# 6 CONCRETE ROAD PAVEMENTS

## 6.1 GENERAL REQUIREMENTS

### 6.1.1 Scope

1 This part of the specification covers the; materials, mix designs, production and laying of pavement quality concrete, lean mix concrete and cement bound materials.

2 Related Sections and Parts are:

This Section
Part 3..... Earthworks
Part 4..... Unbound Pavement Materials
Part 5..... Asphalt Works

Section 5 - Concrete
Part 16 ..... Miscellaneous - Pavement Quality Concrete

### 6.1.2 References

1 The following standards are referred to in this part of the specification

BS 1377: Part 9.....Methods of testing soils – in-situ tests
BS 1881 .....Methods of testing concrete -
BS 1924: Part 1 & 2 ...Stabilised materials for civil engineering purposes
BS 2499 & EN 14188..Hot applied joint sealants for road pavements
BS 2752 .....Chloroprene rubber compounds
BS 3900: Part F12.....Determination of resistance to neutral salt spray
BS 3963 .....Method for testing the performance of concrete mixers
ISO 11600 .....Two part polysulphide sealants
BS 4449 .....Reinforcing bars
BS 4482 .....Cold drawn steel wire for reinforcing concrete
BS 4483 .....Reinforcing mesh
BS 5212: Part 1 & 2 ...Cold applied joint sealants for concrete pavements
EN 206 & BS 8500 .....Supply of concrete
BS 7542 .....Methods for test of curing compounds for concrete
BS 812.....Testing methods for aggregates

ASTM D3406.....Specification for joint sealant - hot applied elastomeric types
ASTM 7116 .....Specification for joint sealant - hot applied elastomeric types (jet fuel resistant)
ASTM D2628.....Specification for preformed joint seals

DTP .....Manual of contract documents for highway works -Volume 1 specification for highway works

### 6.1.3 Quality Control of Concrete Strength

1 Sampling and testing for, and compliance with the specified characteristics strength of designed mixes shall be in accordance with EN 206 & BS 8500, except that it shall be at the following rates of sampling and testing and meet the following requirements:

(a) Concrete cubes of the appropriate size shall be made, cured and tested in accordance with BS 1881 respectively from concrete delivered to the paving plant, each group being from a different delivery of concrete. At least 3 cubes shall be made per group for each 600 $m^2$ of concrete slab and not less than 6 groups shall be made each day, for each type of mix. For areas less than 600 $m^2$, at least 4 cubes shall be made for each 100 $m^2$ or less. This rate of sampling and testing may be reduced at the Engineer's discretion.

(b) For areas of 600 $m^2$ or more, one cube shall be tested in compression at 7 days and the other two at 28 days after mixing. Groups of four consecutive results at 28 days shall be used for assessing the strength for compliance with EN 206 & BS 8500. For areas less than 600 $m^2$, two cubes shall be tested at 7 days and two tested at 28 days and assessed in accordance with EN 206 & BS 8500.

(c) The ratio R between 7 and 28 day strengths shall be established for the mix to be used in the slab by testing pairs of cubes at each age on at least six batches of the proposed mix or it shall be quoted by the supplier of the concrete. The average strength of the 7 day pair of cubes shall be divided by the average strength of the 28-day pair of cubes for each batch and the ratio R shall be the average of these six values. The ratio R shall be expressed to three decimal places.

(d) If during the construction of the trial length or during normal working, the average value of any 4 consecutive 7 day test results falls below the strengths required then the cement content of the concrete shall be increased by 5 % by mass or by an amount agreed by the Engineer. The increased cement content shall be maintained at least until the four corresponding 28-day tests have been assessed. If the cement content is increased, the concrete mix shall be adjusted to maintain the required workability.

(e) The values in columns 3 and 4 of Table 6.1 may only be used with the permission of the Engineer when sufficient test results on trial mixes for calculating the ratio are not available. Once sufficient results are available from normal working the ratio R shall be calculated from the results available on Site.

(f) To assess the time for use of a concrete slab by traffic, the strength development rate may be predetermined by trial mixes. Alternatively pairs of cubes shall be made for each 600 $m^2$ or less and stored alongside the pavement in containers or in such a way that their sides are well insulated. If thermal insulation is used for accelerated curing the cubes shall be similarly insulated. Pairs of cubes shall be tested at intervals decided by the Engineer. Tests for compliance with the specified strength shall be made in the normal way.

Table 6.1
7 Day Cube Strength

| Grade of Concrete | All Mixes, R available | PC Mixes, R not available | PFA or ggbs mixes, R not available N/mm$^2$ |
|---|---|---|---|
| C40 | 43R | 35 | 29 |
| C30 | 33R | 27 | 22 |
| C20 | 22R | 18 | 14 |
| C15 | 17R | 13 | 11 |
| C10 | 10R | 8 | 7 |
| C7.5 | 7R | 5.5 | 4.5 |

## 6.2 TRIAL LENGTH

### 6.2.1 General Requirements for Trial Length

1 Except in rapid construction projects, at least one month prior to the construction of the trial length of surface slabs or CRCR (Continuously Reinforced Concrete Road Base) the Contractor shall submit for the Engineer's approval a detailed description of the proposed materials, mix proportions, plant, equipment and construction methods.

2 No trials of new materials, plants, equipment or construction methods; nor any development of them shall be permitted either during the construction of the trial length or in any subsequent paving work, unless they form part of further approved trials.

3 The Contractor shall demonstrate the materials, mix proportions, plant, equipment and method of construction that are proposed for concrete paving, by first constructing a trial length of slab, at least 150m but not more than 300 m, long for mechanised construction, and at least 30m long for hand guided methods, or otherwise as directed by the Engineer.

4 The mix proportions decided by trial mixes may be adjusted during the trial but shall not be changed once the trial length has been approved except with the agreement of the Engineer.

5 The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of half the proposed trial lengths constructed each day. The trial length shall be constructed at a similar rate to that which is proposed for the main construction in the permanent works.

6 At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs and jointed reinforced concrete slabs in the main construction in the permanent works shall be constructed and assessed in the trial length.

7 If in the trial length expansion joints are not demonstrated, the first 2 expansion joints and at least the first 150 m of longitudinal construction joint for mechanised paving, or 30 m for hand guided method of construction laid in the main construction in the permanent works, shall be considered the trial length for these joints.

8 One construction joint shall be demonstrated in each trial length of CRCP or CRCR.

### 6.2.2 Assessment of Trial Length

1 The trial length shall comply with the Specification in all respects, with the following additions and exceptions provided in (a) through (d) below.

(a) Surface Levels and irregularity

(i) in checking for compliance the levels shall be taken at intervals of not more than 2.5 m along any line or lines parallel to the longitudinal centre line of the trial length.

(ii) The maximum number of permitted irregularities of pavement surfaces shall comply with the requirements for asphalt pavements as per Part 5 for 300 m lengths. Shorter trial lengths shall be assessed pro-rata based on values for a 300 m length.

(b) Joints

(i) At least 3 cores of minimum diameter 100 mm shall be taken from the slab at joints to check the lateral and vertical location of joint grooves and bottom crack inducers.

(ii) After a minimum of 24 hours following construction the removable part of the joint groove former shall be taken out and at least three joints and the sides of the groove shall be inspected for compaction. If there are voids the size and number should be compared with a similar size section of the photograph for 3% excess voidage in BS 1881. If there is excess voidage, additional compaction shall be provided and further joints inspected. The joints so exposed shall be temporarily or permanently sealed

(iii) Alignment of dowel bars shall be inspected in any two consecutive transverse joints. If the position or alignment of the dowel bars at one of these joints does not comply after the next 3 consecutive joints of the same type have been inspected then the method of placing dowels shall be deemed to be satisfactory.

(iv) If there are deficiencies in the first expansion joint constructed as a trial, the next expansion joint shall be a trial joint. Should this also be deficient further trial expansion joints shall be made as part of a trial length which shall not form part of the Permanent Works, unless agreed by the Engineer.

(c) Density

(i) Density shall be assessed from at least 3 cores drilled from each part of the trial length.

(d) Position of Reinforcement and Tie Bars

(i) Compliance for the position of steel reinforcement and for the position and alignment of tie bars shall be checked by drilling additional cores from the slab unless they can be determined from cores taken for density assessment.

### 6.2.3 Approval and Acceptance of Trial Length

1 Approval of the materials, mix proportions, plant, equipment and construction methods will be given when a trial length complies with the specifications. The Contractor shall not proceed with normal working until the trial length has been approved and any earlier defective trial lengths have been removed, unless they can be remedied to the satisfaction of the Engineer.

2 When approval has been given, the materials, mix proportions, plant, equipment and construction methods shall not thereafter be changed, without the approval of the Engineer except for maintenance of plant. Any changes in materials, mix proportions, plant, equipment, and construction methods shall entitle the Engineer to require the Contractor to lay a further trial length as described in this Clause to demonstrate that these changes will not adversely affect the permanent works.

3 Trial lengths which do not comply with the Specification, with the exception of areas within the pavement surface which can be remedied shall be removed immediately upon notification of deficiencies by the Engineer and the Contractor shall construct a further trial length.

## 6.3 REQUIREMENTS FOR PAVEMENT QUALITY CONCRETE

### 6.3.1 Materials and Mix Designs for Pavement Quality Concrete

1 The constituent materials and mix designs for pavement quality control shall be as per Section 5: Part 16.

### 6.3.2 Workability of Pavement Quality Concrete

1 The workability of the concrete at the point of placing shall enable the concrete to be fully compacted and finished without undue flow. The optimum workability for the mix to suit the paving plant being used shall be determined by the Contractor and approved by the Engineer.

2 The workability shall be determined by the compacting factor test, or the Vebe test or alternatively for concrete grade C20 or below, by the slump test, all in accordance with BS 1881, at the minimum rate of one determination per 300 m2 of slab laid or 6 times per day, whichever is greater. For areas less than 300 m2 the rate shall be at least one determination to each 20 m length of slab or at least 3 times per day.

3 Alternatively the volumetric method of determining the Compacting Factor in BS 1881 may be used. Tests for workability shall be carried out at the point of placing, in conjunction with tests for strength and any tests for air content. The workability shall be maintained at the optimum within the following tolerances.

| | |
|---|---|
| Compacting Factor (CF) | +0.03 |
| Slump | +20mm |
| Vebe | +3 seconds or as agreed by the Engineer as a results of trial mixes. |

4 Any alteration to the optimum workability necessitated by a change in conditions shall be agreed beforehand by the Engineer.

5 If any determination of workability gives result outside the tolerance, a further test shall be made immediately on the next available load of concrete. The average of the two consecutive results and the difference between them shall be calculated. If the average is not within the tolerance or the difference is greater than 0.06 for CF or 20 mm for slump, or 6 seconds for Vebe or other value agreed with the Engineer, subsequent samples shall be taken from the delivery vehicles, which shall not be allowed to discharge into the Works until compliance with the Specification has been established.

### 6.3.3 Trial Mixes

1 For concrete grades C15 and above the Contractor shall carry out laboratory trials of designed mixes with the materials from all sources to be used in the Works, in accordance with EN 206 & BS 8500 unless recent data relating entirely to the proposed mix is approved by the Engineer.

2 The trial mixes shall be repeated if necessary until the proportions of ingredients are determined which will produce a concrete which complies in all respects with the Specification.

3 Apart from minor adjustments to the mix as permitted by EN 206 & BS 8500 any changes in sources of materials or mix proportions that are proposed by the Contractor during the course of the Works shall be assessed by making laboratory trial mixes and the construction of a further trial length unless otherwise approval is given by the Engineer.

### 6.3.4 Separation Membrane

1 A separation membrane shall be used between jointed reinforced concrete surface slabs or unreinforced concrete surface slabs and the sub base.

2 Separation membranes shall be impermeable plastic sheeting 125 microns thick laid flat without creases. Where an overlap of plastic sheets is necessary, this shall be at least 300 mm. There shall be no standing water on or under the membrane when the concrete is placed upon it.

3 Under CRCP and CRCR a waterproof membrane shall be provided, which shall be a bituminous spray before concreting. Where a bituminous spray has been used to cure cement bound material or wet lean concrete then only those areas which have been damaged shall be resprayed after making good. The waterproof membrane shall be bituminous cutback in accordance with clause 5.12 of this Section.

### 6.3.5 General Requirements for Steel Reinforcement

1 Reinforcement shall comply with any of the following standards and be in prefabricated sheets or cages, or bars assembled on site and shall be free from oil, dirt, loose rust and scale:

(a) (Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification) BS 4449

(b) (Cold-reduced steel wire for the reinforcement of concrete) BS 4482

(c) (Steel fabric for the reinforcement of concrete) BS 4483

(d) When deformed bars are used they shall conform to Type 2 bond classification of BS 4449.

2 Spacing of bars shall not be less than twice the maximum size of aggregate used. Laps in longitudinal bars shall be not less than 35 times bar diameters or 450 mm which ever is greater.

In continuously reinforced concrete slabs (CRCP or CRCR) only one third of the laps may be in any one transverse section, except in single bay width construction where half the laps may be in any one transverse section. There shall be a minimum of 1.2 m longitudinally between groups of transverse laps or laps in prefabricated reinforcement sheets. Alternatively the reinforcement may be butt welded by a process approved by the Engineer.

3 Laps in a transverse reinforcement shall be a minimum of 300 mm. Where prefabricated reinforcement sheets are used and longitudinal and transverse laps would coincide, no lap is required in the transverse bars within the lap of the longitudinal reinforcement. These transverse bars may be cropped or fabricated shorter so that the requirements for cover are met.

4 If the reinforcement is positioned prior to concreting, it shall be fixed on approved metal supports and retained in position at the required depth below the finished surface and distance from the edge of the slab so as to ensure that the required cover is achieved. Reinforcement assembled on site shall be tied, or firmly fixed, by a procedure agreed with the Engineer, at sufficient intersections to provide sufficient rigidity to ensure that the reinforcement remains in the correct position during construction of the slab.

5 Alternatively, when a reinforced concrete slab (JRC, CRCP or CRCR) is constructed in two layers, the reinforcement in the form of prefabricated sheets may be placed on or into the bottom layer which shall be spread and compacted to such a level that it will support the reinforcement without distortion at the required position in the slab. The sheets shall be tied together at overlaps and after the second layer has been spread and compacted, the reinforcement shall have the required cover.

6 When a reinforced concrete slab is constructed at maximum width the transverse reinforcement in the centre of each slab width shall be a minimum of 12 mm nominal diameter bars at 600 mm centres. This reinforcement shall be at least 600 mm longer than one third of the width of the slab and be lapped to other transverse reinforcement bars or sheets, or be continuous across the whole width of each slab.

### 6.3.6 Jointed Reinforced Concrete Slabs

1 The reinforcement shall be so placed that after compaction of the concrete, the cover below the finished surface of the slab is 50 + 10 mm for slabs less than 200 mm thick, 60 + 10 mm for slabs 200 mm or more but less than 270 mm thick and 70+20 mm for slabs 270 mm thick or more.

2 The negative vertical tolerance shall not be permitted beneath road stud recesses.

3 Where traffic signal detector loops are to be installed, the minimum cover to the reinforcement from the surface shall be 100 mm.

4 The vertical cover between any longitudinal joint groove forming strip and any reinforcement or tie bars shall be at a minimum of 30 mm.

5 Any transverse bars shall be at right angles to the longitudinal axis of the carriageway. Any transverse reinforcement shall terminate at 125+25 mm from the edges of the slab and longitudinal joints, where tie bars are used.

6 No longitudinal bars shall lie within 100 mm of a longitudinal joint. The reinforcement shall terminate 300 mm + 50 mm from any transverse joint, excluding emergency construction joints.

### 6.3.7 Continuously Reinforced Concrete Slabs (CRCP or CRCR)

1 The reinforcement shall be Grade 460 deformed steel bars as detailed on the Contract Drawings.

2 The reinforcement shall consists of bars assembled on site, or of prefabricated sheets.

3 Except where otherwise shown on the Drawings the longitudinal bars shall be parallel to the centre line of the road.

4 The reinforcement shall be positioned so that, after compaction of the concrete, it shall be at the mid depth of the specified thickness of the slab + 25 mm. No longitudinal bar shall lie within 100mm of a longitudinal joint.

5 In reinforcement assembled on site, longitudinal bars shall be placed immediately above any transverse bars, which shall be at right angles to the longitudinal axis of the carriageway. Any transverse reinforcement shall terminate 125+25 mm from the edges of the slab and longitudinal joints where tie bars are used.

### 6.3.8 General Requirements for Transverse Joints

1 Transverse joints shall be provided in unreinforced and jointed reinforced concrete slabs and shall be contraction, expansion or warping joints at the spacing shown on the Drawings such that for unreinforced concrete slabs the length/width ratio shall be not greater than 2.0.

2 Joints in the surface slab and sub-base shall be staggered so that they are not coincident vertically and are at least 1m apart.

3 Transverse joints shall be straight within the following tolerances along the intended line of the joint, which is the straight line transverse to the longitudinal axis of the carriageway at the position proposed by the Contractor and agreed by the Engineer, except at road junctions or roundabouts where the positions shall be as shown on the Drawings:

(a) Deviations of the filler board or bottom crack inducer from the intended line of the joint shall be not greater than ± 10 mm.

(b) The best fit straight line through the joint groove as constructed shall be not more than 25 mm from the intended line of the joint.

(c) Deviations of the joint groove from the best fit straight line of the joint shall be not greater than 10 mm.

(d) When top groove formers and bottom crack inducers are used, the joint groove as constructed shall be located vertically above the bottom crack inducer within a horizontal tolerance of ± 25 mm.

4 Transverse joints on each side of a longitudinal joint shall be in line with each other and of the same type and width. The position of the joints relative to manholes and gullies shall be in accordance with the Drawings.

5 Transverse joints shall have a sealing groove which shall be sealed in compliance with Clause 6.3.20 of the specification.

### 6.3.9 Transverse Contraction Joints

1 Contraction joints shall consist of:

(a) Either a sawn joint groove, or

(b) a wet formed joint groove and a bottom crack inducer

(c) dowel bars

(d) a sealing groove.

### 6.3.10 Transverse Expansion Joints

1 Expansion joints shall consist of:

(a) a joint filler board

(b) dowel bars

(c) a sealing groove.

2 The filler board shall be positioned vertically within the prefabricated joint assemblies along the line of the joint and at such depth below the surface as will not impede the passage of the finishing beams on the paving machines.

3 The joint filler board together with the sealing groove shall provide a complete separation of adjacent slabs and any spaces around dowel bars and between the sub-base and the filler board shall be packed with a suitable compressible material after fixing the joint assembly.

### 6.3.11 Transverse Warping Joints

1 Warping joints shall consist of:

(a) Either a sawn joint groove, or

(b) a wet formed joint groove and a bottom crack inducer

(c) tie bars

(d) a sealing groove.

### 6.3.12 Transverse Construction Joints

1 Construction joints made at the end of a working day in unreinforced concrete slabs and jointed reinforced concrete slabs shall be expansion joints or contraction joints. In the event of mechanical breakdown of the concreting machinery, or at the onset of adverse weather, emergency joints may be formed.

2 Emergency joints in unreinforced concrete slabs shall be either contraction or expansion joints not less than 2.5 m from the preceding or succeeding joint position.

3 Emergency joints in jointed reinforced concrete slabs shall be not less than 2.5 m from the preceding or succeeding joint position. The stop end formwork shall be sufficiently rigid to ensure that dowel bars, tie bars or reinforcement will be held in position in compliance with the specification, and placed in such a position that it permits the longitudinal reinforcement to project through the joint for a distance of at least 750 mm.

4 Construction joints in continuously reinforced concrete slabs (CRCP and CRCR) in an emergency shall not be constructed within 1.5 m of any lap in the longitudinal reinforcement without the approval of the Engineer. The stop end formwork shall be sufficiently rigid to ensure that the longitudinal reinforcement and the tie bars projecting through the joint are held in the correct position.

### 6.3.13 General Requirements for Longitudinal Joints

1 Longitudinal joints shall be provided in surface slabs between or at the centre of traffic lanes within the allowable positions as shown on the Drawings, so that bay widths are not greater than 4.2 m (or 5.0 m with limestone aggregate) for unreinforced slabs, or 6 m (or 7.6 m with limestone aggregate) for reinforced concrete surface slabs with transverse reinforcement.

2 Longitudinal joints shall be provided in CRCR between lanes or at the centre of lanes, within a tolerance of +150 mm so that bay widths are not greater than 6 m (or 7.6 m with limestone aggregate).

3 Joints in the surface slab, road base or sub-base shall be staggered so that they are not coincident vertically and are least 300 mm apart. The positions of all longitudinal joints in any slab shall be agreed by the Engineer prior to construction of the slab.

4 Wet-formed longitudinal joints shall consists of wet-formed joint grooves, bottom crack inducer and tie bars except where transverse reinforcement is permitted in lieu.

5 Longitudinal joints shall be constructed in the positions agreed by the Engineer within the following tolerances:

(a) Deviations of the bottom crack inducer from the intended line of the joint parallel to the axis of the road shall not be greater than +13 m.

(b) The joint groove shall be located vertically above the bottom crack inducers within a horizontal tolerances of +25 mm.

(c) The best fit line along the constructed joint groove, shall be not more than 25 mm from the intended line of the joint.

(d) Deviations of the joint groove from the best fit line of the joint shall be not greater than 10 mm.

6 Tie bars may be replaced by continuous transverse reinforcement across the joints in continuously reinforced concrete slabs, which are constructed in more than one lane width in one operation, provided that the transverse reinforcement is a minimum of 12 mm diameter bars at 600 mm centres.

### 6.3.14 Longitudinal Construction Joints

1 Longitudinal construction joints between separate slabs shall have tie bars with a joint groove. Alternatively, if split forms are used, the transverse reinforcement, if 12 mm diameter or more, may be continued across the joint for a minimum of 500 mm or 30 times the diameter of the transverse reinforcement bars, whichever is greater.

2 A joint sealing groove is not required in construction joints in continuously reinforced concrete road bases. Where the edge of the concrete slab is damaged it shall be made good to the approval of the Engineer before the adjacent slab is constructed.

### 6.3.15 Dowel Bars

1 Dowel bars shall be Grade 250 steel complying with BS 4449 and shall be free from oil, dirt, loose rust and scale. They shall be straight, free of burrs and other irregularities and the sliding ends sawn or, if approved by the Engineer, cropped cleanly with no protrusions outside the normal diameter of the bar. For expansion joints, dowel bars shall be 25mm diameter at 300 mm spacing, 600 mm long for slabs up to 239 mm thick and 32 mm diameter for slabs 240 mm thick or more. For contraction joints, dowels shall be 20 mm diameter at 300 mm spacing 400 mm long for slabs up to 239 mm thick and 25 mm diameter for slabs 240 mm thick or more.

2 Dowel bars shall be supported on cradles in prefabricated joint assemblies positioned prior to construction of the slab. For contraction joints, as an alternative to prefabricated assemblies, dowel bars may be mechanically inserted with vibration into the concrete by a method which shall ensure full recompaction of the concrete around the dowel bars and the surface finished by a diagonal finishing beam. Or a longitudinal oscillating float travelling across the slab.

3 Dowel bars shall be positioned at mid-depth from the surface level of the slab ± 20 mm. They shall be aligned parallel to the finished surface of the slab, to the centre line of the carriageway and to each other within the following tolerances:

(a) for bars supported on cradles prior to construction of the slab and for inserted bars in two layers construction prior to placing the top layer:

(i) All bars in a joint shall be within ± 3 mm per 300 mm length of bars.

(ii) Two thirds of the bars shall be within ± 2 mm per 300 mm length of bar.

(iii) No bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane.

(b) for all bars, after construction of the slab:

(i) Twice the tolerances for alignment as in (i) above.

(ii) Equally positioned about the intended line of the joint within a tolerance of ± 25 mm.

4 Cradles supporting dowel bars shall not extend across the line of the joint.

5 Dowel bars, supported on cradles in assemblies, when subjected to a load of 110N applied at either end and in either the vertical or horizontal direction (upwards and downwards and both directions horizontally) shall not deflect more than the following limits:

6 Two thirds of the number of bars of any assembly tested shall not deflect more than 2 mm per 300 mm length of bar.

7 The remainder of the bars in that assembly shall not deflect more than 3 mm per 300 mm length of bar.

8 The assembly of dowel bars and supporting cradles, including the joint filler board in the case of expansion joints shall have the following degree of rigidity when fixed in position:

9 For expansion joints the deflection of the top edge of the filler board shall be not greater than 13 mm, when a load of 1.3 kN is applied perpendicular to the vertical face of the joint filler board and distributed over a length of 600 mm by means of a bar or timber packing at mid depth and midway between individual fixings, or 300 mm from either end of any length of filler board, if a continuous fixing is used. The residual deflection after removal of the load shall be not more than 3 mm.

10 The joint assembly fixings to the sub-base shall not fail under the 1.3kN load applied for testing the rigidity of the assembly but shall fail before the load reaches 2.6 kN.

11 The fixings for contraction joints shall not fail under a 1.3 kN load and shall fail before the load reaches 2.6 kN when applied over a length of 600 mm by means of a bar or timber packing placed as near to the level of the line of fixings as practicable.

12 Failure of the fixings shall be deemed to be when there is displacement of the assemblies by more than 3 mm with any form of fixing, under the test load. The displacement shall be measured at the nearest part of the assembly to the centre of the bar or timber packing.

13 Dowel bars shall be covered by a thin plastic sheath over the whole length of the bar. The sheath shall be tough, durable and of an average thickness not greater than 1.25 mm. The sheathed bar shall comply with the following pull out test:

14 Four bars shall be taken at random from stock and without any special preparation shall be covered by sheaths. The dowel bars which have been sheathed shall be cast centrally into concrete specimens 150x150x450 mm, made of the same mix proportions to be used in the pavement, but with a maximum nominal aggregate size of 20 mm and cured in accordance with BS 1881. At 7 days a tensile load shall be applied to achieve a movement of the bar at least 0.25 mm. The average bond stress to achieve this movement shall be not greater than 0.14 N/mm2.

15 For expansion joints a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material shall be placed over one end of each dowel bar. An expansion space 10 mm greater than the thickness of the joint filler board shall be formed between the end of the cap and the end of the dowel bar.

16 Tie Bars

17 Tie bars in transverse or longitudinal joints shall be Grade 250 steel or Grade 460 deformed steel bars complying with BS 4449, in accordance with the requirements given below and Table 6.2. Deformed bars shall have Type 2 bond classification. Tie bars shall be free from oil, dirt, loose rust and scale. Tie bars which are to be cranked and later straightened shall be Grade 250.

18 Tie bars projecting across a longitudinal joint shall be protected from corrosion by a flexible polymeric corrosion resistant coating, bonded onto the previously cleaned centre section, leaving between 250 mm and 300 mm of each of the bars uncoated.

19 Where tie bars are cranked for construction joints and later straightened the coating shall be shown to be capable of being straightened through 90 degrees without cracking. The coating shall also be able to withstand 250 hours immersion in a salt fog cabinet complying with BS 3900 : Part F12, without showing any visible cracking, or corrosion of the protected part of the bar. Any damage observed on the coating after straightening shall be made good before the concrete is placed.

20 Tie bars in warping joints and wet-formed longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab.

21 Alternatively, tie bars at longitudinal joints may be mechanically inserted by vibration from above using a method which ensures recompaction of the concrete around the tie bars.

22 At longitudinal construction joints, tie bars may be adequately fixed to side forms or inserted into the side of the slab by a method which ensures recompaction of the concrete around the tie bars and adequate bond and which shall be approved by the Engineer.

23 Tie bars shall be positioned and remain within the middle third of the slab depth, approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of ± 50 mm, and with a minimum cover of 30 mm below any top crack inducer or joint groove for slabs 200 mm thick or more, or 20 mm for slabs up to 200 mm thick.

24 At transverse construction joints in continuously reinforced concrete, tie bars shall be 1.5 m long and of the same grade and size as the longitudinal reinforcement, and shall be fixed at twice the normal spacing midway between the longitudinal reinforcement bars so that 750 mm ± 50 mm extends each side of the joint at the same level as the longitudinal reinforcement and be tied to the transverse reinforcement. Where paving from a construction joint is not resumed within 5 days, and extra longitudinal reinforcement bar at 8 m long shall be lapped and tied to each tie bar. These extra bars may be combined with the tie bars. Where the spacing between longitudinal reinforcement and the extra 8 m long bars is less than 90 mm, the nominal size of aggregate shall be 20 mm for a sufficient number of concrete batches to complete that section of pavement.

25 Where tie bars are used in longitudinal joints in continuously reinforced concrete they shall be placed at the same level as the transverse reinforcement and tied to the longitudinal reinforcement.

Table 6.2
Tie Bar Details

| Joints | Diameter (mm) | Grade of Steel | Length (mm) | Spacing (mm) |
|---|---|---|---|---|
| Transverse construction joints in continuously reinforced concrete | As for main reinforcement | 460 | 1500 | Twice the spacing of main reinforcement |
| Emergency construction joints in jointed reinforced concrete slabs other than at contraction or expansion joints | 12 | 250 or<br>460 deformed | 1000<br>750 | 600<br>600 |
| Warping joints | 12 | 250 or<br>460 deformed | 1000<br>750 | 300<br>600 |
| Longitudinal.<br>All joints, except where transverse reinforcement is permitted in lieu | 12 | 250 or<br>460 deformed | 1000<br>750 | 600<br>600 |

Note: The transverse reinforcement may be continued across the joint in reinforced concrete with the approval of the Engineer if the bars are of a minimum nominal diameter of 12 mm and the bars are protected from corrosion and the cover is as required in this Clause.



### 6.3.16 Joint Grooves

1 Transverse contraction or warping joint grooves shall be sawn in the hardened concrete.

2 Transverse joint grooves which are initially constructed less than the full width of the slab shall be completed by sawing through to the edge of the slab and across longitudinal joints as soon as any forms have been removed and before an induced crack develops at the joint.

3 Sawn transverse joint grooves shall be undertaken as soon as possible after the concrete has hardened sufficiently to enable a sharp edged groove to be produced without disrupting the concrete and before random cracks develop in the slab. The grooves shall be between 1/4 and 1/3 of the specified depth of the slab and of any convenient width not less than 3mm. The sealing groove may be constructed at the same time to be sawn to the required width later. Unless otherwise approved by the Engineer, expansion joint sealing grooves shall be sawn immediately before sealing.

4 Construction Joint Grooves in Surface Slabs shall be formed by fixing a groove-former, strip or cork seal along the top edge of the slab already constructed, before concreting the adjacent slab. Where the edge of the concrete is damaged it shall be ground or made good to the approval of the Engineer before fixing the groove forming strip.

5 Alternatively the subsequent slab may be placed adjacent to the first and a sealing groove sawn later in the hardened concrete to the minimum depth required in Table 6.3 or to the manufacturer's instructions if greater, and to sufficient width to eliminate minor spalling of the joint arris, up to a maximum of 25mm for longitudinal joints and 40mm for transverse joints. The joints shall be sealed.

### 6.3.17 Groove Formers and Bottom Crack Inducers

1 Except where joint grooves are sawn, a bottom crack inducer shall be provided at each contraction, warping or longitudinal joint position.

2 The bottom crack inducer shall be an approved triangular or inverted Y-shaped fillet, with a base width not less than the height, made of timber or rigid synthetic material. It shall be firmly fixed to the sub-base so as to remain in position during the whole process of constructing the slab.

3 The combined depth of groove formers and bottom crack inducers shall be between 1/4 and 1/3 of the depth of the slab and the difference between the depth of the groove former and the height of the bottom crack inducer shall not be greater than 20mm.

4 The groove former for wet formed transverse joint grooves shall be made of an approved rigid material of a width not greater than the required width of sealing groove as in Table 6.3. The groove former shall be smooth sides with rounded protrusions no greater than 3mm. Any removable part of the groove former may be tapered with a maximum difference in width of 2mm in 20mm depth.

5 Groove forming sealing strips for wet formed longitudinal joints shall be of firm compressible strips of ethylene vinyl acetate foam of a minimum density of 90kg/m3, or synthetic rubber, or equivalent material subject to approval by the Engineer. They shall have a minimum thickness of 5mm and shall be sufficiently rigid to remain vertical and straight in the concrete without curving or stretching. They shall be inserted continuously along the joint.

6 For CRCP Universal Beam Anchorage Transverse Joints one side of the beam shall be separated from the CRCP slab by an expansion joint filler board against the vertical face and ethylene vinyl acetate foam or similar compressible material, between 5 mm and 10mm thick, stuck under the top flange.

### 6.3.18 Joint Filler Board

1 Joint filler board for expansion joints and manhole and gully slab joint shall be 25mm thickness unless otherwise shown in the Drawings, within a tolerance of ± 1.5mm.

2 It shall be self expanding cork seal or a firm compressible material or a bonded combination of compressible and rigid materials of sufficient rigidity to resist deformation during the passage of the concrete paving plant.

3 The depth of the joint filler board for manhole and gully slabs shall be the full depth of the slab minus the depth of the sealing groove. In expansion joints, the filler board shall have a ridged top as shown on the Drawings, except where a sealing groove former is permitted by the Engineer.

4 Holes for dowel bars shall be accurately bored or punched out to form a sliding fit for the sheathed dowel bar.

### 6.3.19 Preparation and Sealing of Joint Grooves

1 All transverse joints in surface slabs, except for construction joints in CRCP shall be sealed using one of the joint seals described. Additionally longitudinal joints which are sawn or widened shall be sealed.

2 Joint grooves shall be prepared in accordance with BS 5212: Part 2 and in compliance with (a) through (g) below:

(a) that part of the groove former used to form the sealing groove or any temporary seal shall be removed cleanly without damaging the joint arises to a minimum depth of 25 mm where compression seals are used or otherwise to such depth as will provide an applied seal to the dimensions as will provide in Table 6.3.

(b) if joint grooves are not initially constructed to provide the minimum dimensions for the joint seals as given in Table 6.3, they shall be widened by sawing. Joint grooves formed by tapered formers need not to be widened. The sealing grooves shall be cleaned out immediately after sawing using high pressure water jets, to remove all slurry from the joint, before the slurry hardens.

(c) if rough arrises develop when grooves are made they shall be ground to provide a chamfer approximately 5mm wide. If the groove is at an angle up to 10 degrees from the perpendicular to the surface, the overhanging edge of the sealing groove shall be sawn or ground perpendicular. If spalling occurs or the angle of the former is greater than 10 degrees the joint sealing groove shall be sawn wider and perpendicular to the surface to encompass the defects up to a maximum width, including any chamfer, of 40 mm for transverse joints and 25mm for longitudinal joints. If the spalling cannot be so eliminated then the arris shall be repaired by an approved thin bonded arris repair using cementitious materials.

(d) for applied sealants the sides of the joint sealing groove shall be scoured by dry abrasive blasting. This shall not be carried out before the characteristics compressive strength of the concrete is expected to reach 15 N/mm$^2$. When compression seals are used, the sides of the groove may be ground or wire brushed.

(e) for hot and cold applied sealants, compressible caulking material, debonding strip or tape or cord compatible with the sealant, of a suitable size to fill the width of the sealing groove shall be firmly packed or stuck in the bottom of the sealing groove to such a depth so as to provide the correct depth of seal as described in Table 6.3 with the top of the seal at the correct depth below the surface of the concrete.

(f) all grooves shall be cleaned of any dirt or loose material by air blasting with filtered, oil free compressed air. The groove shall be clean and dry at the time of priming and sealing.

(g) for applied sealants the joint grooves shall be primed with the relevant primer for the hot or cold applied sealant in accordance with the manufacturer's recommendations and with BS 5212: Part 2, except that when necessary the joint grooves may be primed and sealed earlier than 14 days after construction, as soon as the grooves have been grit-blasted and cleaned.

### 6.3.20 Sealing with Applied Sealants

1 Sealing shall be carried out continuously along the full length of joint in any one rip, except for remedial areas. When hot or cold applied sealants are used the sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied sealants shall not be carried out when the naturally occurring temperature in the joint groove to be sealed is below 10 °C except between 8 °C and 10 °C it may be carried out when the temperature is rising.

2 Hot applied sealants shall be heated in and applied from a thermostatically controlled, indirectly heated dispenser with the recirculating pump. The sealant shall not be heated to a temperature higher than the safe heating temperature nor for a period longer than the safe heating period, both as specified by the manufacturer. The dispenser shall be cleaned out at the end of each day and reheated materials shall not be used.

3 The components of cold-applied sealants shall be thoroughly mixed in the correct proportions in accordance with the manufacturer's instructions using an automatic metering and mixing dispenser approved by the Engineer or, for hand application, using a power operated paddle mixer for sufficient time to produce homogenous mix without entrapped air. As soon as possible after mixing and within the worklife of the sealant, the material shall be dispensed into the joint, or applied using a caulking gun, to the correct level below the concrete surface. The tack-free time shall be achieved within 3 hours, for machine dispensed material, or within 12 hours for hand applied material.

4 Test certificates shall be supplied from an approved testing laboratory stating that the sealant complies with the relevant standard. Site testing of cold applied sealants shall be in accordance with BS 5212: Part 2. Hot-applied sealants shall be sampled at the same rate and checked for dimensions as in BS 5212: Part 2 and by the penetration test of the relevant standard for the material.

Table 6.3
Dimensions of Applied Joint Seals

| Type and Spacing of Joints (m) | Minimum Width (mm) | Cold Applied (mm) | Hot Applied (mm) | Impregnated Foam Compression Strips (mm) | Depth of Seal Below the Concrete Surface(mm) |
|---|---|---|---|---|---|
| Contraction: | | | | | |
| 15 and under | 13 (Note 2) | 13 | 15 | 30 | 5+2 |
| Over 15 to 20 | 20 | 15 | 20 | 30 | 5+2 |
| Over 20 to 25 | 30 | 20 | 25 | 40 | 5+2 |
| Expansion All | 30 | 20 | 25 | 40 | 7+2 |
| Transverse Warping | 10 | 10 | 13 | 30 | 5+2 |
| Longitudinal Joints (if sealed) | 10 | 10 | 13 | 30 | 0 to 5 |
| Gully and Manhole Slabs | 20 | 15 | 20 | 30 | 0 to 3 |

Note: (1) The depth of seal is that part in contact with the vertical face of the joint groove. The depth of seal below the surface shall be taken at the centre of an applied seal relative to a short straight edge, 150mm long, placed centrally across the joint within 7 days of sealing.

Note: (2) For cork seals other than in construction joints, grooves shall be 20 mm wide and 50 mm deep.

### 6.3.21 Sealing with Compression Seals

1 When compression seals are used, the widths of the seal shall be selected in relation to the width of the sealing groove, the bay lengths and manufacturer's recommendations so that the estimated maximum width of the joint opening shall be not more than 70% of the original width of the seal, the estimated maximum width being calculated on the basis of a movement of 4mm per 10m run of slab.

2 The maximum calculated width of sealing groove shall be 30mm.

3 The depth of groove shall be such that the contact face of the seal with the side of the groove shall be not less than 20mm and that the top of the seal shall be a minimum of 3mm below the surface of the concrete.

4 Compression seals shall be inserted into the grooves without prior extension or rotation and, where recommended by the manufacturer, with a lubricant adhesive which is compatible with the seal and the concrete. The adhesive shall be applied to both sides of the sealing groove or the seal, or to both. The seal shall be positioned with its axis perpendicular to the concrete surface. Excess adhesive on top of the seal shall be removed to prevent adhesion of the top faces of the seal under compression.

5 Except when compression seals are used in longitudinal joints the transverse joint seal shall be continuous across the slab and the longitudinal joint groove forming strips shall be cut to the required depth after the concrete has hardened for the transverse seal to be inserted.

6 If compression seals are used in longitudinal joints where the grooves have been sawn after construction of the slab they shall be continuous across transverse joints, with the transverse seals butted and fixed to the longitudinal seals with adhesive.

**6.3.22 Joint Seals**

1 Joint seals shall consist of hot or cold applied sealants or compression seals or self expanding cork seals.

2 Hot-applied sealants shall comply with ASTM Standard D3406, or D7116 (for fuel-resistant sealant).

3 For joints between concrete surface slabs and bituminous surfacing, polymer modified bitumen sealing strips shall be used and applied in accordance with the manufacturer's instructions. Hot-applied sealants complying with BS 2499 & EN 14188 may be used for such joints and in joints in asphalt kerbs laid on concrete pavements.

4 Cold applied sealants shall be Type N complying with BS 5212: Part 1 except that Type F shall be used for lay-bys and hardstandings.

5 For joints in kerbs and joints other than in pavements, seals may be any of the pavement sealants if they have the suitable characteristics for the application. Also, gunning grade cold applied plasticised bituminous rubber sealant or gunning grades of two part polysulphid-based sealants complying with ISO 11600 may be used.

6 Alternatively, polyurethane-based sealing compounds may be used provided their performance is not inferior to ISO 11600 material.

7 Compression seals shall be pre-compressed neoprene impregnated expanding foam sealing strip, or rubber seals made of polychloroprene elastomers complying with BS 2752 and conforming to the requirements of ASTM Standard D2628.

8 Compression seals shall be shaped so that they will remain compressed at all times and shall have a minimum of 20mm contact face with the sides of the sealing groove. If lubricant adhesive is used, it shall be compatible with the seal and the concrete and shall be resistant to abrasion, oxidisation, fuels and salt.

9 Self Expanding Cork seals may be used in longitudinal joints, joints for manhole and gully slabs and for transverse joints in short lengths of individual slabs or for replaced slabs.

**6.3.23 Joints at Manhole and Gully Slabs**

1 Manhole covers, gullies and their frames shall be isolated from the pavement slabs and be contained in separate small slabs, which shall be larger than the exterior of the manhole and gully shafts, including any concrete surround less than 150mm below the underside of the sub-base layer. The joint around the manhole or gully slab shall be vertical and incorporate joint filler board but without dowel bars and tie bars.

2 Gully slabs in unreinforced concrete slabs shall be adjacent to or straddle a transverse joint, extending the gully slab as necessary to a maximum of 2m. Where this is impractical, an extra tied warping joint shall be provided adjacent to or within the gully slab and at least 2m from the next transverse joint. If the edge of an isolator slab is within 1m of any longitudinal joint the isolator slab shall be extended to that joint.

3 Manhole slabs in unreinforced concrete slabs shall be adjacent to or straddle transverse or longitudinal joints. If the manhole is within the middle third of the bay length a warping joint shall be constructed on one side of the manhole slab across the whole width of the bay to the nearest longitudinal joint.

4 Reinforcement as shown on the Drawings shall be placed in the main concrete slabs in the corners between the manhole and gully slab and the transverse or longitudinal joints. Extra reinforcement as described in the Contract shall be placed in reinforced concrete slabs around the manhole or gully slabs.

5 Manhole and gully slabs shall have oblique corners, minimum 200mm long, at approximately 45 degrees to the axis of the pavement at all corners which are not adjacent to a transverse or longitudinal joint in the main slab.

6 Reinforcement as shown on the Drawings shall be placed in the gully or manhole slab and concrete grade C40 shall be placed by hand in the space between the main slab and the manhole frame. The concrete shall be fully compacted and finished.

7 A sealing groove shall be made directly above the joint filler board and sealed.

### 6.3.24 Inspection of Dowel Bars

1 The position and alignment of dowel bars at contraction and expansion joints shall be checked by measurement relative to the side form or guide wires.

2 When the slab has been constructed, the position and alignment of dowel bars and any filler board shall be measured after carefully exposing them across the whole width of the slab. When the joint is an expansion joint the top of the filler board shall first be exposed sufficiently in the plastic concrete to permit measurement of any lateral or vertical displacement of the board. During the course of normal working these measurements shall be carried out at a rate of one joint per 1500m length of slab or one per 5 working days whichever occurs the sooner. For small areas the rate shall be decided by the Engineer.

3 If the position or alignment of the bars in a single joint in the slab is unsatisfactory then the next two joints shall be inspected. If only one joint of the three is defective, the rate of checking shall be increased to one joint per day until the Engineer is satisfied that compliance is being achieved. In the event of non-compliance in two or more successive joints, the Contractor shall revert to the construction of trial lengths and make any necessary alterations to the concrete mix, paving plant or methods until the dowel bar position and alignment is satisfactory.

4 After the dowel bars have been examined, the remainder of the concrete shall be removed 500mm on each side of the line of the joint, and reinstated to the satisfaction of the Engineer. Alternatively if the dowels are examined in the penultimate joint of a day's work that joint shall be made a construction joint for the next day's work and the remainder of the concrete in the last slab may be discarded.

### 6.3.25 Side Forms, Rails and Guide Wires

1 All side forms and rails shall be made of steel and be sufficiently robust and rigid to support the weight and pressure caused by the paving equipment. Side forms for use with wheeled paving machines shall incorporate metal rails firmly fixed at a constant height below the top of the forms.

2 The forms shall be secured by using not less than three pins for each 3m length having one pin fixed at each side of every joint. Forms shall be tightly joined together by a locked joint, free from play or movement in any direction. Forms shall be cleaned and oiled immediately before each use. The rails or running surface shall be kept clean in front of the wheels of any paving machine. The forms shall be straight within a tolerance of 3mm in 3m.

3 The forms shall be bedded on low moisture content cement mortar or concrete grade C7.5 and set to the pavement surface level as shown on the Drawings within a tolerance of +3mm. The bedding shall not extend under the slab. There shall be no vertical step between the end of adjacent forms greater than 3mm. The horizontal alignment for forms shall be to the required alignment of the pavement edge as shown on the Drawings within a tolerance of + 10mm. The mortar or concrete bedding shall be broken out after use.

4 Side forms shall not be removed earlier than 6 hours after the completion of the construction of the slab. Care shall be taken to prevent damage to the concrete and any projecting tie bars during the removal of the forms. If the removal of forms results in any damage to the concrete the period of 6 hours shall be increased to that which is necessary to avoid further damage and the Contractor shall make good the damaged areas.

5 Unless otherwise agreed by the Engineer, a guide wire shall be provided along each side of the slab to be constructed by slip form paving plant. Each guide wire shall be at a constant height above and parallel to the required edges of the slab as shown on the Drawings, within a vertical tolerance of + 3mm. Additionally one of the wires shall be at a constant horizontal distance from the required edge of the pavement as shown in the drawings within a lateral tolerance of + 10mm.

### 6.3.26 Delivery, Storage and Batching of Concreting Materials

1 Aggregate for roadworks shall be delivered to and stored on the Site in one of the following ways:

(a) in separate nominal single sizes of coarse aggregate and fine aggregate.

(b) as graded coarse aggregate of appropriate size and fine aggregate.

(c) as all-in aggregate for grades C20 to below.

2 If the Contractor proposes to blend aggregate off the site from two separate sources, he shall obtain the Engineer's approval for the blending process, and for the arrangements for inspection during the course of the work.

3 Aggregate brought on to the Site shall be kept free from contact with deleterious matter. Fine aggregate nominally below 5 mm sieve size shall have been deposited at the site for at least 8 hours before use.

4 Batching plant and storage for aggregate shall comply with the following requirements as appropriate to the method of delivery:

(a) if separate gradings of aggregate are stockpiled, separate accommodation shall be provided for each nominal size of coarse aggregate or blend of fine aggregate. The base for stockpiles shall be suitably surfaced to prevent contamination of the aggregate. Drainage of the stockpile bases shall be provided.

(b) aggregate shall be measured by mass and provision shall be made for batching each nominal size or blend of aggregate separately, to the tolerances specified in EN 206 & BS 8500.

(c) all-in aggregate shall be delivered and stockpiled in such a manner and to a height that avoids segregation.

### 6.3.27 Mixing Concrete

1 Mixing concrete shall conform to the requirements of Section 5 Part 7 except as amended herein.

2 Concrete shall be mixed on site in a stationary batch type mixer in compliance with EN 206 & BS 8500 unless with the approval of the Engineer, ready mixed concrete is supplied from an approved source.

3 The drums or blades of all mixers shall be operated at the speed using for testing, in accordance with BS 3963 for the mix proportions required, within a tolerance of ± 1 revolution per minute. The mixing blades of a pan mixer shall be maintained within the tolerances specified by the manufacturers of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment. All drums or pans which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed in them.

4 The rated output of the batching and mixing plant shall exceed by at least a third the amount of concrete that is required at a constant rate to enable the paving train to move forward continuously, at the planned rate of progress.

### 6.3.28 Transport and Delivery

1 Transportation, delivery of concrete shall conform to the requirements of Section 5 Part 8.

### 6.3.29 General Requirements for Construction by Machine

1 The concrete slab shall be constructed in a continuous process by either slip-form or by fixed form paving plant or by small paving machines or hand guided methods.

2 The slab may be constructed in either one or two layers. In two layer construction the thickness of the top layer shall be not less than 50mm or twice the maximum size of the coarse aggregate whichever is greater, and shall be at least 15 mm thick than the depth of the groove former, if used.

3 While the concrete is still plastic its surface shall be brush-textured and the surface and edges shall be cured.

4 The spreading, compacting and finishing of the concrete shall be carried out as rapidly as possible and the paving operation shall be so arranged as to ensure that the time between the mixing of the first batch of concrete in any transverse section of the slab and the application of the sprayed curing membrane to the surface of that section shall not exceed those given in Table 6.4.

5 Each bay in jointed concrete surface slabs shall be consecutively numbered near the verge next to a transverse joint while the concrete is plastic. In continuously reinforced concrete pavement the slab shall be marked with the chainage at intervals not greater than 50m apart.

### 6.3.30 Construction by Fixed Form Paving Machines

1 A fixed form paving train shall consist of separate, powered machines which spread compact and finish the concrete in a continuous operation.

2 Concrete shall be discharged without segregation into a hopper spreader which is equipped with the means of controlling its rate of deposition onto the sub-base or onto the lower layer. The concrete shall be spread in each layer without segregation and to a uniform uncompacted density over the whole area of the slab.

3 The deposited concrete shall be struck off to the necessary level by the underside of the hopper as it is traversed across the spreading machine.

4 The machine shall be capable of being rapidly adjusted for changes in average and differential surcharge necessitated by changes in slab thickness or crossfall. When the slab is constructed in two layers, the spreading of the concrete in the top layer shall follow the completion of the bottom layer within the times given in Table 6.4.

5 Prior to being compacted, the surface level of each loose spread layer shall be adjusted to the correct surcharge by means of rotating strike-off blades or a screw device.

6 The concrete shall be compacted by vibration or by a combination of vibration and mechanical tamping throughout the full depth of the slab. Poker vibrators shall be used in each layer adjacent to the side forms and the edge of a previously constructed slab.

7 The initial regulation and finish to the surface of the slab shall be effected by means of a beam oscillating transversely or obliquely to the longitudinal axis of the pavement. This beam shall be readily adjustable for both height and tilt.

8 When grooves are wet-formed the concrete shall be recompacted around the former by a hand held vibrating plate compactor drawn along or on each side of the joint, prior to regulation of the surface by the diagonal finishing beam. Or recompacted and finished if the former is inserted after the finishing beam.

9 The regulation and finishing of the surface of the slab shall be carried out by a machine which incorporates twin oblique oscillating finishing beams which shall be readily adjustable for both height and tilt. The beams shall weigh not less than 170 kg/m, be of rectangular section and span the full width of the slab. The leading beam shall be vibrated. The beams shall be supported on a carriage, the level of which shall be controlled by the average level of not less than four points evenly spaced over at least 3.5m of the supporting rail, beam or slab, on each side of the slab that is being constructed. After the final regulation and before texture is applied any excess concrete on top of the groove former shall be removed.

10 When a concrete slab is constructed in more than one width, flanged wheels on the paving machines shall not be run directly on the surface of any completed part of the slab. The second or subsequent slabs shall be constructed either by supporting machines with flanged wheels on flat bottom section rails weighing not less than 15 kg/m laid on the surface of the completed slab, or by replacing the flanged wheels on that side of the machines by smooth flangeless wheel.. Flangeless wheels or rails shall be positioned sufficiently far from the edge of the slab to avoid damage to that edge.

### 6.3.31 Construction by Slip-Form Paving Machine

1 A slip-form paving train shall consist of powered machines which spread, compact and finish the concrete in a continuous operation.

2 The slip-form paving machine shall compact the concrete by internal vibration and shape it between sliding side forms or over fixed side forms by means of either a conforming plate or by vibrating and oscillating finishing beams.

3 The concrete shall be deposited without segregation in front of the slip-form paver across its whole width and to a height which at all times is in excess of the required surcharge. The deposited concrete shall be struck off to the necessary average and differential surcharge by means of a strike-off plate or a screw auger device extending across the whole width of the slab. The equipment for striking off the concrete shall be capable of being rapidly adjusted for changes of the average and differential surcharge necessitated by changes in slab thickness or crossfall.

4 The level of the conforming plate and finishing beams shall be controlled automatically from the guide wires by sensors attached at the four corners of the slip form paving machine. The alignment of the paver shall be controlled automatically from the guide wire by at least one sensor attached to the paver. The alignment and level of ancillary machines for finishing, texturing and curing of the concrete shall be automatically controlled relative to the guide wire or to the surface and edge of the slab.

5 Slip-form paving machines shall have a vibration of variable output, with a maximum energy output of not less than 2.5 kW per metre width of slab per 300mm depth of slab for a laying speed of up to 1.5m per minute or pro rata for higher speeds. The machines shall be of sufficient mass to provide adequate reaction on the traction units to maintain forward movements during the placing of concrete in all situations.

6 Where grooves are wet-formed the concrete shall be compacted around the former by a separate vibrating plate compactor with twin plates. The groove former shall be compacted to the correct level by a vibrating pan which may be included with the transverse joint finishing beam. In addition a hand held vibrating float, at least 1m wide, shall be drawn over the surface along the joint. Alternatively the surface shall be regulated with a longitudinal oscillating float travelling across the slab. Any excess concrete on top of the groove former shall be removed before the surface is textured.

7 Where a concrete surface slab is constructed in more than one width or where the edge needs to be matched for level to another section of surface slab, and the surface levels at the edges are not achieved, paving shall be carried out over separate fixed side forms to support the edge to the required levels.

### 6.3.32 Construction by Small Paving Machines or Hand Guided Methods

1 As an alternative to fixed form or slip-form paving trains, the concrete slab may be constructed using parts of trains, small paving machines, truss type finishing beams or hand guided methods. Hand tamping beams may only be used for short lengths or infill bays or tapers. Reinforcement, dowel bars and tie bars shall be supported in position, except where two layer construction is used and reinforcement is placed on the bottom layer in a method of construction approved by the Engineer.

2 The concrete shall be spread uniformly without segregation or varying degrees of precompaction, by conveyor, chute, blade or auger. The concrete shall be struck off by a screed or auger so that the average and differential surcharge is sufficient for the surface of the slab to be at the correct levels after compaction of the concrete.

3 The concrete shall be compacted by vibrating finishing beams across the slab and with vibrating pokers adjacent to the side forms or the edge of a previously constructed slab. In addition, internal poker vibration shall be used for slabs thicker than 200mm and may be used for lesser thicknesses. When used, the pokers shall be at points not more than 500mm apart over the whole area of the slab, or drawn continuously across the slab in front of the finishing beams.

4 The finishing beams shall be metal with a contact face at least 50mm wide. They shall be rigid or supported by a frame or truss without sag across the width of slab being paved. The beams shall be supported on rails or forms or an adjacent slab and shall be moved forward at a steady speed of 0.5m to 2m per minute whilst vibrating, to compact the concrete and to produce a smooth surface finished to the correct crossfalls, crowns and levels relative to the top of the forms or adjacent slab.

5 Any irregularities at wet-formed joint grooves shall be rectified by means of a vibrating float at least 1.0 m wide drawn along the line of the joint. The whole area of the slab shall be regulated by two passes of a scraping straight edge not less than 1.8m wide or by a further application of a twin vibrating finishing beam. All slabs shall be checked for level using a straight edge at least 4m long. Any excess concrete on top of the groove former shall be removed before the surface is textured.

6 The surface shall be brush textured.

7 The surface shall be cured within the time to completion given in Table 6.4

Table 6.4
Maximum Working Times

| Temperature of concrete at discharge from the delivery vehicle | Reinforced Concrete Slabs Consumed in Two layers | | All other Concrete Slabs | |
|---|---|---|---|---|
| | Mixing first layer to finishing concrete | between layers | Mixing first layer to finishing concrete | between layers in 2 layer work |
| Not more than 25 °C | 3 hours | 1/2 hour | 3 hours | 1 1/2 hours |
| Exceeding 25 °C | 2 hours | 1/2 hour | 2 hours | 1 hour |
| Exceeding 30 °C | unacceptable for paving | | unacceptable for paving | |

### 6.3.33 Surface Textures

1 After the final regulation of the surface of the slab and before the application of the curing membrane, the surface of concrete slabs to be used as running surfaces shall be brush textured in a direction at right angles to the longitudinal axis of the carriageway.

2 The texture shall be applied evenly across the slab in one direction by a brush not less than 450 mm wide. The texture shall be uniform both along and across the slab.

3 Curing

4 Immediately after the surface treatment, the surface and exposed edges of surface slabs shall be cured for a minimum period of 7 days (unless the Engineer agrees to a shorter period). This will be by the application of an approved resin based aluminised curing compound, or polythene sheeting or an approved sprayed plastic film which hardens into a peelable plastic sheet. It shall be removed before road marking and opening to traffic.

5 Resin based aluminised curing compound shall contain sufficient flake aluminium in finely divided dispersion to produce a complete coverage of the sprayed surface with a metallic finish. The compound shall become stable and impervious to evaporation of water from the concrete surface within 560 minutes of application and shall have an efficiency index of 90% when tested as described in BS 7542.

6 The curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate within three weeks after application.

7 Prior to application, the contents of any containers shall be thoroughly agitated. The curing compound shall be mechanically applied using a fine spray onto the surface at a rate of at least 0.221L/m2. For the sides of slip-formed slabs or when the side forms are removed within 24 hours and for small areas where mechanical application cannot be used, the compound shall be sprayed by hand lance at a rate of at least 0.271/m2. The rate of spread shall be checked during construction of each trial length and subsequently whenever required by the Engineer.

8 The mechanical sprayer shall incorporate an efficient mechanical device for continuous agitation and mixing of the compound in its container during spraying.

9 Continuously reinforced concrete road bases shall also be cured. Wet lean concrete road bases and sub-bases shall also be cured.

10 REQUIREMENTS FOR WET LEAN CONCRETE

11 Materials and Mix Designs

12 The constituent materials and the grades of concrete for wet lean mix shall comply with the requirements of Section 5: Part 16.

13 Placing

14 Wet lean concrete shall be spread uniformly without segregation and without varying degrees of pre-compaction.

15 The concrete shall be struck off to a level so that the surcharge is sufficient to ensure that after compaction the surface is at the required level.

16 Compaction

17 The spread wet lean concrete shall be compacted using internal or external vibration, or combination of both to meet the required density.

18 Compaction and finishing to level shall be completed within the times given in Table 6.4.

19 Joints

20 At transverse and longitudinal construction joints between two separately constructed slabs, the previously laid slab end or edge shall present a vertical face before construction of subsequent slabs.

21 Longitudinal joints in wet lean concrete shall be staggered by at least 300mm from the position of longitudinal joints in any superimposed concrete slab, and by 1m for transverse joints.

**6.3.34 Strength**

1 From each sample, three cubes of the appropriate size shall be made, cured and tested in compliance with BS 1881.

2 One of each group shall be tested at 7 days and the other two at 28 days. The cubes shall be assessed for compliance on groups of four 28-day test results in accordance with EN 206 & BS 8500 for compliance with the grade required.

3 If the average value of any four consecutive results of tests at 7 days falls below the required values the cement content of the mix shall be increased by an amount agreed with the Engineer which shall be maintained until the corresponding 28-day test results have been assessed.

**6.3.35 Trial Mixes**

1 Trial mixes complying with the requirements for pavement quality concrete shall be required for designed mixes for Grade C15 and above, unless recent data relating to the proposed mix is approved by the Engineer.

### 6.3.36 Trial Length

1 At least 10 days before the start of the main wet lean concrete works a trial length of at least 400 m2 for mechanised construction and 30m for hand guided methods shall be constructed.

2 The trial length shall be laid to assess the suitability of the proposed material, plant, equipment and construction methods to meet the requirements of the Specification.

3 The main construction in the permanent works shall not start until the trial length has been approved by the Engineer.

4 If any trial length does not conform to the Specification another trial length shall be constructed. Trial lengths not complying with the Specification shall be removed unless they can be rectified to comply with the Specification to the satisfaction of the Engineer.

5 After approval has been given, the material plant, equipment and construction methods shall not be changed without the approval of the Engineer.

6 Any proposed changes shall entitle the Engineer to require the Contractor to lay a further trial length to assess the suitability of the proposed changes.

### 6.3.37 Surface Finish

1 The surface of the wet lean concrete after compaction and finishing and before overlaying shall be free from ridges, loose material, pot holes, ruts or other defects.

2 The surface texture shall comply with the sub-Clause for pavement quality concrete, Section 5: Part 16.

## 6.4 REQUIREMENTS FOR CEMENT BOUND MATERIALS

### 6.4.1 General Requirements for Cement Bound Materials

1 Cement bound materials shall be made and constructed as described in the following clauses.

2 Cement bound materials shall be tested in accordance with this specification for the requirements of Table 6.5

3 Cement water and aggregates shall comply with the requirements of the Section 5: Part 16.

4 Cement for use in all cement bound materials and aggregates for use in CBM3 and CBM4 shall be delivered and stored in compliance with the requirements of Section 5: Part 16.

Table 6.5
Cement Bound Materials Field Requirements

| Category | Mixing Plant | Method of Batching | Moisture Content | Minimum Compaction |
|---|---|---|---|---|
| CBM 1 | mix in place or mix in the plant | volume or mass | NOTE 1 | NOTE 2 |
| CBM 2 | mix in place or mix in the plant | volume or mass | NOTE 1 | NOTE 2 |
| CBM 3 | mix in the plant | mass | NOTE 1 | NOTE 2 |

| | | | | |
|---|---|---|---|---|
| CBM 4 | mix in place or mix in the plant | volume or mass | NOTE 1 | NOTE 2 |

NOTE 1 to suit the requirements for strength surface, level regularity and finish
NOTE 2 95% of cube strength

Table 6.6
Cement Bound Materials Specimen Requirements

| Category | Curing | Compressive Strength Testing | Minimum 7 days Cube Strength | |
|---|---|---|---|---|
| | | | Average (Note1) (MPa) | Individual (Note2) (MPa) |
| CBM 1 | BS 1924 Part 2 1990 | BS 1924 Part 2 1990 or BS 1881Part 116 | 4.5 | 2.5 |
| CBM 2 | BS 1924 Part 2 1990 | BS 1924 Part 2 1990 or BS 1881 Part 116 | 7.0 | 4.5 |
| CBM 3 | BS 1881 Part 111 | BS 1881 Part 116 | 10.0 | 6.5 |
| CBM 4 | | BS 1881 Part 116 | 15.0 | 10.0 |

NOTE 1 The average strength of 5 cubes shall not be less than the stated figure
NOTE 2 The strength of any individual cube shall not be less than the stated figure

### 6.4.2 Batching and Mixing

1 Batching and mixing shall be carried out in the appropriate manner described in Table 6.5.

2 Where the mix-in plant method is used and materials are batched by mass, the materials shall be batched and mixed in compliance with EN 206 & BS 8500. Where continuous mixers are used and materials are batched by mass, the continuous mixers shall comply and tested in accordance with BS 3963.

### 6.4.3 Transporting

1 Plant-mixed cement bound material shall when mixed be removed at once from the mixer, transported directly to the point where it is to be laid and protected from the weather both during transit from the mixer to the laying site and whilst awaiting tipping.

### 6.4.4 Laying

1 All cement bound material shall be placed and spread evenly in such manner as to prevent segregation and drying.

2 Spreading shall be undertaken either concurrently with placing or without delay.

3 Road base cement bound material shall be spread using a paving machine or a spreader box approved by the Engineer and operated with a mechanism which levels off the cement bound material to an even depth.

4 Cement bound material shall be spread in one layer so that after compaction the total thickness is as specified.

5 At longitudinal or transverse construction joints, unless vertical forms are used, the edge of compacted cement bound material shall be cut back to a vertical face where the correct thickness of properly compacted cement bound material has been obtained.

6 In the case of cement bound sub bases under a concrete surface slab or continuously reinforced concrete road base, longitudinal construction joints in the sub-base shall be staggered by at least 300mm from the position of the longitudinal joints in the concrete surface slab or continuously reinforced concrete road base, and by 1m for transverse joints.

### 6.4.5 Compacting

1 Compaction shall be carried out immediately after the cement bound material has been spread and in such a manner as to prevent segregation.

2 Special care shall be taken to obtain full compaction in the vicinity of both longitudinal and transverse construction joints.

3 Compaction shall be carried out in compliance with Table 6.5 and be completed within 2 hours of the addition of the cement. The 2 hours may be varied at the discretion of the Engineer if the preliminary trial indicates that this is necessary or appropriate. After compaction has been completed, compacting equipment shall not bear on cement bound material for the duration of the curing period.

4 The surface of any layer of cement bound material shall on completion of compaction and immediately before overlaying, be well closed, free from movement under compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer and new cement bound material laid and compacted.

### 6.4.6 Curing

1 Immediately on completion of compaction, the surface of concrete or wet lean concrete or cement bound road bases and sub-bases shall be cured for a minimum period of 7 days (unless the Engineer agrees to a shorter period) by one of the following methods:

2 Covering with an impermeable sheeting with joints overlapping at least 300 mm and set to prohibit egress of moisture. The sheeting shall be removed at the end of the curing period.

3 Bituminous spraying which shall only be applied when there is no visible water. When the cement bound material is likely to be exposed to high temperatures and solar radiation, the bituminous spray shall be blinded with light coloured material.

4 Spraying with a curing compound.

5 Spraying with an approved plastic film which when hardened shall be removed before applying any other pavement layer.

6 Whichever method is used, immediately prior to overlaying with any bituminous layer in cationic bituminous tack coat shall be applied at a rate between 0.351/m2 to 0.551/m2.

### 6.4.7 Preliminary Trial

1 At least 10 days before the start of the main cement bound material works a trial area of at least 400 m2 shall be laid to asses the suitability of the proposed materials, mix proportions, mixing, laying, compaction plant and construction procedures.

2 When applicable the area shall include one longitudinal and one transverse construction joint. The location and area of the trial shall be subject to the approval of the Engineer.

3 The rate of testing for the trial area shall not be less than that required in this section of the specification.

4 The trial area will only be accepted for main construction in the Permanent Works if it complies with the Specification.

5 The main construction in the Permanent Works shall not start until the trial has been approved by the Engineer.

6 After approval has been given, the materials, mix proportions, mixing, laying compaction plant and construction procedures shall not be changed without the approval of the Engineer who may require the Contractor to lay a further trial area to assess the suitability of the proposed changes.

### 6.4.8 Cement Bound Material Category 1 (CBM1)

1 CBM1 shall be made from material which has a grading finer than the limits of Table 6.7

2 In addition to the requirements of Table 6.6 the average compressive strength determined after immersion in water of five test specimens of CBM1 shall not be less than 80% of the average compressive strength of five control specimens when subjected to the test procedure described in BS 1924: Part 2: 1990, clause 4.3.

3 After the 7 days immersion period the specimens shall not show any signs of cracking or swelling.

Table 6.7
Material for CBM1 - Limit of Grading

| BS Sieve Size (mm) | Percentage by Mass Passing |
|---|---|
| 50 | 100 |
| 37.5 | 95 |
| 20 | 45 |
| 10 | 35 |
| 5 | 25 |
| 0.600 | 8 |
| 0.300 | 5 |
| 0.075 | 0 |

NOTE: The particle size distribution shall be determined by the washing and sieving method of BS812:

### 6.4.9 Cement Bound Material Category 2 (CBM2)

1 CMB2 shall be made from gravel sand, a washed or processed granular material, crushed rock, all in aggregate or any combination of these. The material shall fall within the grading limits of Table 6.8.

2 The material shall have 10 % fines value of 50 kN or more when tested in accordance with BS 812 with samples in a soaked condition.

3 In addition to the requirements of Table 6.6 the average compressive strength determined after immersion in water of five test specimens of CBM2 shall not be less than 80% of the average compressive strength of five control specimens when subjected to the test procedure described in BS 1924: Part 2: 1990, clause 4.3. After the 7 days immersion period the specimen shall not show any signs of cracking or swelling.

Table 6.8
Material For CBM2 - Range Of Grading

| BS Sieve Size | Percentage by Mass Passing |
|---|---|
| 50 | 100 |
| 37.5 | 95-100 |
| 20 | 45-100 |
| 10 | 35-100 |
| 5 | 25-100 |
| 2.36 | 15-90 |
| 0.600 | 8-65 |
| 0.300 | 5-40 |
| 0.075 | 0-10 |

NOTE: The particle size distribution shall be determined by the washing and sieving method of BS 812.

**6.4.10 Cement Bound Material Category 3 (CBM3)**

1 CBM3 shall be made from aggregates as in the sub-Clause 6.5.9.

2 The grading of the aggregate shall be within the limits of Table 6.9.

**6.4.11 Cement Bound Material Category 4 (CBM4)**

1 CBM4 shall be made from aggregates as in sub-Clause 6.5.9

2 The grading of the aggregate shall be within the limits of Table 6.9.

Table 6.9
Material for CBM3 and CBM4 - Range of Grading

| BS Sieve Size (mm) | Percentage by Mass Passing. Nominal Maximum Size | |
|---|---|---|
| | 40 mm | 20 mm |
| 50 | 100 | - |
| 37.5 | 95-100 | 100 |
| 20 | 45-80 | 95-100 |
| 5 | 25-5- | 35-55 |
| 0.600 | 8-30 | 10-35 |
| 0.150 | 0.8* | 0-8* |
| 0.075 | 0.5 | 0-5 |

NOTE: The particle size distribution shall be determined by the washing and sieving method of BS 812.

*0-10 for crushed rock fines

### 6.4.12 Testing of Cement Bound Materials

1 Samples shall be provided in accordance with BS 1924: Part 1: 1990 Clause 5 from the laid cement bound material before compaction. One group of five samples shall be provided from five locations equally spaced along a diagonal that bisects each 800 mm2 or part thereof laid each day. The number of groups may be increased if required by the Engineer.

2 One 150 mm cube shall be made from each sample taken in accordance with sub-clause 1 of this clause. The cubes shall be made in accordance with BS 1924: Part 2: 1990, clause 4.2.5 without further mixing of the material and within 2 hours of the addition of the cement. Cubes shall be cured and tested in accordance with Table 6.6.

3 To determine the wet density of cubes the mould shall be weighed prior to making the cube and the mass recorded. Immediately after completion of compaction, the cube and mould shall be weighed and the mass recorded. These masses together with the nominal volume of the mould shall be used to derive the wet density of the cube.

4 The in-situ wet density of a layer of cement bound material shall be taken as the average of the wet densities at five locations equally spaced along a diagonal that bisects each 800 m2 or part thereof laid each day. The wet density at each location shall be the average of two readings obtained using a nuclear density gauge complying with BS 1377: Part 9. The two readings shall be taken at 180 degrees to each other using the same source rod hole. The source rod shall be lowered to within 25mm of the bottom surface of the layer. Readings shall be taken within two hours of completing final compaction.

### 6.4.13 Special Requirements for Cement Bound Materials

1 Where specified in the contract documents or on the project drawings cement bound road base in flexible composite construction shall be laid in individual widths with longitudinal construction joints in locations as detailed below:

(a) Single All purpose. One longitudinal construction joint at the centre lane line marking.

(b) Dual 2 lane All-purpose. One longitudinal construction joint at the lane line marking.

(c) Dual 3 lane All-purpose. Two longitudinal construction joints, one at each of the lane line markings.

(d) Dual 2 lane Motorway. Two longitudinal construction joints, one at the lane line marking and one at the edge line marking between hard shoulder and left hand lane.

(e) Dual 3 lane Motorway. Three longitudinal construction joints, one at each lane line marking and one at the edge line markings between hard shoulder and left hand lane.

(f) Dual 4 lane Motorway. Four longitudinal construction joints, one at each lane line marking and one at the edge line marking between hard shoulder and left hand lane.

2 Longitudinal constructions joints shall not be more than 150 mm from the centre of the centre line, lane line, or edge line marking, with individual widths not exceeding 4.75 m.

3 Longitudinal construction joints shall not be located within the left hand lane or dual carriageways. At tapers and other changes in section the construction joint layout shall be agreed with the Engineer, and where necessary joints shall also be permitted within 150 mm of the mid-point of the traffic lane.

END OF PART