be tested to determine the relative compaction. Tests shall be carried out after the sub-base material has been laid and compacted in the final position.

(2) Two tests shall be carried out on each area of 1000 m² or part thereof laid and compacted each day.

(3) Tests shall be carried out at positions, which in the opinion of the Engineer are representative of the area of compacted sub-base as a whole.

(4) The method of testing for relative compaction shall be as stated in Clause 6.81(4).

Compliance criteria: 9.49 The results of tests for relative compaction of sub-base shall comply with the requirements stated in Clause 9.31(6).
relative compaction of sub-base

Non-compliance: 9.50 If the result of any test for relative compaction of sub-base does not comply with the specified requirements for relative compaction of sub-base, the area shall be re-compacted and two additional tests for relative compaction of sub-base shall be carried out on the area.
relative compaction of sub-base

TESTING: AGGREGATES, FILLER AND BITUMEN FOR BITUMINOUS MATERIALS

Batch: 9.51 A batch of aggregates, filler or bitumen for bituminous materials is any quantity of aggregates, filler or bitumen for bituminous materials of the same type, manufactured or produced in the same place and covered by the same certificates delivered to the Site at any one time.
aggregates, filler and bitumen for bituminous materials

Samples: 9.52 (1) One sample of each type of aggregate, filler and bitumen for bituminous materials shall be provided from each batch.
aggregates, filler and bitumen for bituminous materials
(2) The size of each sample and the method of sampling shall be as stated in Table 9.10.

Table 9.10: Size of samples and method of sampling for aggregates, filler and bitumen

Material	Minimum size of sample	Method of sampling
Aggregate, nominal maximum aggregate size exceeding 28 mm	50 kg	BS 812: Part 102
Aggregate, nominal maximum aggregate size 5 mm to 28 mm	25 kg	
Aggregate, nominal maximum aggregate size less than 5 mm	10 kg	
Filler	5 kg	ASTM D 242
Bitumen	2 litres	ASTM D 140

Testing:
aggregates, filler and
bitumen for
bituminous materials

9.53 Each sample of aggregate, filler and bitumen for bituminous materials shall be tested to determine the properties stated in Table 9.11. The method of testing shall be as stated in Table 9.11.

Table 9.11: Testing aggregates, filler and bitumen for bituminous materials

Material	Property	Method of testing
Coarse aggregate	Relative density Water absorption	BS 812: Part 2
	Ten percent fines value	BS 812: Part 111
	Particle size distribution	BS 812: Part 103.1
	Flakiness index	BS 812: Part 105
Fine aggregate	Relative density Water absorption	BS 812: Part 2
	Particle size distribution	Geospec 3, Test Method 8.2
Filler	Relative density	BS EN 196-6
	Particle size distribution	BS 812: Part 103.1
Bitumen	Relative density	ASTM D 3289
	Softening point	BS 2000
	Penetration	ASTM D 5
	Ductility	ASTM D 113
	Retained penetration after thin film oven test	ASTM D 1754
	Solubility	ASTM D 2042
	Viscosity	ASTM D 2171 or BS 2000
	Loss on heating	BS 2000

TESTING: BITUMINOUS MATERIALS OTHER THAN BITUMINOUS FRICTION COURSE MATERIAL

Batch: bituminous materials other than bituminous friction course material 9.54 A batch of bituminous materials other than bituminous friction coarse material is a quantity not exceeding the limits stated in Table 9.12 of bituminous materials of the same type and same mix produced at the same mixing plant in one day.

Table 9.12: Maximum size of batch for bituminous materials other than bituminous friction course material

Material	Maximum batch size
Wearing course	100t
Base course	150t
Road base	200t

Samples: bituminous materials other than bituminous friction course material 9.55

- (1) One sample of bituminous materials other than bituminous friction course material shall be provided from each batch unless otherwise required by the Engineer.
- (2) The size of each sample shall be as stated in Table 9.13.
- (3) Samples shall be taken at the mixing plant or at the location where the bituminous material will be laid as instructed by the Engineer. Samples taken at the mixing plant shall be taken from the delivery vehicle immediately after loading from the plant or from the surge bin. Samples taken at the location where the bituminous materials will be laid shall be taken from the delivery vehicle.
- (4) Unless otherwise agreed by the Engineer the method of sampling shall be in accordance with ASTM D 979.

Table 9.13: Size of samples for bituminous materials other than bituminous friction course material

Material	Minimum size of sample (in kg)
Wearing course (10mm nominal maximum aggregate size)	10
Wearing course (20mm nominal maximum aggregate size)	16
Base course	24
Roadbase	24

Testing:
*bituminous materials
 other than bituminous
 friction course
 material*

- 9.56 (1) Each sample of bituminous materials taken as stated in Clause 9.55(1) shall be tested to determine the particle size distribution, bitumen content and Rice's specific gravity.
- (2) The method of testing shall be in accordance with the following:

Particle size distribution : ASTM C 136 with modifications and ASTM C 117, Method B

Bitumen content : ASTM D6307 or
ASTM D 2172, Method A

Rice's specific gravity : ASTM D 2041,
Weighing-in-water method

Bulk specific gravity : ASTM D 2726

- (3) For particle size distribution tests in accordance with ASTM C 136, the modifications are:

(a) Sieves to BS 410 instead of sieves to ASTM E 11 shall be used.

(b) Each sample of bituminous materials taken as stated in Clause 9.55 shall be reduced to a test specimen of suitable size as follows:

<u>Nominal Maximum Aggregate Size (mm)</u>	<u>Minimum Sample Size (kg)</u>
37.5	2.5
28.0	2.0
20.0	1.5
10.0	1.0

- (4) The residual pressure manometer specified in ASTM D 2041 may be replaced by a vacuum gauge.

Compliance criteria:
*bituminous materials
 other than bituminous
 friction course
 material*

- 9.57 (1) The results of tests on bituminous materials other than bituminous roadbase and friction course materials shall comply with the following requirements:

(a) The particle size distribution shall be such that not more than two points on the particle size distribution curve are outside the approved gradation envelopes determined as stated in Clause 9.22(2). Notwithstanding the above distribution, the percentage passing the 75 μ m BS test sieve shall not exceed the approved design value by more than 3%.

(b) The bitumen content shall be within the approved bitumen content range determined as stated in Clause 9.22(3).

- (2) The results of tests on bituminous roadbase material shall comply with the following requirements:

(a) The particle size distribution shall be such that not more than two points on the particle size distribution curve are outside the design limit as stated in Table 9.4. Notwithstanding the above

distribution, the percentage passing the 75 μ m BS test sieve shall not exceed 8 % as specified in Table 9.4.

- (b) The bitumen content shall be within the allowable bitumen content range as specified in Table 9.4.

TESTING: BITUMINOUS FRICTION COURSE MATERIAL

- Batch:**
bituminous friction course material 9.58 A batch of bituminous friction course material is a quantity not exceeding 100 t of bituminous friction course material of the same mix produced at the same mixing plant in one day.
- Samples:**
bituminous friction course material 9.59 (1) One sample of bituminous friction course material shall be provided from each batch of bituminous friction course material.
- (2) The size of each sample shall be at least 15 kg.
- (3) Samples shall be taken at the mixing plant from the delivery vehicle immediately after loading from the plant or from the surge bin.
- (4) Unless otherwise agreed by the Engineer the method of sampling shall be in accordance with ASTM D 979.
- Testing:**
bituminous friction course material 9.60 (1) Each sample of bituminous friction course material shall be tested to determine the particle size distribution and bitumen content.
- (2) The method of testing shall be in accordance with the following:
- Particle size distribution : ASTM C 136 with modifications and ASTM C 117, Method B
- Bitumen content : ASTM D 2172, Method A
- (3) For particle size distribution tests in accordance with ASTM C 136, the modifications are:
- (a) Sieves to BS 410 instead of sieves to ASTM E 11 shall be used.
- (b) Each sample of bituminous materials taken as stated in Clause 9.59 shall be reduced to a test specimen of suitable size as follows:

<u>Nominal Maximum Aggregate Size (mm)</u>	<u>Minimum Sample Size (kg)</u>
37.5	2.5
28.0	2.0
20.0	1.5
10.0	1.0

- Compliance criteria:** 9.61 The results of tests on bituminous friction course material shall comply with the following requirements:
- bituminous friction**
- cours material**
- (a) The particle size distribution shall be within the approved gradation envelopes as determined in Clause 9.22(2).
 - (b) The bitumen content shall be within the approved bitumen content range as determined in Clause 9.22(3).

TESTING: BITUMINOUS MATERIAL CORES

- Samples:** 9.62
- bituminous material**
- cores**
- (1) Each area of roadbase, base course and wearing course which contains bituminous material of the same type and same mix produced at the same mixing plant and which is laid and compacted in a single layer in one day shall be tested to determine the compacted layer thickness.
 - (2) Unless otherwise approved by the Engineer each area of bituminous material to be tested shall be divided into approximately equal sub-areas as stated in Table 9.14. One core shall be taken at random from each sub-area.
 - (3) Cores shall not be taken from within 300 mm of covers, frames and other hardware, or construction joints in the bituminous material.
 - (4) Cores shall be taken by a mechanically operated coring machine.
 - (5) Cores shall be 150 mm diameter for bituminous material with a designed layer thickness of 40 mm or greater and shall be 100 mm diameter for bituminous material with a designed layer thickness of less than 40 mm.
 - (6) Cores shall be taken as soon as practicable but not later than 48 hours after completion of the paving operation.
 - (7) If agreed by the Engineer, the sampling rate for roadbase may be applied to wearing course and base course.
 - (8) Holes formed by taking cores shall be filled with compatible bituminous material as soon as practicable after the core has been taken.

Table 9.14: Rate of sampling for bituminous material cores

Area of bituminous material laid and compacted in one day	No. of sub-areas/cores	
	Roadbase	Wearing course and Base course
< 5 000 m ²	4	10
5 000 - 10 000 m ²	10	15
> 10 000 m ²	20	20

**Testing:
bituminous material
cores**

- 9.63 (1) Each bituminous material core shall be measured to determine the compacted layer thickness of the bituminous material and tested to determine the air void content.
- (2) The method of testing for air void content shall be in accordance with ASTM D 3203.

**Compliance criteria:
bituminous material
cores**

- 9.64 The results of tests on bituminous material cores shall comply with the following requirements:
- (a) The average air void content of the cores taken from an area of bituminous base course or wearing course material shall be not less than 3.0% and not greater than 6.0%.
 - (b) The air void content of each core taken from an area of bituminous base course or wearing course material shall be not less than 2.5% and not greater than 7.5%.
 - (c) The air void content of each core taken from an area of bituminous roadbase material shall be not less than 3.0% and not greater than 9.0%.
 - (d) The compacted layer thickness as measured from each core shall comply with the thickness requirements stated in Clause 9.40(4) and shall be compatible with the level tolerances stated in Table 9.9.

**Non-compliance:
bituminous material
cores**

- 9.65 (1) If the result of any test for air void content of cores does not comply with the specified requirements for air void content, the following procedure shall apply:
- (a) Four additional cores shall be taken from each sub-area for which the original core did not comply with the specified requirements for air void content. The cores shall be taken at locations evenly spaced throughout the sub-area such that in the opinion of the Engineer they are representative of the sub-area as a whole.
 - (b) Each additional core shall be tested to determine the air void content and the test results of the additional cores from the same sub-area shall be averaged.
 - (c) The average air void content of the sub-area thus obtained shall replace the original air void content of the respective sub-area. The new average air void content of the area of bituminous material tested shall then be calculated for compliance checking.
- (2) If the air void content of any of the four additional cores determined as stated in Clause 9.63(2) is less than 2.5% or greater than 7.5% for bituminous base course material and bituminous wearing course material, or less than 3.0% or greater than 9.0% for bituminous roadbase material, the sub-area from which the cores were taken shall be considered as not complying with the specified requirements.

(3) The area of bituminous material tested shall be considered as not complying with the specified requirements for average air void content if the average air void content of the cores taken from the area does not comply with the specified requirements for average air void content.

(4) If the result of any test for compacted layer thickness of cores is not compatible with the requirements of Table 9.9 or Clause 9.40(4), four additional cores shall be taken from the same sub-area and the average compacted layer thickness determined. The cores shall be taken at locations evenly spaced throughout the sub-area such that in the opinion of the Engineer they are representative of the sub-area as a whole.

(5) If the average compacted layer thickness determined as stated in Clause 9.65(4) is not in accordance with the permitted compacted layer thickness stated in Clause 9.64(d), the sub-area from which the cores were taken shall be considered as not complying with the specified requirements.

TESTING: TEXTURE DEPTH AND PERMEABILITY

Testing: texture depth and permeability

9.66

(1) Unless otherwise agreed by the Engineer each area of friction course to be tested shall be divided into approximately equal sub-areas as stated in Table 9.15. Tests for texture depth and permeability shall be carried out on each sub-area at positions, which in the opinion of the Engineer are representative of the sub-area of friction course as a whole. No measurement shall be taken within 300 mm of the longitudinal edge of the carriageway.

(2) If agreed by the Engineer the number of tests for texture depth and permeability may be reduced to the minimum stated in Table 9.15.

(3) Tests shall be carried out before the area of friction course is used by construction plant or other vehicles.

(4) Testing to determine the texture depth will be carried out by the Engineer. The method of testing shall be by the sand patch test in accordance with Appendix 10.1.

(5) Testing to determine the permeability will be carried out by the Engineer. The method of testing shall be in accordance with Appendix 9.1.

Compliance criteria: texture depth

9.67

The results of tests for texture depth on an area of friction course shall comply with the following requirements:

(a) The average texture depth shall not be less than 1.5 mm.

(b) Not more than one of the tests for texture depth shall give a result of less than 1.2 mm.

Compliance criteria: 9.68 The time for 150 mL of water to drain into the friction course in the permeability test stated in Clause 9.66(5) shall not exceed 30 seconds.

permeability

Table 9.15: Rate of testing for texture depth and permeability

Area of bituminous material laid and compacted in one day	No. of sub-areas/tests	
	Normal	Minimum
< 5 000 m ²	10	4
5 000 - 10 000 m ²	15	10
> 10 000 m ²	20	20

APPENDIX 9.1

DETERMINATION OF THE PERMEABILITY OF FRICTION COURSE MATERIAL

<i>Scope</i>	9.1.1	This method covers the determination of the permeability of friction course material by measuring the time taken for 150 mL of water to drain into the material.
<i>Apparatus</i>	9.1.2	<p>The following apparatus is required:</p> <ul style="list-style-type: none"> (a) A non-porous ring with an internal diameter of 150 mm \pm 2 mm, and a minimum height of 20 mm. (b) Suitable sealant for sealing one end of the ring onto the friction course surface. (c) A measuring cylinder for measuring 150 mL of water to an accuracy of 1 mL. (d) Two containers, each suitable for containing and pouring 150 mL of water. (e) A stopwatch.
<i>Procedure</i>	9.1.3	<p>The procedure shall be as follows:</p> <ul style="list-style-type: none"> (a) Carefully inspect the specified test location and record any unusual features. (b) Place one end of the ring on the friction course at the location to be tested, and seal the interface with sealant to prevent any leakage of water. (c) Prepare two volumes of water of 150 mL each using the measuring cylinder and the two containers. (d) Pour one 150 mL measure of water into the ring quickly and steadily without spillage. (e) As soon as all of the water has drained into the friction course, pour the second 150 mL of water into the ring quickly and steadily without spillage, and at the same time start the stopwatch. (f) Record the time taken for the second 150 mL of water to drain into the friction course surface.
<i>Reporting of results</i>	9.1.4	<p>The following shall be reported:</p> <ul style="list-style-type: none"> (a) The test location. (b) The time taken for the second 150 mL of water to drain into the friction course surface, to the nearest one second. (c) That the test was carried out in accordance with this Specification.

**GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS**

**SECTION 3
CONCRETE CARRIAGEWAYS**

SECTION 3

CONCRETE CARRIAGEWAYS

GENERAL

<i>General requirements</i>	10.01	The works and materials specified in Clauses 10.02 to 10.06 shall comply with the sections stated, unless otherwise stated in this Section.
<i>Formwork and finishes</i>	10.02	Formwork and finishes to concrete for concrete carriageways shall comply with Section 14.
<i>Reinforcement</i>	10.03	Steel reinforcement for concrete carriageways shall comply with Section 15.
<i>Concrete</i>	10.04	Concrete for concrete carriageways shall comply with Section 16.
<i>Curing compound</i>	10.05	Curing compound for concrete carriageways shall comply with Section 16.
<i>Earthworks</i>	10.06	Earthworks for concrete carriageways shall comply with Section 6.

MATERIALS

<i>Reinforcement</i>	10.07	<p>(1) Fabric reinforcement shall be steel fabric complying with BS 4483. The fabric shall be manufactured from steel wire which complies with BS 4482 and which has a type 2 bond classification.</p> <p>(2) Dowel bars, tie bars, cradles and tie bars for cradles shall be Grade 250 plain round steel bars complying with CS 2. Dowel bars and tie bars shall be straight. Both ends of dowel bars and one end of tie bars shall be sawn square with all burrs removed.</p>
<i>Cement mortar for cradles</i>	10.08	Cement mortar for supporting cradles shall consist of 1 part of cement to 3 parts of fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for the required work. Fine aggregates shall be sand or crushed rock to BS 1200 and shall pass a 5 mm BS test sieve.
<i>Fine aggregate</i>	10.09	Fine aggregate for concrete shall be natural river-deposited sand consisting of at least 95% by mass of quartz grains or clean, hard and durable crushed rock in accordance with Section 16.
<i>Polyethylene sheeting</i>	10.10	Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.
<i>Joint filler</i>	10.11	Joint filler shall be of a proprietary type approved by the Engineer and shall be a firm, compressible, single thickness, non-rotting filler.
<i>Joint sealant</i>	10.12	(1) Joint sealant shall be of a grade suited to the climatic conditions of Hong Kong and shall perform effectively over a temperature range of 0°C to 60°C.

		(2) Joint sealant shall be a cold poured two-part polymer-based sealant complying with BS 5212, Type N.
		(3) Primers and caulking material for use with joint sealant shall be of a proprietary types recommended by the joint sealant manufacturer and approved by the Engineer.
<i>Bond breaker tape</i>	10.13	Bond breaker tape shall be of a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer. The tape shall be a polyethylene film with adhesive applied on one side and shall be the full width of the groove.
<i>Groove forming strip</i>	10.14	<p>(1) Groove forming strip shall be of a proprietary type approved by the Engineer. The strip shall be a firm compressible strip of either ethylene vinyl acetate foam with a density of at least 90 kg/m³ or synthetic rubber. The strip shall be 25 mm deep and 5 mm thick and shall be sufficiently rigid to remain in position during concreting without deforming or stretching.</p> <p>(2) Adhesive for groove forming strip shall be of a proprietary type recommended by the groove forming strip manufacturer and approved by the Engineer.</p>
<i>Sleeves for dowel bars and tie bars</i>	10.15	Sleeves for dowel bars and tie bars shall be uPVC and shall have a nominal wall thickness not exceeding 1.5 mm. The sleeves shall fit tightly to the bars.
<i>Epoxy resin grout</i>	10.16	Epoxy resin grout shall be of a proprietary type approved by the Engineer.

CONCRETE

<i>Concrete mix</i>	10.17	<p>Concrete for concrete carriageways shall comply with the following requirements:</p> <p>(a) Concrete shall be Grade 40/20 and shall be a designed mix.</p> <p>(b) The concrete mix shall contain either PFAC or a minimum of 265 kg of PC plus a minimum of 85 kg of PFA per m³ of compacted concrete.</p> <p>(c) The percentage by mass of fine aggregate to total aggregate shall be at least 30%.</p> <p>(d) The workability in terms of designed slump value shall not exceed 30 mm.</p>
<i>Cementitious content of concrete</i>	10.18	The minimum cementitious content of concrete for concrete carriageways shall be 350 kg/m ³ .

SUBMISSIONS

***Particulars of
materials for joints***

- 10.19 (1) The following particulars of the proposed materials for joints in concrete carriageways shall be submitted to the Engineer:
- (a) Manufacturer's literature and a certificate for joint filler showing the manufacturer's name, the date and place of manufacture and showing that the joint filler complies with the requirements stated in the Contract and including results of tests for:
 - Disintegration and shrinkage
 - Recovery value and reduction in mass
 - Extrusion,
 - (b) Manufacturer's literature for joint sealant, including details of the method and time required for mixing the different components, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the sealant complies with the requirements stated in the Contract and including results of tests for:
 - Application life
 - Tack-free time
 - Resistance to flow
 - Recovery
 - Adhesion and cohesion in tension and compression
 - Resistance to heat ageing,
 - (c) Manufacturer's literature and a certificate for groove-forming strip showing the manufacturer's name, the date and place of manufacture and showing that the groove forming strip complies with the requirements stated in the Contract and including results of tests for density, and
 - (d) Particulars of primers and caulking material for joint sealant, adhesive for groove forming strip, bond breaker tape and sleeves for dowel bars and tie bars.
- (2) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material delivered to the Site.

***Particulars of methods
of construction***

- 10.20 Particulars of proposed methods of construction for concrete carriageways shall be submitted to the Engineer at least 7 days before the trial length is constructed.

<i>Samples of materials</i>	10.21	<p>Samples of the following proposed materials shall be submitted to the Engineer at the same time as particulars of the material are submitted:</p> <ul style="list-style-type: none"> (a) Polyethylene sheeting, (b) Joint filler, (c) Bond-breaker tape, (d) Groove-forming strip, and (e) Sleeves for dowel bars, including compressible filler, and for tie bars.
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TRIALS

<i>Compliance criteria: trial-mix concrete</i>	10.22	<p>The results of the tests on trial-mix concrete for concrete carriageways shall comply with the following requirements:</p> <ul style="list-style-type: none"> - Each of the six slump values shall not exceed 40 mm, and the average of the six slump values shall not exceed 35 mm.
<i>Trial length</i>	10.23	<p>(1) A trial length of concrete carriageway shall be constructed to demonstrate that the proposed materials, mix design, methods of production and methods of construction will produce a concrete carriageway which complies with the specified requirements.</p> <p>(2) The trial length shall be constructed using the materials, mix design, methods of production and methods of construction submitted to the Engineer.</p> <p>(3) If it is not stated in the Contract that the trial length is to be constructed in a location separate from the permanent carriageway, the trial length shall be the first 30 m of the permanent carriageway, or such other length agreed by the Engineer. The trial length shall be constructed over a width of two bays and shall include at least one expansion joint, one contraction joint and the longitudinal joint between the bays.</p> <p>(4) The Contractor shall inform the Engineer at least 48 hours, or within a shorter period agreed by the Engineer, before constructing the trial length.</p> <p>(5) The trial length shall be completed in sufficient time before the permanent carriageway is constructed to allow the Engineer a period of at least 7 days to determine if the specified requirements have been complied with in the trial length.</p> <p>(6) The trial length shall be protected from damage and shall be left in position unless the Engineer instructs its removal. A trial length which forms part of the permanent carriageway and which complies with the specified requirements shall not be removed.</p>

<i>Testing: trial length</i>	10.24	<p>(1) The trial length shall be tested to determine the accuracy of the alignment and level, the surface regularity and the texture depth. The method of testing the surface regularity shall be as stated in Clause 10.55. The method of testing the texture depth shall be as stated in Clause 10.57.</p> <p>(2) Concrete cores shall be cut from the trial length to determine the thickness of the slab, the positions of the reinforcement and joint components, the amount of segregation of the constituents and the presence of voids. The method of taking, preparing, inspecting and testing concrete cores shall be as stated in Clauses 10.62 and 10.63.</p>
<i>Compliance criteria: trial length</i>	10.25	<p>The results of tests on trial lengths shall comply with the following requirements:</p> <ul style="list-style-type: none"> (a) The alignment, levels and thickness of the carriageway shall comply with Clauses 10.53 and 10.54. (b) The surface regularity shall comply with Clause 10.56. (c) The texture depth shall comply with Clause 10.58. (d) The positions of the reinforcement and joint components shall comply with Clauses 10.49, 10.50, 10.51 and 10.53. (e) The amount of segregation of the constituents and the presence of voids shall comply with Clause 10.64.
<i>Non-compliance: trial length</i>	10.26	<p>(1) If the result of any test on the trial length does not comply with the specified requirements for the trial length, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer. Further trial lengths shall be constructed until the result of every test on the trial length complies with the specified requirements for the trial length. Further trial mixes shall be made unless in the opinion of the Engineer non-compliance of the trial length was not due to the concrete mix.</p> <p>(2) Unless otherwise permitted by the Engineer, trial lengths, or parts of trial lengths, which do not comply with the specified requirements for the trial length shall be removed.</p>
<i>Commencement of concreting</i>	10.27	<p>(1) Concrete shall not be placed in the permanent carriageway other than in a trial length until the result of every test on the trial length complies with the specified requirements for the trial length.</p> <p>(2) Concrete may be placed in the permanent carriageway before the results of tests for compressive strength of the trial mix are available provided that the result of every other test on the trial mix and trial length complies with the specified requirements for trial mix concrete and for the trial length.</p>
<i>Changes in materials and methods of construction</i>	10.28	<p>Unless permitted by the Engineer, the materials, mix design, methods of production and methods of construction used to produce a trial length which complies with the specified requirements shall not be changed.</p>

STORAGE OF MATERIALS

<i>Storage of materials for joints and polyethylene sheeting</i>	10.29	<p>(1) Joint sealant, primer for joint sealant and adhesive for groove forming strip shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions that may adversely affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.</p> <p>(2) Polyethylene sheeting, joint filler, bond breaker tape, groove forming strip and sleeves for dowel bars and tie bars shall be stored in accordance with the manufacturers' recommendations in a dry, weatherproof store with a raised floor. Joint filler shall be stored in sealed plastic bags and shall not be exposed to moisture or air.</p>
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PRELIMINARY WORK

<i>Installation of utilities</i>	10.30	<p>(1) Pipes, cables, manholes, chambers, gullies and other utilities below concrete carriageways shall be completed and fill material shall be deposited and compacted in trenches before the carriageway is constructed. Openings to manholes, chambers and gullies shall be protected by temporary covers or by other methods agreed by the Engineer.</p> <p>(2) Box-outs shall be formed in concrete carriageways for covers, frames and other hardware. The covers, frames and other hardware shall be fixed in position after the main slab has been concreted and before the infill slab is concreted.</p>
<i>Preparation of formation and sub-base</i>	10.31	Construction of concrete carriageways shall start as soon as practicable after the formation or sub-base has been completed. The formation shall be protected as stated in Clause 6.52 and the sub-base shall be protected as stated in Clause 9.35 until construction of the carriageway starts.
<i>Laying polyethylene sheeting</i>	10.32	Polyethylene sheeting below concrete carriageways shall be laid flat without creases. Laps shall be at least 300 mm and there shall be no gaps at the edges of bays.

FORMWORK

<i>Formwork</i>	10.33	<p>(1) Unless otherwise approved by the Engineer, formwork for concrete carriageways shall be steel. The finish to concrete surfaces for transverse and longitudinal joints shall be Class F3. The finish to concrete surfaces for other edges of the carriageway shall be Class F2.</p> <p>(2) Concrete shall not be placed against excavated surfaces or against kerbs unless permitted by the Engineer.</p> <p>(3) Formwork shall not be loosened or removed until at least 7 hours after concreting has been completed.</p>
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FORMING JOINTS

- | | | |
|----------------------------|-------|--|
| <i>Forming joints</i> | 10.34 | <p>(1) Materials for joints in concrete carriageways shall be used in accordance with the manufacturers' recommendations or as otherwise stated in the Contract.</p> <p>(2) Dowel bars, tie bars and their sleeves shall be securely fixed in position through holes in the formwork before concreting. The bars shall be parallel to the top surface of the slab and to each other. Bars at transverse joints shall be parallel to the adjacent longitudinal joint or to the longitudinal axis of the carriageway if there is no longitudinal joint or to other lines instructed by the Engineer.</p> <p>(3) Joint filler shall be cut to size before fixing and shall be securely fixed in position to the existing concrete surface before concreting. There shall be no gaps between the joint filler and the formation. Holes in joint filler for dowel bars shall be cut to form a sliding fit to the sleeved bar.</p> <p>(4) Joints shall be formed perpendicular to the top surface of the slab.</p> |
| <i>Transverse joints</i> | 10.35 | <p>(1) Unless otherwise permitted by the Engineer, transverse joints in concrete carriageways shall be straight and perpendicular to the longitudinal axis of the carriageway.</p> <p>(2) Transverse expansion joints and transverse contraction joints shall be formed only at the specified positions. The joints shall be continued across longitudinal joints and shall be in line and of the same type on both sides of the longitudinal joint. The joints shall be continued through kerbs, edgings and quadrants and their foundation and backing. The joint dimensions and materials shall be the same as the transverse joints with the omission of dowel bars. The location of additional contraction joints in accordance with Clause 11.54(3) shall be as instructed by the Engineer.</p> <p>(3) The joint filler and groove for joint sealant at transverse expansion joints shall provide complete separation of adjacent slabs.</p> |
| <i>Longitudinal joints</i> | 10.36 | Longitudinal joints in concrete carriageways shall be formed only at the specified positions. |
| <i>Isolation joints</i> | 10.37 | Isolation joints shall be formed in concrete carriageways at manholes and chambers. |
| <i>Forming grooves</i> | 10.38 | <p>(1) Grooves in concrete carriageways for joint sealant shall be straight, shall have parallel sides and shall be perpendicular to the top surface of the slab. The bottom of the groove shall be flat and shall be parallel to the top surface of the slab.</p> <p>(2) Grooves at transverse expansion joints and at isolation joints at manholes and chambers shall be formed by sawing the groove to the specified width and depth not less than 7 days after concreting. The grooves shall be located over the joint filler such that the upper surface of the joint filler is entirely contained in the groove.</p> <p>(3) Grooves at transverse contraction joints shall be formed using one of the following methods:</p> |

Method 1: An initial groove shall be sawn as soon as practicable after concreting without causing spalling of the edges. The width of the initial groove shall be less than the specified width of the final groove and the depth of the initial groove shall be between 1/4 and 1/3 of the thickness of the slab. The final groove shall be sawn to the specified width and depth not less than 7 days after concreting. The center-lines of the initial and final grooves shall coincide.

Method 2: The final groove shall be sawn to the specified width and depth as soon as practicable after concreting without causing spalling of the edges.

(4) Grooves at transverse construction joints shall be formed by fixing groove-forming strip with adhesive to the concrete already placed before concreting the adjacent slab.

Protection of grooves 10.39 Before permanent sealing, grooves in concrete carriageways for joint sealant shall be protected from contamination by a temporary sealing strip or by other methods agreed by the Engineer.

Sealing joints 10.40 (1) The permanent sealing of joints in concrete carriageways shall be carried out at least 7 days after concreting unless otherwise permitted by the Engineer.

(2) Immediately before permanent sealing, groove forming strips, temporary seals, dirt and loose material shall be removed from the groove and the sides of the groove shall be cleaned and roughened by water jetting, sand blasting or by other methods agreed by the Engineer.

(3) Caulking material shall be firmly packed in the bottom of the groove if the joint sealant is not required to extend to the bottom of the groove.

(4) Bond breaker tape shall be fixed continuously and evenly along the bottom of the groove for the full width and length of the groove.

(5) Primer for the joint sealant shall be applied to the sides of the groove in accordance with the manufacturer's recommendations.

(6) Joint sealant shall be applied between the minimum and maximum drying times of the primer recommended by the manufacturer. The components of the sealant shall be thoroughly mixed in accordance with the manufacturer's recommendations using a power operated paddle mixer for sufficient time to produce a homogeneous mass without entrapped air. The sealant shall be dispensed into the groove as soon as practicable after mixing and within the time recommended by the manufacturer.

(7) The groove shall be clean and dry at the time of applying the primer and joint sealant.

(8) Excess joint sealant shall be removed by using a purpose made finishing tool such that the finished surface of the sealant is between 4 mm and 6 mm below the surface of the slab.

PLACING AND COMPACTING CONCRETE

Placing and compacting concrete

- 10.41
- (1) Concrete shall be placed continuously between the joints in concrete carriageways unless otherwise permitted by the Engineer.
 - (2) Concrete in unreinforced slabs shall be placed and compacted to the full thickness of the slab in one operation.
 - (3) Unless otherwise permitted by the Engineer, concrete in reinforced slabs shall be placed and compacted to the specified level of the fabric reinforcement. The fabric reinforcement shall be placed in position and concrete shall be placed and compacted to the remaining thickness of the slab. The time between compaction of the first layer and placing of the remaining layer shall not exceed 30 minutes unless in the opinion of the Engineer the concrete already placed is sufficiently workable and the permission of the Engineer has been obtained. If permission is not obtained, a construction joint shall be formed as stated in Clause 16.45. Concrete shall not be placed against the concrete already placed for at least 24 hours unless permitted by the Engineer.
 - (4) Concrete in infill slabs at covers, frames and other hardware shall be placed and compacted after the covers, frames and hardware have been fixed in position and shall not be placed at the same time as the concrete in the main slab.
-

CONSTRUCTION JOINTS

Construction joints

- 10.42
- (1) Construction joints shall be formed in concrete carriageways only where approved by the Engineer or in cases of emergency if concreting is interrupted by adverse weather, plant breakdown or similar circumstances. Construction joints shall not be formed within 2.5 m of an existing or planned expansion or contraction joint.
 - (2) Transverse construction joints shall be formed by either:
 - (a) Using formwork and cast-in tie bars, or
 - (b) Breaking back from an unformed edge and fixing the tie bars and sleeves with epoxy resin grout in drilled holes.
-

SURFACE FINISH

Surface regulation

- 10.43
- (1) Unless combined double beam compactor-levellers are being used, then after compaction, the concrete in concrete carriageways shall be struck off to slightly above the levels of the formwork and the surface shall be regulated by a regulating machine or a vibrating beam.
 - (2) Regulating machines shall be purpose made and shall span the full width of the slab either transversely or obliquely. The machine shall be equipped with at least two oscillating-type transverse screeds and shall be supported on a carriage.

(3) Vibrating beams shall have a steel or aluminium surface and shall be mounted on a separate carriage. The beam shall be driven by a motor to provide a vibration frequency of at least 3500 cycles per minute.

(4) After regulation by the regulating machine or vibrating beam, the surface of the carriageway shall be regulated by at least two passes of a scraping straight edge with a blade length of at least 1.8 m. Scraping straight edges that operate in conjunction with regulating machines shall pass across the surface at right angles to the longitudinal axis of the carriageway. If the surface is torn by the straight edge, the surface shall be regulated again by the regulating machine or vibrating beam and by the scraping straight-edge.

(5) Wooden floats may be used to tamp and regulate small areas of the carriageway as agreed by the Engineer. Steel floats or trowels shall not be used.

Surface texturing

- 10.44 (1) After the surface of the concrete carriageway has been regulated and before the curing compound is applied, the surface, other than the surface of channels and edges of slabs that do not require to be textured, shall be textured by brushing with a wire broom.
- (2) The wire broom shall be at least 450 mm wide and shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in each row shall be at 10 mm centres and in line with the centre of the gaps between the tufts in the other row. The tufts shall contain an average of 14 wires, each of 32 gauge and initially 100 mm long. The broom shall be replaced if any tuft wears down to a length of 90 mm.
- (3) The surface texture shall be produced by brushing evenly across the slab in one direction at right angles to the longitudinal axis of the carriageway. Brushing shall be carried out after the moisture film has disappeared from the concrete surface and before the initial set is complete.

CURING CONCRETE

Curing concrete

- 10.45 The surface and edges of concrete carriageways shall be protected by one of the methods stated in Clause 16.46 except that covering with hessian, sacking, canvas or other absorbent material as stated in Method 2 shall not be used. If Method 1 is used, the curing compound shall be applied to the surface immediately after the surface has been textured and shall be applied to the edges immediately after the formwork has been removed.

PROTECTION OF CONCRETE CARRIAGEWAY

Protection of concrete carriageway

- 10.46 (1) Immediately after the curing system has been applied, the concrete carriageway shall be fenced off from pedestrian traffic and covered with protective sheeting for at least 24 hours. The sheeting shall be lapped and securely held in position in such a manner that the surface of the carriageway will not be damaged.

(2) Loads from materials not forming part of the permanent work or from construction plant or other vehicles shall not be applied to the concrete carriageway until at least 7 days after concreting has been completed and until all grooves at joints have been temporarily or permanently sealed or protected.

TOLERANCES

<i>Tolerances: sub-base</i>	10.47	The level of the sub-base below concrete carriageways shall not be more than 10 mm higher, and shall not be more than 20 mm lower, than the specified level.
<i>Tolerances: formwork</i>	10.48	<p>(1) The line of formwork for concrete carriageways shall be within 10 mm of the specified line of the concrete carriageway.</p> <p>(2) The level of the top of the formwork shall be within 3 mm of the specified level of the concrete carriageway.</p> <p>(3) Abrupt irregularities in the line of the formwork and in the level of the top of formwork shall not exceed 3 mm.</p>
<i>Tolerances: reinforcement</i>	10.49	The cover to fabric reinforcement in concrete carriageways shall be within 10 mm of the specified cover.
<i>Tolerances: dowel bars and tie bars</i>	10.50	<p>(1) Dowel bars at joints in concrete carriageways shall be within 20 mm of the mid-depth of the slab.</p> <p>(2) Dowel bars shall be parallel to within 3 mm in half the length of the bar to:</p> <ul style="list-style-type: none"> (a) The longitudinal joint, or the longitudinal axis of the concrete carriageway if there is no longitudinal joint, (b) The top surface of the slab, and (c) Adjacent dowel bars.
<i>Tolerances: grooves</i>	10.51	Unless otherwise recommended by the manufacturer of the joint sealant the depth of grooves for joint sealant in concrete carriageways shall be within 3 mm of the specified depth.
<i>Tolerances: covers, frames and other hardware</i>	10.52	The level of covers, frames and other hardware shall not be higher than, and shall not be more than 3 mm lower than, the surface of the adjacent carriageway.
<i>Tolerances: alignment of concrete carriageway</i>	10.53	<p>(1) The best-fit straight line of straight joints and of straight edges of concrete carriageways shall be within 25 mm of the specified line. The line of straight joints and of straight edges of concrete carriageways shall be within 10 mm of the best-fit straight line.</p> <p>(2) The best fit curved line of curved joints and of curved edges of concrete carriageways shall be as agreed by the Engineer and shall be within 25 mm of the specified line. The line of curved joints and of curved edges of concrete carriageways shall be within 10 mm of the best-fit curved line.</p>

		(3) Joints in concrete carriageways shall be continuous across intersections of joints to within 5 mm of the best fit straight lines or best fit curved lines of each joint.
<i>Tolerances: level of concrete carriageway</i>	10.54	<p>(1) The levels of the surface of concrete carriageways shall be determined 200 mm from the edges of each bay at 10 m centres in the longitudinal direction and at 2 m centres in the transverse direction.</p> <p>(2) The level of the surface of concrete carriageways shall be within 6 mm of the specified level. In low lying and flat areas the Contractor shall pay special attention to level control to ensure that falls on the surface of the carriageway are in the specified direction.</p> <p>(3) The difference in level of the surface of concrete carriageways across joints shall not exceed 3 mm.</p> <p>(4) The thickness of concrete carriageway slabs shall not be less than the specified thickness minus 10 mm.</p>

TESTING: SURFACE REGULARITY

<i>Testing: surface regularity</i>	10.55	<p>(1) The surface regularity of concrete carriageways shall be determined by measuring the number of irregularities in the surface. An irregularity means that the gap between the surface of the carriageway, and a 3 m straight-edge placed on the surface of the carriageway, exceeds the specified amount. Irregularities shall be measured in millimetres perpendicular to the straight edge.</p> <p>(2) The longitudinal surface regularity of carriageways with a total length of 75 m or more may be measured using a rolling straight-edge of the type designed by the UK Transport and Road Research Laboratory. The longitudinal surface regularity of carriageways with a total length of less than 75 m and the transverse surface regularity of carriageways shall be measured using a 3 m straight edge.</p> <p>(3) The longitudinal surface regularity shall be measured along lines parallel to the longitudinal axis of the carriageway and approximately 1 m from the nearside edge of each carriageway lane. The transverse surface regularity shall be measured along lines at right angles to the longitudinal axis of the carriageway at 10 m intervals along the length of the carriageway.</p> <p>(4) Testing to determine the surface regularity will be carried out by the Engineer.</p>
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Compliance criteria: 10.56 The results of tests for surface regularity of carriageways shall comply with the following requirements:

surface regularity

- (a) The size and number of irregularities in the longitudinal direction shall not exceed the size and permitted number of irregularities stated in Table 10.1.
- (b) There shall be no irregularity exceeding 4 mm in a 3 m length in the transverse direction for Category A roads and there shall be no irregularity exceeding 7 mm in a 3 m length in the transverse direction for Category B roads.

Table 10.1: Permitted irregularities in the longitudinal direction

Total length of carriageway	Size of irregularity	Permitted number of irregularities (Category A road)	Permitted number of irregularities (Category B road)
< 75 m	> 4 mm	(9 x total length)/75	(18 x total length)/75
	> 7 mm	1	2
75 m - 300 m	> 4 mm	9 in any 75 m length	18 in any 75 m length
	> 7 mm	1 in any 75 m length	2 in any 75 m length
> 300 m	> 4 mm	20 in any 300 m length	40 in any 300 m length
		9 in any 75 m length	18 in any 75 m length
	> 7 mm	2 in any 300 m length	4 in any 300 m length
		1 in any 75 m length	2 in any 75 m length

Category A roads are roads with a legal speed limit greater than 70 kilometre per hour. All other roads are Category B roads.

Irregularities greater than 7 mm shall also be counted as greater than 4 mm.

No irregularity greater than 10 mm shall be permitted.

TESTING: TEXTURE DEPTH

- Testing: texture depth** 10.57
- (1) The texture depth of concrete carriageways shall be determined by the sand patch test. Tests shall be carried out at least 2 days after the surface texturing has been carried out and before the area is used by construction plant or other vehicles.
 - (2) Each carriageway lane shall be divided into sections of equal length not exceeding 150 m. Tests shall be carried out at ten locations on each Section at approximately equal spacings as instructed by the Engineer. No measurement shall be taken within 300 mm of the longitudinal edges of the sections.

(3) Testing to determine the texture depth will be carried out by the Engineer. The method of testing shall be in accordance with Appendix 10.1.

<i>Compliance criteria: texture depth</i>	10.58	<p>The results of tests for texture depth for each Section of concrete carriageway lane shall comply with the following requirements:</p> <p>(a) The average texture depth shall not be less than 0.70 mm, and</p> <p>(b) Not more than one out of the ten measured texture depths shall be less than 0.6 mm.</p>
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TESTING: CONCRETE

<i>Testing: workability and compressive strength of concrete</i>	10.59	Testing to determine the workability and compressive strength of concrete in concrete carriageways shall be as stated in Clauses 16.52 to 16.62 except as stated in Clauses 10.60 and 10.61.
<i>Compliance criteria: workability of concrete</i>	10.60	The average slump value of the two specimens taken from one sample of concrete shall not exceed the approved slump value by more than 10 mm.
<i>Samples: compressive strength of concrete</i>	10.61	One sample of concrete shall be provided from each 25 m ³ or 25 batches of concrete or from the amount of concrete produced each day, whichever is less.

TESTING: CONCRETE CORES FROM TRIAL LENGTHS

<i>Samples: concrete cores from trial lengths</i>	10.62	<p>(1) Two concrete cores shall be provided from each bay, and one core shall be provided from each joint, of concrete carriageway in the trial length. The positions from which the cores are taken shall be as instructed by the Engineer.</p> <p>(2) Concrete cores shall be 150 mm diameter unless otherwise permitted by the Engineer and shall be the full depth of the slab. Cores shall be taken as soon as the concrete has hardened sufficiently for the core to be taken.</p> <p>(3) The method of taking concrete cores shall be in accordance with CS1.</p> <p>(4) Holes formed by taking concrete cores from trial lengths that form part of the permanent carriageway shall be reinstated using the approved concrete mix. Joints shall be repaired as instructed by the Engineer.</p>
<i>Testing: concrete cores from trial lengths</i>	10.63	<p>(1) Each concrete core from trial lengths in concrete carriageways shall be inspected to determine the thickness of the slab and the positions of the reinforcement and joint components. Each core shall be inspected for evidence of segregation of the constituents and for the presence of voids.</p> <p>(2) The method of preparing and inspecting concrete cores shall be in accordance with CS1.</p>

<i>Compliance criteria: concrete cores from trial lengths</i>	10.64	The concrete core shall be considered as non-compliant if it exhibits honeycombing which means interconnected voids arising from, for example, inadequate compaction or lack of mortar.
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TESTING: MATERIALS FOR JOINTS

<i>Batch: joint filler, joint sealant</i>	10.65	A batch of joint filler or joint sealant shall comply with Clause 16.89.
<i>Samples: joint filler, joint sealant</i>	10.66	Samples of joint filler or joint sealant shall comply with Clause 16.90.
<i>Testing: joint filler, joint sealant</i>	10.67	Testing of joint filler and joint sealant for joints in concrete carriageways shall be as stated in Clauses 16.91 and 16.92 except as stated in Clause 10.68.
<i>Testing: joint sealant</i>	10.68	Each sample of joint sealant shall be tested to determine the application life, tack-free time, resistance to flow, recovery, adhesion and cohesion in tension and compression and resistance to heat ageing. The method of testing shall be in accordance with BS 5212.

APPENDIX 10.1

DETERMINATION OF THE TEXTURE DEPTH OF CARRIAGEWAYS

Scope 10.1.1 This method covers the determination of the texture depth of carriageways by the sand patch test.

Materials 10.1.2 The following material is required:

Dry natural sand, with a rounded particle shape, which has been washed and then screened such that it meets the grading stated in Table 10.1.1.

Table 10.1.1: Grading of sand

BS test sieve	Percentage by mass passing
600 μm	100
300 μm	95 - 100
150 μm	0 - 6

Apparatus 10.1.3 The following apparatus is required:

- (a) A soft brush.
- (b) A robust measuring cylinder having an internal diameter of 20 ± 2 mm and a flat top surface such that its internal volume is 25 ± 0.1 mL.
- (c) A flat wooden disc of 65 ± 2 mm diameter with a 1.5 mm minimum thickness hard rubber disc attached to one face and a handle fixed to the other face.
- (d) A steel rule calibrated to 1 mm.
- (e) A suitable windshield.
- (f) A funnel with an outlet tube at least 100 mm long with a bore of between 4 mm and 6 mm, and capable of accepting a volume of at least 200 mL.
- (g) A steel straight edge for screeding off the measuring cylinder.
- (h) A steel-wire brush.

Procedure 10.1.4 The procedure shall be as follows:

- (a) The test location shall be at least 300 mm square. It shall be vigorously brushed ten times in two directions at right angles using the steel wire brush, and then dried and swept clean with the soft brush.

- (b) Sand shall be poured into the measuring cylinder to fill it to overflowing, and any excess sand shall be screeded off using the straight edge. All sand on the outside of the cylinder shall be removed, taking care not to drop any sand onto the test location. Alternatively, this step in the procedure may be carried out in a laboratory, and the sand transferred to a suitable container ready for pouring.
- (c) The measured volume of sand shall be poured onto the centre of the test location through the funnel to form a heap. The windshield shall be used to protect the test location if required.
- (d) The sand shall be spread outwards with a circular motion over the test location, using the rubber-faced disc with its face parallel to the surface of the carriageway. This shall be continued until the patch of sand is approximately circular and will spread outwards no more.
- (e) The size of the circular patch of sand shall be measured to the nearest 1 mm along three diameters, which are aligned at approximately 120 degrees to each other.
- (f) If the difference between the maximum and minimum of the three measurements exceeds 20% of the average of the three measurements, then all the measurements shall be discarded and the test repeated at an adjacent location.
- (g) The test shall be repeated for all the ten test locations for each Section of carriageway lane.

Calculation

- 10.1.5 (1) The texture depth (T) for each test shall be calculated from the equation:

$$T = 31000 / D^2 \text{ mm}$$

where:

- D is the average of the three diameter measurements of the sand patch calculated to the nearest 1 mm.

- (2) The average texture depth for the ten tests shall be calculated.

Reporting of results

- 10.1.6 The following shall be reported:

- (a) The test location.
- (b) The average diameter of the sand patch for each test to the nearest 1 mm.
- (c) The texture depth for each test to the nearest 0.1 mm.
- (d) The average texture depth to the nearest 0.1 mm.
- (e) That the test was carried out in accordance with this Specification.

**GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS**

**SECTION 4
MISCELLANEOUS ROADWORKS**

SECTION 4

MISCELLANEOUS ROADWORKS

PART 1: GENERAL REQUIREMENTS

GENERAL

<i>General requirements</i>	11.01	The works and materials specified in Clauses 11.02 to 11.08 shall comply with the sections stated, unless otherwise stated in this Section.
<i>Earthworks</i>	11.02	Earthworks shall comply with Section 6.
<i>Sub-base material and bituminous materials</i>	11.03	Sub-base material and bituminous materials shall comply with Section 9.
<i>Joints in concrete</i>	11.04	Joints in concrete shall comply with Section 10.
<i>Formwork</i>	11.05	Formwork and finishes to concrete shall comply with Section 14.
<i>Reinforcement</i>	11.06	Steel reinforcement shall comply with Section 15.
<i>Concrete</i>	11.07	Concrete shall comply with Section 16.
<i>Steelwork</i>	11.08	Steelwork shall comply with Section 18.

MATERIALS

<i>Cement mortar</i>	11.09	Cement mortar shall consist of one part of cement to three parts of fine aggregate by volume together with the minimum amount of water necessary to achieve a consistency suitable for the required work. Fine aggregates shall be sand or crushed rock to BS 1200 and shall pass a 5 mm BS test sieve.
<i>Polyethylene sheeting</i>	11.10	Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

PART 2: CONCRETE PROFILE BARRIERS

MATERIALS

<i>Concrete mix</i>	11.11	Concrete for concrete profile barriers shall be Grade 30/20.
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SUBMISSIONS

<i>Particulars of concrete profile barriers</i>	11.12	<p>(1) The following particulars of the proposed methods of construction for concrete profile barriers shall be submitted to the Engineer:</p> <ul style="list-style-type: none"> (a) Particulars of formwork as stated in Clause 14.21 for in-situ construction using fixed forms, (b) Details of slip-form machine for in-situ construction between sliding forms, and (c) Methods of manufacture, handling, transport, storage and fixing in position of precast units. <p>(2) The particulars shall be submitted to the Engineer for information at least 14 days before construction of concrete profile barriers starts.</p>
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TRIALS

<i>Trial length</i>	11.13	<p>(1) A trial length of concrete profile barrier shall be constructed to demonstrate that the proposed materials, mix design, methods of production and methods of construction will produce a concrete profile barrier which complies with the specified requirements. If it is not stated in the Contract that the trial length is to be constructed in a location separate from the permanent concrete profile barrier, the trial length shall be the first 25 m of the permanent barrier.</p> <p>(2) The trial length shall be constructed in sufficient time before the permanent barrier is constructed to allow the Engineer a period of at least 7 days to determine if the specified requirements have been produced in the trial length.</p> <p>(3) The Contractor shall inform the Engineer at least 24 hours, or such shorter period agreed by the Engineer, before constructing the trial length.</p> <p>(4) The trial length shall be constructed using the materials, mix design, methods of production and methods of construction submitted to the Engineer.</p> <p>(5) The trial length shall be used as a means of comparison against which the Engineer shall determine the compliance or otherwise of the permanent concrete profile barrier. The trial length shall be protected from damage and shall be left in position unless the Engineer instructs its removal. A trial length which forms part of the permanent barrier and which complies with the specified requirements shall not be removed.</p>
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<i>Testing: trial length</i>	11.14	<p>(1) The trial length shall be tested to determine the accuracy of the alignment and level and the finish of the concrete surface.</p> <p>(2) Concrete cores shall be cut from the trial length to determine the amount of segregation of the constituents and the presence of voids. The method of taking, preparing, inspecting and testing concrete cores shall be as stated in Clause 11.26.</p>
<i>Compliance criteria: trial length</i>	11.15	<p>The results of tests on trial lengths shall comply with the following requirements:</p> <p>(a) The alignment and levels of the barrier shall comply with Clause 11.25.</p> <p>(b) The finish of concrete surfaces shall comply with Clause 14.44.</p> <p>(c) The amount of segregation of the constituents and the presence of voids shall comply with Clause 10.64 for concrete carriageways.</p>
<i>Non-compliance: trial length</i>	11.16	<p>(1) If the result of any test on the trial length does not comply with the specified requirements for the trial length, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer. Further trial lengths shall be constructed until the result of every test on the trial length complies with the specified requirements for the trial length. Further trial mixes shall be made unless in the opinion of the Engineer non-compliance of the trial length was not due to the concrete mix.</p> <p>(2) Unless otherwise permitted by the Engineer, trial lengths, or parts of trial lengths, which do not comply with the specified requirements for the trial length shall be removed.</p>
<i>Commencement of concreting</i>	11.17	<p>(1) Except as stated in Clause 11.17(2) concrete shall not be placed in the permanent barriers until the result of every test on the trial length complies with the specified requirements for the trial length.</p> <p>(2) Concrete may be placed in the permanent barriers before the results of tests for compressive strength of the trial mix are available provided that the result of every other test on the trial mix and trial length complies with the specified requirements for trial mix concrete and for the trial length.</p>
<i>Changes in materials and methods of construction</i>	11.18	<p>Unless permitted by the Engineer, the materials mix design, methods of production and methods of construction used to produce a trial length that complies with the specified requirements shall not be changed. Further trial lengths shall be constructed to demonstrate any proposed changes unless otherwise permitted by the Engineer.</p>

FORMWORK AND FINISHES TO CONCRETE

<i>Formwork</i>	11.19	<p>(1) Formwork for concrete profile barriers shall be steel unless otherwise permitted by the Engineer.</p>
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		(2) Formwork shall not be loosened or removed until at least 7 hours after concreting has been completed.
<i>Finishes to concrete</i>	11.20	<p>(1) The finish to unformed concrete surfaces of concrete profile barriers shall be Class U5.</p> <p>(2) The finish to concrete surfaces for transverse joints shall be Class F3 and the finish to exposed concrete surfaces shall be Class F5.</p>

JOINTS IN CONCRETE PROFILE BARRIERS

<i>Joints in concrete profile barriers</i>	11.21	<p>(1) Joints shall be formed in concrete profile barriers at locations which coincide with expansion or construction joints in the adjoining structure or carriageway or at intervals not exceeding 12 m, whichever is less.</p> <p>(2) Joints in concrete profile barriers shall comply with Section 16.</p>
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CONSTRUCTION OF CONCRETE PROFILE BARRIERS

<i>Construction by slip-form machine</i>	11.22	Construction of concrete profile barriers by slip-form machine between sliding forms shall be carried out in accordance with BS 5931. Slip-form machines shall comply with BS 5931, Appendix A.
<i>Construction using precast units</i>	11.23	Precast concrete profile barriers shall be laid on a cement mortar regulating layer of between 10 mm and 40 mm thick.

PROTECTION OF CONCRETE PROFILE BARRIERS

<i>Protection of concrete profile barriers</i>	11.24	Immediately after the formwork has been removed or the curing compound has been applied, concrete profile barriers shall be protected by polyethylene sheeting for at least 24 hours from exposure to conditions that may affect the concrete. The sheeting shall be lapped and securely held in position in such a manner that the surface of the concrete will not be damaged.
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TOLERANCES

<i>Tolerances: concrete profile barriers</i>	11.25	<p>Concrete profile barriers shall comply with the following requirements:</p> <ul style="list-style-type: none"> (a) The horizontal dimensions of cross-sections shall be within 5 mm of the specified dimensions. (b) The vertical dimensions of cross-sections shall be within 10 mm of the specified dimensions. (c) The horizontal alignment along the centreline shall be within 10 mm of the specified centreline.
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- (d) The level of the formation shall be within 10 mm of the specified level.
 - (e) The level of the top of the barriers shall be within 10 mm of the specified level.
 - (f) The barriers shall form a smooth alignment.
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TESTING: CONCRETE CORES FROM TRIAL LENGTHS

*Testing: concrete
cores from trial
lengths*

- 11.26
- (1) Two concrete cores shall be provided from each trial length of concrete profile barriers. The positions from which the cores are taken shall be as instructed by the Engineer.
 - (2) Samples, testing and compliance criteria for concrete cores from trial lengths shall be as stated in Clauses 10.62 (2) to (4), 10.63 and 10.64 for concrete carriageways.
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PART 3: PEDESTRIAN GUARD-RAILING

GENERAL

<i>Design of pedestrian guard-railing</i>	11.27	Pedestrian guard-railing which is proposed by the Contractor as an alternative to that stated in the Contract or which is erected as Temporary Works shall be designed in accordance with BS 3049, Table 1, Class C.
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MATERIALS

<i>Steel</i>	11.28	Steel for pedestrian guard-railing shall comply with the following:	
		Hot finished seamless tubes	: BS 6323: Part 3
		Steel tubes and tubulars suitable for screwing to BS 21 pipe threads	: BS 1387
		Hot rolled sections	: BS 4: Part 1
		Hot rolled structural steel sections - equal and unequal angles	: BS 4848: Part 4
		Weldable structural steels	: BS 4360.
<i>Stainless steel</i>	11.29	Stainless steel for pedestrian guard-railing shall be Grade 316 S 31 and shall comply with the following:	
		General inspection and testing procedures and specific requirements for carbon, carbon manganese and stainless steels	: BS 970: Part 1
		Stainless steel tubes suitable for threading in accordance with BS 21	: BS 6362.

Aluminium

- 11.30 (1) Aluminium for pedestrian guard-railing shall be H 30 TF and shall comply with the following:

Wrought aluminium and
aluminium alloys for
general engineering
purposes

- plate, sheet and strip : BS 1470

- drawn tube : BS 1471

- bars, extruded round
tubes and sections : BS 1474.

- (2) Aluminium shall be anodised to Grade AA 25 in accordance with BS 1615.

**Bolts, nuts, screws,
washers and rivets**

- 11.31 (1) Bolts, nuts, screws, washers and rivets for pedestrian guard-railing shall comply with the following:

ISO metric black
hexagon bolts,
screws and nuts : BS 4190

ISO metric black cup
and countersunk head
bolts and screws with
hexagon nuts : BS 4933

Metal washers for
general engineering
purposes : BS 4320

Rivets for general
engineering purposes : BS 4620

Wrought aluminium and
aluminium alloys for
general engineering
purposes
- rivet, bolt and
screw stock : BS 1473.

- (2) The length of bolts shall be such that the threaded portion of each bolt projects through the nut by at least one thread and by not more than four threads.

- (3) Rag, indented and expansion bolts and resin bonded bolts shall be of proprietary types approved by the Engineer and shall be capable of withstanding the design loading.

- (4) Galvanized bolts, nuts, screws, washers and rivets shall be used with galvanized pedestrian guard-railing. Aluminium materials shall be insulated from ferrous materials by a non-conductive insulator at least 2 mm thick of a type approved by the Engineer.

<i>Mesh infill</i>	11.32	Mesh infill for pedestrian guard-railing shall comply with BS 4483. The mesh infill shall be free of surface defects, surface irregularities and mesh misalignment.
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FABRICATION OF PEDESTRIAN GUARD-RAILING

<i>Galvanizing to steel</i>	11.33	<p>(1) Steel components forming pedestrian guard-railing shall be hot-dip galvanized in accordance with BS EN ISO 1461.</p> <p>(2) Galvanizing to steel shall be applied after welding, drilling and cutting are complete.</p>
<i>Welding steel</i>	11.34	<p>(1) Welding for fabrication of pedestrian guard-railing shall be fillet welds. Welded surfaces shall be clean and flush before application of the protective coating.</p> <p>(2) Steel shall not be welded after galvanizing unless permitted by the Engineer. If permitted, the welded areas shall be free of scale and slag and shall be treated with an alternative zinc-coating system approved by the Engineer.</p>

SUBMISSIONS

<i>Particulars of pedestrian guard-railing</i>	11.35	<p>(1) The following particulars of the proposed pedestrian guard-railing shall be submitted to the Engineer:</p> <ul style="list-style-type: none"> (a) A certificate from the manufacturer showing the manufacturer's name, the date and place of manufacture and showing that the materials comply with the requirements stated in the Contract, and (b) Details of alternative designs proposed by the Contractor, including drawings, showing the proposals and that the pedestrian guard-railing has been designed in accordance with Clause 11.27. <p>(2) The particulars shall be submitted to the Engineer at least 28 days before fabrication of the pedestrian guard-railing starts.</p>
<i>Samples of materials</i>	11.36	<p>Samples of the following proposed materials shall be submitted to the Engineer for approval of the source and type of each material at the same time as particulars of the pedestrian guard-railing are submitted:</p> <ul style="list-style-type: none"> (a) Each type of pedestrian guard-railing, (b) Mesh infill, and (c) Each type of bolt, nut, and washer.

STORAGE OF MATERIALS

<i>Storage of pedestrian guard-railing</i>	11.37	Pedestrian guard-railing shall be stored off a levelled, well drained and maintained hard-standing ground on level supports and in a manner which will not result in damage or deformation to the guard-railing or in contamination of the guard-railing. Pedestrian guard-railing shall be protected from damage and damaged guard-railing shall not be used in the permanent work unless permitted by the Engineer. Measures to protect the materials from the effects of weather shall be submitted to the Engineer for approval.
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INSTALLATION OF PEDESTRIAN GUARD-RAILING

<i>Installation of pedestrian guard-railing</i>	11.38	<p>(1) Pedestrian guard-railing shall be installed to a smooth alignment to within 10 mm of the specified position and height.</p> <p>(2) Pedestrian guard-railing which is to be installed to a radius of less than 45 m shall be curved in the workshop and shall not be made up of a series of straight lengths.</p> <p>(3) Pedestrian guard-railing shall be fixed to concrete using rag, indented, expansion or resin bonded bolts and shall be bolted to metalwork. Bolts for fixing to concrete shall be fitted into pockets filled with cement mortar or resin grout.</p>
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PART 4: UNTENSIONED BEAM BARRIERS

MATERIALS

Beams

- 11.39 (1) Beams for untensioned beam barriers shall be formed from steel plates complying with BS 1449: Part 1, type BHR, Grade 43/25.
- (2) The beams shall be capable of withstanding a tensile force of at least 300 kN and shall not deflect by more than 40 mm when loaded centrally with a point load of 1 t over a simply supported span of 3 m.
- (3) Beams shall comply with the following requirements:
- (a) The base metal thickness shall be within 0.2 mm of the specified thickness.
 - (b) The strip width shall be within + 2.5 mm and - 0 mm of the specified width.
 - (c) The camber of the strip length shall be within 8 mm of the specified camber.
 - (d) The beam shall be straight to within 1.5 mm in a 1.5 m length.
 - (e) Angles at bends shall be within 2° of the specified angle.
- (4) Bolt slots in beams for connection to posts shall be prepared in the workshop by cold saw-cutting. The spacing of the slots shall be such that posts will be spaced at either 4 m or 2 m.
- (5) Beams shall be hot-dip galvanized to BS EN ISO 1461.
- (6) Welds for end beam sections shall be full-penetration butt welds.

Posts

- 11.40 (1) Posts for untensioned beam barriers shall be formed from Grade 43A steel complying with BS 4360.
- (2) Posts shall be hot-dip galvanized in accordance with BS EN ISO 1461:1999.
- (3) Posts fabricated from hollow sections shall be sealed by welding mild steel sealing plates over the open ends. The plates shall be at least 3 mm thick.
- (4) Posts shall be within the tolerances stated in BS 4.

Cleats and struts

- 11.41 (1) Cleats and struts for untensioned beam barriers shall be fabricated from angle sections complying with BS 4 and shall be weldable structural steel complying with BS 4360, Grade 43A.
- (2) Cleats and struts shall be hot-dip galvanized in accordance with BS EN ISO 1461:1999.
- (3) The dimensional tolerances of steel angles for cleats and struts shall comply with BS 4.

Bolts and nuts

- 11.42 (1) Bolts for untensioned beam barriers shall be M 16 size and strength Grade 4.6 complying with BS 4190. Bolts for beam splicing, bolts for connecting beams to posts and bolts for connecting beams to cleats shall be round or button-headed with oval shoulders. Other bolts shall be ISO metric black hexagon type.
- (2) Nuts for untensioned beam barriers shall be strength Grade 4 or 5 complying with BS 4190.
- (3) Bolts and nuts shall be hot-dip galvanized in accordance with BS EN ISO 1461:1999.
- (4) Nuts shall be tapped 0.4 mm oversize to accommodate the galvanized coating.
- (5) The length of bolts shall be such that the threaded portion of each bolt projects through the nut by at least one thread and by not more than four threads.
- (6) Rag, indented and expansion bolts and resin bonded bolts shall be of a proprietary type approved by the Engineer and shall be capable of withstanding the design loading.

Washers

- 11.43 (1) Washers for untensioned beam barriers shall be black mild steel and shall comply with BS 4320, Form E, F or G. Washers shall be manufactured from steel complying with BS 1449: Part 1, Grade 250.
- (2) Plain washers shall be 2 mm thick and shall be of dimensions suitable for use with M 16 bolts and nuts.
- (3) Plain washers shall be hot-dip galvanized in accordance with BS EN ISO 1461:1999.
- (4) Shaped washers shall have a thickness of at least 5 mm and shall be cast iron complying with BS 3468. The washers shall be shaped to fit the curvature of circular hollow sections used as posts.

SUBMISSIONS***Particulars of untensioned beam barriers***

- 11.44 (1) The following particulars of the proposed materials and methods of construction for untensioned beam barriers shall be submitted to the Engineer:
- (a) A certificate from the manufacturer for beams in the format stated in BS 4360 showing the manufacturer's name, the date and place of manufacture and showing that the beams comply with the requirements stated in the Contract and including carbon equivalent values, and
 - (b) Details of method of installation.
- (2) The particulars, including certificates, shall be submitted to the Engineer for approval of the source and type of materials at least 14 days before installation of the beams starts. Certificates shall be submitted for each batch of beams delivered to the Site.

<i>Samples of materials</i>	11.45	Samples of the following proposed materials shall be submitted to the Engineer for approval of the source and type of each material at the same time as particulars of the material are submitted: <ul style="list-style-type: none"> (a) Beams, (b) Posts, cleats and struts, and (c) Bolts, nuts and washers.
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STORAGE OF MATERIALS

<i>Storage of beams and posts</i>	11.46	Beams and posts for untensioned beam barriers shall be stored off a levelled, well drained and maintained hard-standing ground on level supports and in a manner that will not result in damage or deformation to the beams and posts or in contamination of the beams and posts. Beams and posts shall be protected from damage and damaged beams and posts shall not be used in the permanent work unless permitted by the Engineer. Measures to protect the materials from the effects of weather shall be submitted to the Engineer for approval.
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CONSTRUCTION OF UNTENSIONED BEAM BARRIERS

<i>Installation of untensioned beam barriers</i>	11.47	<p>(1) Untensioned beam barriers shall be ready for assembly when delivered to Site. Beams and posts shall be free of blisters, flux, uncoated spots and other defects.</p> <p>(2) Untensioned beam barriers shall be installed to a smooth alignment to within 10 mm of the specified position and height. Transition sections shall provide a smooth and uniform transition.</p> <p>(3) Beams which are to be installed to a radius of less than 45 m shall be curved in the workshop.</p> <p>(4) Untensioned beam barriers shall be fixed to concrete using rag, indented, expansion or resin bonded bolts and shall be bolted to metalwork. Bolts for fixing to concrete shall be fitted into pockets filled with cement mortar or resin grout.</p>
<i>Compacted earth footings</i>	11.48	<p>(1) Sub-base material shall be deposited and compacted in the bottom 250 mm of pits for foundations of untensioned beam barriers with compacted earth footings. Fine fill material shall be deposited and compacted to the remainder of the pit. The sub-base material and fill material shall be compacted to obtain a relative compaction of at least 95% throughout.</p> <p>(2) Posts for untensioned beam barriers shall be securely fixed in position during deposition and compaction of fill material.</p>

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| <i>Concrete footings</i> | 11.49 | (1) Concrete for concrete footings shall be Grade 20/20.

(2) The top surface of concrete footings shall be finished level with the adjoining ground. The finish to the concrete surface shall be Class U5.

(3) Posts shall be surrounded with polyethylene sheeting before concrete is placed and shall be securely fixed in position during concreting. |
| <i>Anchor blocks</i> | 11.50 | (1) Concrete for anchor blocks shall be Grade 20/20.

(2) The finish to concrete surfaces of anchor blocks shall be Class F5 for formed finishes and Class U5 for unformed finishes. |
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PART 5: KERBS, EDGINGS AND QUADRANTS

MATERIALS

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| <i>Concrete kerbs, edgings and quadrants</i> | 11.51 | <p>(1) Concrete for kerbs, edgings and quadrants shall be Grade 30/20. Concrete for foundations and backings to kerbs, edgings and quadrants shall be Grade 20/20.</p> <p>(2) Precast concrete kerbs, edgings and quadrants shall comply with BS 7263: Part 1 except that the requirement for testing of water absorption shall not be applied. The nominal length of kerbs shall be 1 m and the nominal length of edgings shall be 750 mm.</p> |
| <i>Granite kerbs, edgings and quadrants</i> | 11.52 | <p>(1) Granite kerbs, edgings and quadrants shall be worked straight or circular. Corners shall be square and the top front and back edges shall be parallel. The length of granite kerbs and edgings shall be at least 600 mm.</p> <p>(2) The ends of the kerbs, edgings and quadrants shall be chisel-dressed square to form a close butt-joint with adjacent kerbs. Kerbs shall be chisel-dressed to a depth of at least 140 mm on the front face, at least 75 mm on the back face and for the full width of the top face.</p> |
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CONSTRUCTION OF KERBS, EDGINGS AND QUADRANTS

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| <i>Construction of precast concrete and granite kerbs, edgings and quadrants</i> | 11.53 | <p>(1) Precast concrete and granite kerbs, edgings and quadrants shall be laid and bedded on a regulating layer of cement mortar. The thickness of the layer shall be at least 10 mm and shall not exceed 40 mm.</p> <p>(2) Except as stated in this clause, joints between each kerb, edging and quadrant shall not exceed 10 mm in width and shall be filled and flush pointed with cement mortar. Joints in kerbs, edgings and quadrants at expansion joints on bridge decks shall be as stated in the Contract. Transverse expansion and contraction joints in kerbs, edgings and quadrants laid on or adjacent to concrete carriageways shall be in accordance with Clause 10.35(2).</p> <p>(3) Radius kerbs shall be used for curves less than 10 m external radius.</p> |
| <i>Construction of in-situ kerbs, edgings and quadrants</i> | 11.54 | <p>(1) In-situ concrete kerbs, edgings and quadrants shall be constructed in accordance with BS 5931 and shall be laid by an automatic extrusion machine of a type approved by the Engineer.</p> <p>(2) In-situ concrete kerbs, quadrants and edgings shall have regular sides, edges, arrises and chamfers. The finish to the concrete surface shall be Class U5. Kerbs, edges and quadrants shall not be finished or dressed with cement mortar.</p> <p>(3) Contraction joints shall be formed at intervals not greater than approximately 4 m. Transverse expansion and contraction joints in kerbs, edgings and quadrants which are laid on or adjacent to concrete carriageways shall be in accordance with Clause 10.35(2). Joints shall be flush pointed with cement mortar.</p> |

TOLERANCES

*Tolerances:
kerbs, edgings and
quadrants*

- 11.55 (1) The line of kerbs, edgings and quadrants shall be within 3 mm of the specified line.
- (2) The level of the top of kerbs, edgings and quadrants shall be within 3 mm of the specified level.
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PART 6: FOOTWAYS, CYCLETRACKS AND PAVED AREAS

MATERIALS

<i>Concrete for footways, cycletracks and paved areas</i>	11.56	Concrete for footways, cycletracks and paved areas shall be Grade 30/20.
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CONSTRUCTION OF FOOTWAYS, CYCLETRACKS AND PAVED AREAS

<i>In-situ concrete footways, cycletracks and paved areas</i>	11.57	In-situ concrete for footways, cycle tracks and paved areas shall be laid in areas not exceeding 20 m ² . The finish to the concrete surface shall be Class U4.
<i>Flexible surfacing to footways, cycletracks and paved areas</i>	11.58	<p>(1) Bituminous materials for footways, cycletracks and paved areas shall be laid and compacted with steel-wheeled and pneumatic-tyred rollers. Compaction shall start before the temperature of the newly laid material falls below 100°C and shall continue until all roller marks have been removed. For locations where rollers cannot operate effectively, the bituminous material can be compacted by hand-operated mechanical compaction plant approved by the Engineer.</p> <p>(2) Cores shall be taken in accordance with Clause 9.62 for the checking of air void content and compacted layer thickness of the bituminous material for works with area of not less than 200m². For works with area smaller than 200m² but greater than 50m², at least 2 cores shall be taken from each layer of bituminous material laid. For works with area less than 50m², no coring is required unless otherwise instructed by the Engineer.</p> <p>(3) The cores taken in accordance with Clause 11.58(2) shall be tested to determine the air void content. The average air void content of the cores shall be not less than 3% nor greater than 9%. If the test result does not comply with the specified requirement, 2 additional cores shall be taken at locations agreed by the Engineer and the average air void content determined from these 2 cores shall replace the original value for compliance checking. Notwithstanding this, no cores shall have an air void content of less than 2.5% nor greater than 10%.</p> <p>(4) Each core taken from the final surfacing layer shall also be measured to determine the compacted layer thickness that shall not deviate by more than 5mm from the specified thickness. If the measured thickness does not comply with the requirement, 2 additional cores shall be taken at locations agreed by the Engineer and the average thickness determined from these 2 cores shall replace the original measured value for compliance checking.</p> <p>(5) If no bulk sample is taken for determination of the Rice's specific gravity, the corresponding value obtained from the mix design shall be used in determining the air void content of the core unless other value is suggested by the Contractor and agreed by the Engineer.</p>

(6) If either the air void content or the compacted thickness of the core is outside the specified limits, the sub-area from which the cores were taken shall be considered as not complying with the requirements specified in this clause.

PROTECTION OF FOOTWAYS, CYCLETRACKS AND PAVED AREAS

*Protection of footways,
cycletracks and paved
areas*

11.59

Footways, cycletracks and paved areas shall not be used by construction plant or vehicles other than those, which in the opinion of the Engineer are essential to construct the subsequent work.

PART 7: PRECAST CONCRETE UNITS FOR PAVING

GLOSSARY OF TERMS

<i>Unit</i>	11.60	<p>(1) Unit is a term used to describe a precast concrete paving slab, block or sett unless otherwise specified by the Engineer.</p> <p>(2) Depending on their quality, units are classified as either Grade A or Grade B as follows:</p> <ul style="list-style-type: none"> - Grade A units shall comply with all the clauses of this PS. - Grade B units shall comply with all the clauses of this PS except those stipulated for Grade A units only.
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MATERIALS

<i>Units</i>	11.61	<p>(1) The dimensions of units shall be within 3 mm of the specified dimensions unless otherwise stated. Chamfers shall not exceed 5 mm in width and depth or shall be round unless otherwise approved by the Engineer.</p> <p>(2) Units may incorporate integral spacer nibs to aid the laying but these spacer nibs shall not be included in the size of the units.</p> <p>(3) Units shall come in wide ranges of colours to facilitate pavement design by the Engineer. The colours of units shall be consistent over the area to be paved, stable and fade resistant under any outdoor climate situations.</p> <p>(4) Units shall not exhibit defects such as cracking or flaking.</p> <p>(5) Units shall be free of any surface sealant unless otherwise directed by the Engineer.</p>
<i>Precast concrete paving slabs</i>	11.62	<p>(1) Paving slabs shall be square or rectangular of metric size 200 mm x 300 mm or 300 mm x 300 mm unless otherwise specified by the Engineer.</p> <p>(2) Paving slabs shall be 60 mm thick for footpaths. Paving slabs of other thickness may be used if approved by the Engineer.</p>
<i>Precast concrete paving blocks</i>	11.63	<p>(1) Paving blocks shall be as shown in relevant Highways Department Standard Drawings, unless otherwise specified by the Engineer. 200 x 200 x 60 mm paving units shall be considered as paving blocks.</p> <p>(2) Paving blocks shall be 60 mm thick for footpaths and 80 mm thick for carriageways and vehicular accesses. Paving blocks of other thickness may be used if approved by the Engineer.</p>
<i>Precast concrete paving setts</i>	11.64	<p>(1) Paving setts shall be square of metric size 100 mm x 100 mm unless otherwise specified by the Engineer.</p> <p>(2) Paving setts shall be 60 mm thick for footpaths and 80 mm thick for carriageways and vehicular accesses. Paving setts of other thickness may be used if approved by the Engineer.</p>

Concrete

11.65 (1) Concrete for units in footways and cycle tracks shall be Grade 30. Concrete for units in carriageways or areas to which vehicles will have access shall be Grade 45.

(2) The nominal maximum aggregate size for concrete in precast units shall be 10 mm.

Additional requirements for Grade A units

11.66 (1) Grade A units shall have an abrasion resistance of not more than 23 mm to BS 6717.

(2) Colour Pigments for Grade A units shall comply with BS 1014. They shall be UV-stable and shall be iron oxides, chrome oxide, titanium oxide or cobalt aluminium oxide unless otherwise approved by the Engineer.

Sand

11.67 (1) Sand for bedding units shall have the particle size distribution stated in Table 11.1. The sand shall have a moisture content exceeding 4% and not exceeding 8% at the time of laying.

(2) Sand for filling joints between precast units shall have the particle size distribution stated in Table 11.2. The sand shall have a moisture content of less than 0.5% at the time of filling joints.

Table 11.1: Particle size distribution of sand for bedding units

BS test sieve size	Percentage by mass passing
10 mm	100
5 mm	85 - 100
2.36 mm	65 - 100
1.18 mm	40 - 98
600 μ m	25 - 72
300 μ m	10 - 35
150 μ m	0 - 15
75 μ m	0 - 10

Table 11.2: Particle size distribution of sand for filling joints between units

BS test sieve size	Percentage by mass passing
2.36 mm	100
1.18 mm	90 - 100
600 μ m	60 - 90
300 μ m	30 - 60
150 μ m	15 - 30
75 μ m	5 - 10

SUBMISSIONS

- | | | |
|---|-------|--|
| <i>Particulars of paving units</i> | 11.68 | <p>(1) The Contractor shall submit the following particulars of the proposed materials and methods of construction for the paving units to the Engineer:</p> <ul style="list-style-type: none"> (a) Name and address of manufacturer, (b) A certificate from the manufacturer showing the source and the particle size distribution of the aggregates, (c) A certificate from the manufacturer showing the manufacturer's name, the date and place of manufacture, and results of tests for: <ul style="list-style-type: none"> - compressive strength of concrete cubes at 28 day, - bending strength of paving slabs to BS 7263-1; and - compressive strength of paving blocks and setts to Appendix 11.1. (d) Drawings showing the layout of the units within the paved area. <p>(2) The particulars as required under Clause 11.68 (1) shall be submitted to the Engineer for approval of the source, type and layout of the units at least 14 days before laying of units starts.</p> |
| <i>Particulars of units - additional requirements for Grade A units</i> | 11.69 | <p>(1) The following particulars of the proposed materials for Grade A units shall be submitted to the Engineer:</p> <ul style="list-style-type: none"> (a) A certificate from the manufacturer showing the results of tests for: <ul style="list-style-type: none"> - Dimensional deviations of paving slabs to BS 7263-1; ; - Dimensional deviations of paving blocks and setts to BS6717; - Slip/skid resistance value of paving slabs to BS EN 1344; - Slip/skid resistance value of paving blocks to BS EN 1344, or unpolished slip/skid resistance value of paving blocks to BS 6717; - Slip/skid resistance value of paving setts to BS EN 1342; - 24-hour cold water absorption value of paving slabs, blocks and setts to AS/NZS 4456.14; and - Abrasion resistance of paving slabs, blocks and setts to BS 6717. |

<i>Samples of materials</i>	11.70	Samples of each type of units shall be submitted to the Engineer for approval of the source and type of each unit at the same time as particulars of the units are submitted.
<i>Samples of materials - additional requirements for Grade A units</i>	11.71	<p>(1) Samples of each type of Grade A units showing the actual size, colour, variation in colour, finish/texture as specified, and general characteristics of the appearance shall be submitted to the Engineer for approval at the time as particulars of the units are submitted.</p> <p>(2) Samples submitted to the Engineer shall be subject to a visual inspection by the Engineer and shall comply with the following requirements:</p> <ul style="list-style-type: none"> (a) When examined in accordance with BS 6717, there shall not be significant visible differences in colour and texture between any samples; (b) When examined in accordance with BS 6717, the samples shall not exhibit defects such as cracking, flaking or dislodging of aggregates; (c) Fine materials shall not be easily dislodged from the surfaces of any samples during gentle manual handling; and (d) The edges of all samples shall be sharp and straight without any defect.

HANDLING AND STORAGE OF MATERIALS

<i>Handling and storage of units</i>	11.72	Units shall be handled and stored on pallets to avoid damage to corners and chamfer edges. Pallets shall be stored on a levelled, well drained and maintained hard-standing ground and in a manner which will not result in damage or contamination to the units. The units shall be protected from damage and damaged units shall not be used unless permitted by the Engineer.
<i>Storage of sand</i>	11.73	Sand for filling joints between units shall be stored off ground in waterproof bags and shall be kept under cover on a levelled, well drained and maintained hard-standing ground on level supports until use.

LAYING UNITS

<i>Laying units</i>	11.74	<p>(1) Units shall not be laid until the layout of the units within the paved area has been approved by the Engineer.</p> <p>(2) Kerbs and edgings shall be completed before the units are laid. The compressive strength of the concrete used for in-situ concrete kerbs and edgings shall be at least 20 MPa before units are laid.</p> <p>(3) Measures shall be taken to prevent water draining across or through the area during laying, bedding and compaction of the units.</p>
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(4) Laying of units shall start as soon as practicable after the formation has been completed. The formation shall be protected as stated in Clause 6.55 until laying starts.

(5) Paving blocks for carriageways and paved areas to which vehicles will have access shall be laid in a herringbone pattern unless otherwise stated in the Contract.

(6) Units shall be cut to size where required using mechanical cutting devices. The cut edge shall be true to line and free of chips and cracks.

(7) The units shall be laid to any design or pattern specified by the Engineer. The design or pattern may involve a single colour or a combination of different colours.

Laying sand

11.75

(1) A layer of sand shall be laid and shall be screeded and tamped to a uniform depth over the complete width of the area to be paved. The quantity and thickness of sand shall be appropriate to the methods of preparation of the sand layer, and shall be sufficient to give the required nominal thickness of the sand layer after compaction of the sand and units.

(2) The sand layer shall not be disturbed by additional compaction, footmarks or other damage after the layer has been screeded and tamped to the required level and before the units are laid.

Bedding paving slabs

11.76

(1) Paving slabs shall be laid on the prepared sand layer immediately after screeding and tamping in such a manner that the sand is not disturbed.

(2) Paving slabs shall be adjusted to form uniform joints between 2 mm and 3 mm wide and shall be bedded into the final position using a wooden mallet or a plate vibrator fitted with a rubber base-pad.

(3) Paving slabs shall not be bedded within 1 m of an unrestrained edge of the screeded sand layer.

(4) Final levelling of the paving slabs shall be carried out as soon as practicable after bedding and before changes in the moisture content of the prepared sand layer occur.

(5) Damaged paving slabs shall be immediately removed and replaced.

Bedding paving blocks and setts

11.77

(1) Paving blocks and setts shall be laid on the prepared sand layer immediately after screeding and tamping in such a manner that the sand is not disturbed. Paving blocks and setts shall be individually laid on the prepared sand layer by manual methods or in clusters by mechanical methods.

(2) Paving blocks and setts shall be laid in such a manner that the blocks and setts are not in direct contact with each other and that uniform joints of between 2 mm and 3 mm wide are formed. Paving blocks and setts shall be bedded flush by at least two passes of a heavy-duty plate compactor fitted with a rubber base-pad.

(3) Final levelling of the paving blocks and setts shall be carried out as soon as practicable after bedding and before changes in the moisture content of the prepared sand layer occur.

(4) Paving blocks and setts shall not be bedded within 1 m of an unrestrained edge of the screeded sand layer.

(5) Damaged paving blocks and setts shall be immediately removed and replaced.

**Filling joints and
compaction of units** 11.78

(1) After the units have been bedded, sand for filling joints shall be spread over the surface of the units and brushed into the joints in such a manner that all joints are completely filled.

(2) Joints shall be filled as soon as practicable after bedding and on the day the units are laid and bedded.

(3) After all joints are completely filled with sand, units shall be fully compacted by using a plate compactor fitted with a rubber base-pad. Additional sand shall be added to refill the joints as required and compacted into the joints by using the plate compactor with two or more passes.

(4) Carriageways and paved areas with regular heavy traffic shall be compacted by at least ten evenly-spaced passes of a pneumatic tyred roller having a gross weight of between 10 t and 12 t, or by a plate compactor which shall have the following capacity:

- Minimum plate area of 0.25 m²;
- Minimum effective force per unit area of plate of 75 kN/ m²;
- Frequency of 65 –100 Hz; and
- Minimum mass of 200 kg.

Other suitable compacting equipment to the approval of the Engineer can be used. Sand shall be added as required and brushed and compacted into the joints.

(5) Units shall not be compacted closer than 1 m behind the laying edge of the units other than on completion of the paved area against a kerb or edging.

(6) Excess sand shall be removed after completion of compaction.

(7) Damaged units shall be immediately removed and replaced.

**Mortar and concrete
seal** 11.79

Pigmented mortar or concrete shall be placed to full depth of the units to fill up the gaps between units and adjacent kerbs, edgings, quadrants, covers, frames and other hardware. The work shall only be carried out upon the approval by the Engineer. Unless otherwise instructed by the Engineer, colour of pigmented mortar or concrete shall match the colour of the adjacent units.

REINSTATEMENT OF UNITS

Reinstatement of units 11.80

(1) If excavation is to be carried out in areas paved with units, the units shall be extracted by manual methods for a distance of at least 300 mm beyond the limit of the excavation.

(2) Unbroken units shall be thoroughly cleaned to remove all sand and deleterious material. The units shall be stacked on pallets for re-use.

(3) Units to be re-used shall be re-laid in accordance with Clauses 11.74 to 11.79.

TOLERANCES

<i>Levels</i>	11.81	The level of paved areas constructed using units shall be within 3 mm of the specified level. The difference in level of adjacent units shall not exceed 2 mm.
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TESTING

<i>Batching</i>	11.82	<p>(1) A batch of units shall be any quantity of paving slabs, blocks, or setts of the same type, size, and finish, of the same concrete grade, manufactured in the same place, covered by the same certificates and delivered to the Site at any one time. Paving slabs, blocks, or setts of different colours can be grouped together to form their respective batches provided that they are manufactured with the same type of materials and production methods.</p> <p>(2) Sampling shall be carried out at random. The sample shall comprise units that are distributed throughout the batch.</p>
<i>Testing requirements for units</i>	11.83	<p>(1) Paving slabs shall be tested for bending strength as stated in Clause 11.84.</p> <p>(2) Paving blocks shall be tested for compressive strength as stated in Clause 11.85.</p> <p>(3) Paving setts need not be tested for bending strength, compressive strength or slip/skid resistance unless otherwise required by the Engineer.</p>
<i>Bending strength test of paving slabs</i>	11.84	<p>(1) One sample of units in a batch shall be provided from every 1000 m² of units or part thereof. A batch with units for area(s) less than 1000 m² may be added to the untested previous or following batch(es) as the case may be for testing purposes. The number of specimens in each sample shall be 8.</p> <p>(2) Each sample of paving slabs shall be tested to determine the bending strength to BS 7263-1.</p> <p>(3) The mean bending strength of a sample of paving slabs shall not be less than 3.7 MPa with bending strength of individual paving slabs not less than 3.0 MPa.</p>
<i>Compressive strength test of paving blocks</i>	11.85	<p>(1) One sample of units in a batch shall be provided from every 1000 m² of units or part thereof. A batch with units for area(s) less than 1000 m² may be added to the untested previous or following batch(es) as the case may be for testing purposes. The number of specimens in each sample shall be 8. For paving blocks of size 200x200x60mm, specimens of size 200x100x60mm shall be cut from these blocks in accordance with Clause 11.74 (6) to form samples.</p>

(2) Each sample of paving blocks shall be tested to determine the characteristic compressive strength at 28 days.

(3) The method of testing shall be as stated in Appendix 11.1.

(4) The characteristic compressive strength of a sample of paving blocks shall be:

- (a) 30 MPa for paving blocks in footways and cycle tracks, and
- (b) 45 MPa for paving blocks in carriageways and paved areas to which vehicles will have access.

Additional testing for Grade A units: dimensional deviation of paving slabs, blocks and setts

11.86 (1) One sample of units in a batch shall be provided from every 1000 m² of units or part thereof. A batch with units for area(s) less than 1000 m² may be added to the untested previous or following batch(es) as the case may be for testing purposes. The number of specimens in each sample shall be 8. The sample can be used for other tests.

(2) The overall dimensions and thickness of each sample of paving slabs shall be measured in accordance with BS 7263-1.

(3) The overall dimensions and thickness of each sample of paving blocks and setts shall be measured in accordance with BS 6717.

(4) The tolerances for the dimensions of each individual units shall be within ± 2 mm for length and width, and ± 3 mm for thickness.

Additional testing for Grade A units: slip/skid resistance of paving slabs and blocks

11.87 (1) One sample of units in a batch shall be provided from every 1000 m² of units or part thereof. A batch with units for area(s) less than 1000 m² may be added to the untested previous or following batch(es) as the case may be for testing purposes. The number of specimens in each sample shall be 5. The sample can be used for other tests.

(2) Each sample of paving slabs shall be tested to determine the slip/skid resistance to BS EN 1344.

(3) Each sample of paving blocks shall be tested to determine the slip/skid resistance to BS EN 1344.

(4) The mean slip/skid resistance of a sample shall not be less than 45 Skid Resistance Value for units in footways and cycle tracks.

(5) Notwithstanding sub-clause (4) above, if considered appropriate by the Engineer for application on steep roads, pavements with steep pedestrian crossings or exceptional high cross fall, or other difficult site conditions, the required slip/skid resistance of the units in footways and cycle tracks may be increased up to 60 Skid Resistance Value.

Additional testing for Grade A units: water absorption value of paving slabs and blocks

11.88 (1) One sample of units in a batch shall be provided from every 1000 m² of units or part thereof. A batch with units for area(s) less than 1000 m² may be added to the untested previous or following batch(es) as the case may be for testing purposes. The number of specimens in each sample shall be 10. The sample can be used for other tests.

(2) Each sample of paving slabs and blocks shall be tested to determine the 24-hour cold water absorption value to AS/NZS 4456.14.

(3) The sample shall have a characteristic water absorption value not more than 6% by 24-hour cold immersion method to AS/NZS 4456.14.

(4) The characteristic water absorption value (W_c) shall be calculated from the following equation:

$$W_c = W_m + 1.65 X_s \%$$

where:

- W_m is the average water absorption rate of the sample
 - X_s is the unbiased standard deviation as stated in AS/NZS 4456.2.
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APPENDIX 11.1

DETERMINATION OF CHARACTERISTIC COMPRESSIVE STRENGTH OF PAVING BLOCKS

- Scope* 11.1.1 This method covers the determination of the characteristic compressive strength at 28 days of paving blocks by means of a load test.
- Apparatus* 11.1.2 The following apparatus is required:
- (a) A compression test machine complying with CS1. Bearing faces of the platens on the test machine shall be at least as large as the paving blocks and shall have a flatness tolerance of 0.05 mm.
 - (b) If a test machine with platens smaller than the paving blocks is used, auxiliary plates of adequate size shall be placed centrally between the platens and the paving block to be tested. The flatness tolerance of the bearing faces of the auxiliary platens measured in accordance with CS1 shall not be more than 0.05 mm and the thickness of the plates shall be at least 25 mm.
 - (c) Two pieces of packing, each with a thickness of between 5 mm and 6 mm and dimensions exceeding the paving block by between 15 mm and 25 mm. The packing shall be plywood, chipboard or medium density hardboard.
- Procedure* 11.1.3 The procedure shall be as follows:
- (a) The paving block shall be capped on the running surface and underside with a suitable capping material in accordance with Clause 15.5.2 of CS1 and immersed in water for at least 24 hours before compression.
 - (b) The paving block shall be placed symmetrically on the lower platen of the test machine, between the two pieces of packing with the running surface facing upwards.
 - (c) Load shall be applied without shock and shall be steadily increased at a constant rate within a stress range of between 150 kPa/s and 700 kPa/s.
 - (d) The load at which the paving block fractures shall be recorded as the breaking load.
 - (e) The test shall be repeated for the other seven paving blocks.

Calculation

- 11.1.4 (1) The compressive strength (C) of each paving block shall be calculated from the equation:

$$C = \frac{W}{A} \times \frac{2.5}{1.5 + \frac{L}{H}} \quad \text{MPa}$$

where:

- W is the breaking load (N)
- A is the nominal gross plan area based on the manufacturing dimensions of the paving blocks or the area of the tested portion if the block size is reduced for testing (mm²)
- L is the lesser of the two plan dimensions (mm)
- H is the thickness of the block (mm)

- (2) The unbiased standard deviation (s) shall be calculated from the following equation:

$$s = \sqrt{\frac{\sum C^2 - n(Cm)^2}{n-1}} \quad \text{MPa}$$

- where:
- n is the number of paving blocks
- $\sum C^2$ is the sum of the square of the compressive strengths of the n number of paving blocks (MPa)
- Cm is the average of the compressive strengths of the n number of paving blocks

- (3) The characteristic strength (Cc) of the batch shall be calculated from the following equation:

$$Cc = Cm - 1.65s \quad \text{MPa}$$

where:

- Cm is the average of the compressive strengths of the n number of paving blocks as stated in Clause 11.1.4(2)
- s is the unbiased standard deviation as stated in Clause 11.1.4(2)

Reporting of results

- 11.1.5 The following shall be reported:

- (a) Source, name of manufacturer and type of paving blocks.
- (b) Identification marks of paving blocks.
- (c) Date of manufacture of paving blocks.

- (d) Nominal gross plan area of each block to the nearest 100 mm².
 - (e) Nominal height of each block to the nearest mm.
 - (f) Breaking load of each block to the nearest kN.
 - (g) Compressive strength of each block to the nearest MPa.
 - (h) Average of the n number of compressive strengths to the nearest MPa.
 - (i) Unbiased standard deviation to the nearest MPa.
 - (j) Characteristic compressive strength to the nearest MPa.
 - (k) That the test method used was in accordance with this Specification.
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