SERIES NG 1000 ROAD PAVEMENTS - CONCRETE MATERIALS (05/05)

Contents

ROAD PAVEMENTS - CONCRETE MATERIALS (05/05)

NG 1000 General

1 (11/03) Advice on the design, construction and maintenance of concrete roads and for concrete mix design is published in Standards and Advice Notes and

Design:	The Design Manual for Roads and Bridges (DMRB), Volume 7
Construction:	Mechanical Construction of Concrete Pavements and Ancillary Works, Concrete Society, Technical Report No. 45
Mix Design:	Design of Concrete Mixes, SO, 1988
Remedial Works:	Concrete Pavement Maintenance Manual published by the Concrete Society

2 (05/01) The pavement design requirements for concrete pavements should be based on the Design Manual for Roads and Bridges Volume 7 and shown in Appendices 7/1 and 10/1.

3 (11/05) The philosophy for compliance has now changed to that of an end performance requirement of the finished pavement with cores being taken and assessed for density and compressive strength as specified in BS EN 13877-2. This is supplemented by determination of the air voids in the concrete, minimum cement content, control of the water cement ratio and use of suitable materials for durability purposes. There is no assessment of concrete cubes for compliance, however, the contractor may wish to operate an early age cube testing regime for concrete control purposes.

4 (11/03) With the use end performance specifications, subject to meeting the requirements of the specification, the choice of construction methods and consistence should solely be that of the contractor. However, the exception to this would be for the final regulation of concrete surface slabs where the use of a longitudinal oscillating float is required to provide necessary evenness prior to macro texture being applied. The requirements for pavement construction details and location of joints should be accordance with this Series.

5 (11/05) For small contracts, and with the agreement of the Overseeing Organisation, the requirements of BS EN 13877-1 may be employed with a recipe specification, compliance by cube testing and density complying with Clause 1003. With a recipe specification the method of construction should comply with the requirements of this Series.

6 (11/05) For new construction and major maintenance the end performance specification should be used. The pavement should meet the requirements of BS EN 13877-2 and Clauses 1001 to 1004 are the appropriate Clauses for assessment of the pavement quality and wet lean concretes.

NG 1001 (11/03) Strength Classes of Concrete and Constituent Materials for Pavement Layers

1 (11/05) Clauses 1001 and 1002 give the requirements for constituent materials and limits for designed concrete in the form required in BS EN 206-1, BS EN 13877-1, BS EN 13877-2, BS 8500-1 and BS 8500-2.

2 (05/06) Six strength classes of concrete are included to meet the needs of sub-bases, bases with flexible surfacing, continuously reinforced concrete bases with flexible surfacing and slabs in the pavement surface.

3 (11/03) The strength classes for pavement surface concrete has been selected to provide greater durability for increasingly heavy traffic.

4 (11/03) The minimum cement or combination content is given in BS 8500-1 Table A18 and is dependent on the maximum aggregate size in the concrete.

5 (11/03) In addition to Portland cement CEM I, the term ‘cement’ includes other hydraulic binders such as combinations of CEM I and ground granulated blastfurnace slag (ggbs) and pozzolanic cements such as blends of CEM I and pulverised-fuel ash (pfa), whether they are blended on site or manufactured by blending or intergrinding. These include Portland blastfurnace cement, Portland CEM II/B-V cement and pozzolanic pfa cement.

6 (11/03) Portland limestone cement should not be used in the top 50 mm of the road surface, as this would increase the fine calcium carbonate content and lead to slipperiness. Microsilica may be used with CEM I to obtain high early strength concrete.

7 (11/03) For durability it is necessary to have a water/cement ratio below 0.45 for pavement surface slabs. The water/cement ratio is defined as the ratio of free water to total cementitious content of the concrete.

8 (11/03) High early strength Portland cements should only be used where rapid construction is required. In such cases, insulation blankets will be required over the concrete to provide suitable curing conditions which will reduce the risk of thermal cracking of the concrete.

9 (11/03) High early strength cements, high cement contents and low water/cementitious ratios may be used when there is a need to open a section of concrete pavement to traffic early. Prescribed concretes of fixed proportions may be used in rapid construction for high early strength concrete. The proportions of ingredients to be used should be decided by trial concrete mixes which when tested provide the quality, consistence and strength development required for the particular application.

10 (11/05) Both CEM I /pfa and CEM I /ggbs concrete have a long term increase in strength greater than CEM I concretes for the same 28 day strength and provide greater durability and resistance to chemical attack. However, there is evidence that all but the strongest concretes in the top 50 mm of a road pavement which contain more than 25% pfa or 35% ggbs are more likely to suffer from damage under freeze/thaw conditions, and is the reason the amount of pfa and slag is limited to these values. If pfa is included in the concrete it permits lower water/cement ratios for a required consistence, so providing denser concrete of lower permeability and greater durability.

Admixtures

11 (11/05) Air entraining agents are essential in all but the strongest pavement surface slabs to reduce freeze/thaw damage. Asphalt material provides some protection to concrete slabs and air entraining agents are not necessary unless the concrete is to be exposed to freeze/thaw cycling before the surfacing is applied or before the concrete has gained sufficient strength. A small loss in strength is to be expected with air entrained concrete compared with plain concrete with the same mix proportions.

12 (11/03) Plasticisers can be used to reduce water in the concrete, increase strength and maintain consistence at the required level. They can be beneficial in concretes with blends of CEM I with ggbs or pfa, as the water reduction partially compensates for the loss of early strength.

13 (11/03) Where low water/cement ratios are used to obtain CC37 or C32/40 strength, retarders can be used in high summer temperatures, to ensure that the finishing processes can be completed in time.

Aggregates

14 (11/03) The maximum size of aggregate allowed is 40 mm, but the Contractor's choice of size will depend on construction methods, and his ability to achieve surface regularity, properly constructed joints and correct alignment of dowels. Larger aggregate provides an advantage in producing a more stable concrete in the lower layer, while 20 mm aggregate is preferable in the top course for forming joints and achieving a good finish.

15 (11/03) Popouts can occur in the surface of the concrete slab when freeze/thaw susceptible particles are included in the aggregate. If there is a sufficient proportion of such particles this can lead to 'D' cracking which is a form of cracking caused by expansion due to freeze/thaw, close to transverse and longitudinal joints. The particles which can cause popouts with flint gravel aggregates are clay or chalk impurities or white flint particles.

16 (11/03) The white flints consist of nodules of cortex or harder flints covered in cortex which is weathered flint and is porous. Research has shown that all flint aggregates are porous but to varying degrees. Black flint is of very low porosity. Brown flints are three times more porous than black, and white flints are about four times more porous than brown flints. The overall porosity of an aggregate will depend on the proportion of white flints. Smaller particles tend to have higher absorption than larger aggregate sizes. In addition to freeze/thaw damage due to absorption of water there is a higher risk of alkali silica reaction in the presence of moisture in the porous aggregates.

17 (11/03) Porous flint aggregates have been found to be widely spread in the South of England, including certain marine sources. However, where local knowledge or experience of a particular source is satisfactory and the material properties are constant, the need for testing may be reduced.

18 (11/03) When dissimilar aggregates are used in two layer construction the effect of different thermal coefficients should be assessed. More easily-sawn aggregates may be preferred so that joint grooves can be made, but if used in the top layer above flint gravel for example, the effects of different thermal coefficients should be considered. The time for sawing joints will be dictated by the thermal characteristics of the flint gravel aggregate in the lower layer and not by the other aggregates.

19 (11/03) Although cracking due to alkali silica reaction (ASR) is rare in concrete pavements, identical requirements to those for structural concrete are specified. (See also NG 1704.)

20 (11/03) Where the magnesium sulfate (MS) test is used as a means of confirming source suitability, a certificate from a testing laboratory accredited in accordance with EN 45002 by an appropriate organisation accredited in accordance with sub-Clauses 105.3 and 105.4 for those tests, showing a value no higher than the minimum specified and dated not more than 6 months previous to the start of the contract, should be provided.

For those sources seeking suitability based on historical evidence of satisfactory use, the following should be provided:

(i) Dated certification showing supply of materials conforming with all other aspects of Clause 1001.6.

(ii) Copies of dated delivery tickets showing materials, source and site supplied.

(iii) Documentary evidence of material source, site and tonnage supplied.

Evidence should be provided for at least two major sites.

Routine water absorption (WA) tests should be made on the delivered material. If any result from these tests exceeds the declared value (d) by more than 0.5 ie, > (d + 0.5) %, further investigation will be required.

21 (11/03) When recycled coarse aggregate or recycled concrete aggregate is used as an aggregate, grading variations and quality should be carefully monitored to ensure the requirements of BS EN 12620 and Table 2 of BS 8500-2 are achieved. Material quality should also be controlled by determining the resistance to fragmentation by the Los Angeles (LA) test method in BS EN 1097-2. When flint coarse aggregate containing white flints is present in the crushed concrete, the requirements of sub-Clause 1001.9 should be taken into account.

22 (11/03) The test procedure for identifying and quantifying constituent materials in recycled aggregates is described in Clause 710.

23 (11/03) When recycled coarse aggregate or recycled concrete aggregate is used, the maximum allowable proportion as part of the coarse aggregate should be determined from trial mixes.

24 (11/03) The method of test for chloride ion content in recycled coarse aggregate and recycled concrete aggregate should differ from that for natural and artificial aggregates due to the potential chloride content within any adhering cement fractions which needs to be taken into account.

25 (11/03) The acid soluble content of the fine aggregate is determined using BS EN 196-21 to assess the carbon dioxide conent (in %) and then multiplying this by the conversion factor of 100/44 from BRE Special Digest 1 to obtain the acid soluble carbonate content.

26 (05/06) To ensure adequate resistance to fragmentation of the aggregate, the aggregate should be Category LA_{35}. LA_{40} would be acceptable for the lower layer in two layer construction, and also for CRCB pavements.

NG 1002 (11/03) Air Content

1 See sub-Clause NG1001.11.

NG 1003 Density

1 (11/03) Density is required to be measured at regular intervals during paving as well as the trial length. Until nuclear density meters are proven as acceptable for plastic concrete, cores will be required to be cut for compliance purposes. However, nuclear density meters may be used for quality control purposes. The density requirement is now a comparison of cored specimens against moulded specimens from the same concrete. To prevent undue damage to the slabs, cores should not be taken at points of high stress such as corners of slabs. The most desirable position for taking cores for routine density and inspection checks is as follows:

(i) Between quarter points along the slab.

(ii) Within 0.5 m of any longitudinal joint in a hard shoulder, hard strip or the least trafficked lane of the section being inspected.

2 (11/03) The minimum volume of the core, or any part of it, to be tested should not be less than one litre or (50 x D_{MAX}^3), where D_{MAX} is the nominal maximum size of the course aggregate in mm.

3 (11/05) The minimum number of cores that should be tested is three. However, for small areas, Category 0 in BS EN 13877-2 may be specified by the Overseeing Organisation, which does not require density testing.

4 (11/03) The water-displacement method is recommended as this is the most precise technique for determining the volume of the core.

5 (11/03) Where cores contain tie bars or other reinforcement, allowance for the amount of steel should be made in any calculation of the density of the concrete.

6 (11/03) As a rough rule for assessment of strength, a 1% reduction in density equates to a 5% loss of strength of concrete.

7 (11/03) When two radically different concretes are used in the slab in two-layer construction, the density assessment should be carried out on the two concretes separately.

8 (11/03) The same cores can be used for the density and strength testing.

NG 1004 (11/03) Pavement Concrete Strength

1 (11/05) BS EN 13877-2 is used as the basis for the sampling and compliance testing for the strength of the pavement concrete. The sampling rate is 1 core per 1000 m^2 of concrete laid, this amounts to approximately one core every 250 m for single lane laying or approximately one core every 125 m for double lane laying. A minimum number of three cores must be taken.

2 (11/05) The average diameter of the core should be at least 4 times the maximum aggregate size and not less than 100 mm. A correction factor for h/d ratios greater than one is given in Table 1 of BS EN 13877-2. The core should be tested in a saturated condition and no allowance should be made for any steel in the core.

3 (11/03) The core dimensions, the shape and the flatness tolerance of the ground surface should conform to the requirements of BS EN 12390-1. The top and bottom faces of the core should be ground as this gives more consistent results and eliminates the health and safety problems associated with other end preparation techniques.

4 (11/03) The tested specimen should be representative of the concrete from the full depth of the pavement. The whole core should be tested as taken, but where the core is tested in two parts, the lower corrected strength should be taken as representative of the concrete strength at that location.

5 (11/03) The characteristic core strengths and the 7 day core strengths have been determined from an analysis of corrected core and cube strengths taken from concrete used at the same location on a number of recently laid pavements. The corrected core strengths were determined using the CEN relationship in draft prEN 13887-2 with no account taken for any steel in the cores. A linear relationship was derived such that:

Corrected core strength = 0.92 x Cube strength

It was also found that when considering all the sites, the within site standard deviation of the cubes and cores were similar.

6 (11/03) The 7 day core strengths from tests on the trial slab are used to give early warning of the possibility of low results and the need for additional cement or improved compaction and can be verified by the test results at 28 days.

7 (11/05) The 28 day acceptance criteria specified in BS EN 13877-2 for corrected core compressive strength in N/mm^2 are:

(i) The mean value of any four consecutive results $\geq f_{ck,core} + 4$

ii) Any individual value $\geq f_{ck,core} - 4$

Where $f_{ck,core}$ is the specified characteristic core strength.

8 (11/03) The average value of 4 results represents 4000 m² of work at the specified rate of testing. If the Contractor wishes to reduce the area of pavement at risk he may wish to arrange for a higher rate of testing.

9 (11/05) To reduce the risk to the Contractor it is recommended that some form of concrete testing supplements the end performance testing. It is intended that the introduction of end performance testing should not require any changes to the concrete specified for pavements. Consequently, the former compliance requirements for the concrete (SHW, May 2001), or a derivative of this based on cubes, could still be employed by the Contractor for his own concrete control purposes as specified in BS EN 13877-1, BS EN 206-1, BS 8500-1 and BS 8500-2.

10 (11/03) In the event of the pavement concrete failing to meet the compliance criteria the amount of substandard pavement should be determined. This is achieved by taking cores in an area deemed acceptable and determining the mean value of four cores. Additional cores should be taken at either end of the area that does not comply until the running mean of four, at each end, is at least equal to the mean of the four cores from the acceptable area.

11 (11/03) When two radically different concretes are used in the slab in two-layer construction, the statistical check on strength results should be carried out on the concretes separately.

12 (11/03) The same cores can be used for the strength and density testing.

13 (11/05) When working to BS EN 13877-1 and BS 8500-1 the average value of any four consecutive 7 day results should not fall below the strengths in Table NG 10/1.

TABLE NG 10/1: (11/03) **7 Day Cube Compressive Strengths**

Class of concrete	CEM I concretes N/mm²	CEM I with pfa or ggbs concretes N/mm²
C32/40	35	29
C25/30	27	22
C16/20	18	14
C12/15	13	11
C8/10	8	7
C6/8	5.5	4.5

NG 1005 (11/03) Consistence (Workability)

1 (11/03) The consistence of the concrete at the point of placing should enable the concrete to be fully compacted and finished without undue flow. The optimum consistence for concrete to suit the paving plant being used should be determined by the Contractor.

2 (11/03) The Degree of Compactibility (Compaction Index or CI) test is a suitable consistence test for most of the stiff concretes required for machine paving. The CI test or the Vebe test should be used on trials of cohesive concretes, eg. when ggbs or pfa are used, to measure the effect of vibration for a range of CI values.

3 (11/03) The optimum CI at the paver will need to be reassessed at intervals depending on the climatic conditions.

4 (11/03) Consistence should be constant. A useful check on whether the consistence is constant can be obtained by noting the power input to the mixer. If necessary, plasticising or retarding admixtures should be used to suit local or weather conditions.

5 (11/03) The target values for the Compaction Index will vary with the concretes and materials used and with the weather. Peliminary work indicated that:

Compaction Index = 2.676 - 1.633 x Compacting Factor

Giving approximate values of:

(i) single layer construction 1.37 - 1.29

(ii) two layer construction
top layer 1.37 - 1.32
bottom layer 1.45 - 1.40

Low consistence is required in the concrete to ensure that inserted dowel bars are retained in position. Higher consistence is necessary to allow the texturing and finishing to be completed satisfactorily within the time available. In practice a compromise is required depending on the method of construction. However, it is likely that all concretes will be in Compaction Class C1.

6 (11/03) As uniform consistence is of prime importance for the slab to meet the requirements of the Specification, it is in the Contractor's interest to control it by frequent testing at the batcher so that adjustments can be made quickly before too much concrete is transported to the paver. Tests at the paver are also required to ensure that the concrete placed in the paver is within specified limits.

7 (11/03) For small scale works where ready mixed concrete is used, no water other than any amount required to produce the specified consistence, should be added to the truck mixer drum before discharge. No additional water should be permitted in concrete which has been in transit for more than two hours.

8 (11/03) Although no precision data is available for the Compaction Index test it is suggested that a similar tolerance should be achievable to that formerly required for the Compacting Factor test.

NG 1006 (11/03) Not Used

NG 1007 (05/01) Separation and Waterproof Membranes

1 (05/01) A separation membrane is required to prevent loss of water from the fresh concrete. For jointed pavements a degree of slip is desirable, so polythene sheet is normally used. For continuously reinforced concrete (CRC), a waterproof bituminous spray should be used on the sub-base because a degree of restraint is required.

NG 1008 Steel Reinforcement

1 Supports for reinforcement should be sufficiently numerous and rigid so that the reinforcement will withstand a man's weight with no greater vertical distortion at any point than half the allowable vertical tolerance for the position of the reinforcement.

2 (05/02) When fixed height supports are used, eg. rings of standard mesh reinforcement, it is necessary to ensure a good surface regularity to the sub-base or base on which the reinforcement is laid.

3 When prefabricated sheets are laid in two layer construction it is permissible to lay alternate sheets along the pavement with transverse steel uppermost. This allows the transverse lap to be made by placing one transverse bar of one sheet within the first mesh of the next sheet. This requirement will not apply if flying ends are provided in the prefabricated sheets at the position of the laps.

NG 1009 Transverse Joints

1 Transverse joints are normally contraction joints. Warping joints are retained in Clause 1009 for special cases, eg. for extra joints at manhole positions or when unreinforced slabs are alongside reinforced slabs, or in long narrow or tapered URC slabs between normal joint positions, to reduce the length/width ratio of the slabs to 2 or less, and in other similar situations. Alternatively, instead of extra joints, slabs with an aspect ratio greater than 2 may be reinforced. The spacing of transverse joints should be described in Appendix 7/1.

2 (11/03) Structures within the pavement depth should be isolated by at least 5 m of hot rolled asphalt or dense bitumen macadam base.

3 (05/06) At buried structures the concrete slabs and sub-base should be continued over the structure. The sub-base should be isolated from the structure by not less than 150 mm of granular fill. Composite bases should not be permitted to abut the structure.

4 (05/06) At the ends of CRCP, jointed reinforced slabs with expansion joints should be constructed between the anchorages and any other form of pavement. At the ends of CRCB, a jointed unreinforced slab with an expansion joint should be constructed between the anchorages and any other form of pavement. Between anchorages the only joints will be construction joints.

5 Where an unreinforced carriageway is constructed in more than one width and transverse cracking occurs before concreting the adjacent width, repair of the cracks should be carried out before the laying of adjoining slabs to reduce the risk of sympathetic cracking. If extra joints are put in as part of the repair, they should be matched in adjacent subsequently laid slabs.

NG 1010 Longitudinal Joints

1 Longitudinal joints are required at such a spacing as will reduce the combination of thermal warping stresses and loading stresses to a minimum and reduce the risk of longitudinal random cracking. The maximum bay width is therefore set at 4.2 m, except when reinforced pavements are constructed in widths up to 6.0 m (or 5.0 m and 7.6 m respectively with limestone aggregate).

2 Joints may be situated at or near lane lines or in the centre of a lane, whichever is the most economical for the Contractor’s method of construction, but they should not be near the wheel track especially in heavily trafficked lanes.

NG 1011, NG 1012, NG 1019 Placing and Inspection of Dowel Bars and Tie Bars

1 When dowel and tie bars are to be inserted vertically into fresh concrete the concrete should be fully compacted over them. Tie bars may be inserted into the side of a slab provided the method ensures a good bond to the concrete.

2 The fixings for dowel bar assemblies should be tested for strength in the trial lengths. Once the type of assembly has been approved, sample testing should be carried out in the main construction in the Permanent Works to ensure that standards are maintained.

3 To check the alignment of dowel bars it is necessary to remove the fresh concrete carefully to expose the top half of each end of each bar across the whole width of the slab under construction. The position of the ends of the bars can be measured relative to the side forms or wires by means of steel tapes stretched between the forms or wires, using a vertical spirit level placed alongside the bars.

The alignment for level can be measured from nylon lines pulled taut across the forms or measured using a gauge incorporating a spirit level with legs 300 mm apart with forks at the ends for placing over the bars. The legs can include rules to measure the position of the bar ends below the steel tapes.

4 (11/03) As the measurement of all the bars in any one joint is time consuming it will not be possible to complete the measurement, recompact and finish the concrete within the normal time allowed in Table 10/7. It will be necessary to reinstate with a l m long reinforced slab as a full depth repair. Alternatively the penultimate joint in a day’s work could be selected for the dowel alignment check. The remaining concrete in the last slab is then discarded before work starts again.

5 (05/01) Dowel bars, tie bars and transverse reinforcement across a longitudinal joint need to be protected from corrosion. Suitable bituminous protective paint is allowed for reinforcement. Tie bars and dowel bars should be protected by bonded polymeric corrosion resistant coatings.

NG 1013 Joint Grooves

1 (11/04) Sawn grooves are preferred for transverse contraction and warping joints in summer work as they avoid disturbance to the surface of the plastic concrete. Because of the risk of cracking starting from the bottom in winter and the fact that bottom crack inducers are not used with sawn joints, joint grooves may be formed in winter (31 October to 1 April). The timing of sawing the hardened concrete is critical. If sawn too soon the aggregate will be plucked out, if too late, the concrete will have cracked already. With flint gravel aggregates in normal strength concrete, cracking may occur before sawing can begin. With high early strength concrete there is a better opportunity for sawing flint gravel concrete. In two course construction, with flint gravel in the bottom layer, the time for sawing before cracking will be governed by the flint gravel, as it has the highest coefficient of expansion. If a crack forms before or during sawing, it should be left without sawing alongside it until the time comes to seal it. If the crack cannot be encompassed within a 40 mm wide joint, the slab should be repaired. In slabs constructed in more than one pass of the paver (one rip) cracks may occur earlier in the second pass under the influence of joint movement of the first pass unless sawing is carried out as soon as possible.

2 Narrow crack-inducing grooves should be sawn first and widened for sealing later. In order to meet the requirements for high paving speeds with an economical number of saws and still reduce the risk of random cracking, it is common practice for approximately every third joint to be sawn as early as possible; the intermediate joints being sawn within the next few hours.

3 Wet-formed joint grooves with bottom crack inducers will be allowed for winter work to ensure cracks appear at joint positions. In such cases it is important that the concrete is fully recompacted around the former or cork seal. As the joint groove former is placed just below the surface of the concrete, it is important to ensure that the surface of the concrete is a straight plane between the forms at wet-formed joints. Otherwise if the surface level is bowed by excess concrete the former will be tilted by the diagonal finisher when planing off the excess concrete. The depth of the top layers should be considerably greater than the depth of the joint former so that the positions of the formers are not influenced by the stiffness of the bottom layer.

4 It is not good practice to set the formers low and pull them up again after the diagonal finisher. It is likely to cause lack of compaction of the concrete adjacent to the former and may lead to separation of the removable part of the former and bridging by mortar under it, which may cause horizontal cracking. However, it may be necessary on occasions to adjust the depth of former in which case the whole former must be raised in a vertical plane only using suitable tools. If excess concrete is not cleaned off above the former, concrete or mortar will bridge over the joint and will cause spalling of the arrises before sealing.

5 The joint groove must form a complete discontinuity across the slab, so that the concrete will crack along the joint position. It is necessary to ensure that the groove is continued across the longitudinal joint and to the edge of the slab by sawing when forms have been removed.

6 In normal summer work in URC only about one joint in four will crack initially. These joints tend to have greater movement at first until the other joints crack later with seasonal temperature changes or under traffic. In pavements constructed in two or more slabs the movement of joints in one slab will influence the cracking of uncracked joints in the adjacent slab from the longitudinal construction joint to the outer edge. A lack of discontinuity along the joint or dowel restraint may result in a crack appearing off line. This can be avoided by cleaning the top of the joint formers, using bottom crack inducers, and ensuring dowel alignment is satisfactory.

NG 1015 Joint Filler Board

1 Expansion joint filler board should have a pointed ridge as shown in the HCD, drawing number C2. The top of the ridge should be below the surface of the concrete but just within the depth of the sealing groove. It acts as a crack inducer initially and the sealing groove is sawn out later. Any other method of forming the sealing groove should be demonstrated in a trial.

NG 1016, NG 1017 Preparation and Sealing of Joint Grooves

1 One of the main causes of compression failures and damage to joints is the ingress and build up of solids or water-borne silt in the joint over a long period preventing or limiting proper movement at the joint. The requirements of a pavement joint sealant are:

(i) It should prevent the ingress of any solid matter into the joint.

(ii) It should form a waterproof seal and prevent most of the surface water from entering the joint crack.

(iii) It should be robust, have high extensibility, be resilient, be resistant to tearing, have a good bond to concrete and be unaffected by ageing and weathering.

2 Preparation of the sealing groove is most important. In order to remove any laitance from the groove sides and to provide a good key for applied seals, the joint sides must be grit blasted. Grinding may be permitted to clean small lengths of groove where grit blasting is impracticable. Wire brushes may be used to remove filler board prior to grit blasting, and for preparing grooves for compression seals.

3 Cracks will appear at transverse joints sporadically in new unreinforced concrete construction. Those that crack the earliest tend to have greater movement than would be expected if all the joints cracked evenly. This means that the groove width in winter may be wider than originally constructed, and allowance for future compression of the sealant should be made when sealing in cooler periods and the joint grooves should not be overfilled. Because of the extra movement in new URC pavement joints, cork and compression seal widths need to be greater to maintain them in compression.

4 For compression seals the width of the seal required is governed by the calculated movement to ensure that the seal remains always in compression.

5 With all sealants except cork seals which should be flush with the surface it is important to keep the top of the sealant below the surface at transverse joints to prevent damage by traffic when the joints are compressed in summer. When sealing in colder periods the level of the seal should be lower than in summer to allow for the compression of the seal upwards in warm periods. When longitudinal joints are sealed, the seal should be just below the surface.

6 There are two grades of two part cold-applied sealing compounds to BS 4254, used in structures and kerbs, etc; one for horizontal joints and the other for vertical joints. The grade offered by the Contractor should be suitable for the particular joint.

7 Although the British Standards refer to two part sealants some types have three parts. These sealants may also be permitted as it is often advantageous to vary the quantity of retarder (within limits set by the manufacturer) according to the temperature conditions at the time of sealing, rather than include it in the hardener. In cooler weather cold applied sealants take longer to cure.

8 (05/01) In circumstances where longitudinal joints may not be on line with road markings, consideration should be given to the avoidance of contrasting colours of joint sealant and pavement. The requirements for joint sealant colour should be included in Appendix 7/2.

NG 1018 Joints at Manhole and Gully Slabs

1 Wherever possible, manholes and gullies should be sited outside the pavement, but if they occur in the pavement they should either straddle or be adjacent to a transverse joint in jointed concrete pavement. If the joint spacings are such that a manhole or gully position is in the middle of the slab, an extra joint is necessary which should be a tied warping joint.

2 Details of the reinforcement required in the main slab and in CRC slabs around manhole or gully slabs are given in the HCD.

3 Gully and manhole slabs should have square corners as in the HCD, on the sides that are not adjacent to a joint to avoid a proliferation of cracks induced from oblique corners.

NG 1020 Side Forms, Rails and Guide Wires

1 In order to avoid adverse effects on the riding quality it is most important to check that all the sensors on any wire-guided machine are functioning within the correct tolerances during all paving, especially if the machine has been standing overnight in wet conditions.

2 The sub-base or any bedding for forms should be of sufficient strength to carry the train or paver without vertical movement and where necessary to carry any construction traffic. Cement bound bedding should have sufficient time to reach the necessary strength before paving begins. Precautions should be taken to prevent any construction traffic from damaging the subgrade next to the rails or paver tracks and so altering the levels after they have been set. Bedding other than the sub-base itself should be broken out after any section of pavement has been constructed and before any adjacent concrete is laid alongside, so that drainage of the sub-base and pavement is not impaired.

NG 1021 (11/03) Not Used

NG 1022, NG 1023 (11/03) Not Used

NG 1024 Construction by Machine

1 Descriptions of two main types of pavers (fixed form and slip-form) are given in the Guide to Concrete Road Construction (SO 1978). With either type of machine the slab may be laid in one or two layers. However, there are more restrictions on single course paving.

2 (11/03) With fixed form paving, the control of surface levels is mainly governed by the spreader being able to spread the concrete evenly to the correct surcharge. It is bad practice to rely on subsequent regulating beams and the diagonal finisher to achieve the correct levels by a major planing operation. If the first regulating beam in the compactor/finisher has too big a roll of concrete anywhere along the beam the setting of the spreader should be changed. The roll in front of the regulating beam or diagonal finisher should be between 100 mm and 150 mm evenly distributed along the beam. If the roll is too great then adjustment should be made at the spreader. If segregation occurs in the roll, adjustments to the consistence of the concrete may be necessary.

3 With slip-form pavers there is a tendency for edge slump in the concrete immediately after leaving the paver. If the slump is out of tolerance for level fixed side forms are required where concrete being placed has to be matched to another section of pavement, eg. at slip road tapers or when construction is in two or more strips. In other work it is advisable for transverse finishing operations to be made against the crossfall to reduce the effect of flow towards the low side. Similarly on steep longitudinal gradients construction should preferably be up the gradient.

4 Joint groove formers should be cleaned prior to and after texturing to prevent concrete or mortar bridging over them, which would later cause spalling of the joint arrises.

NG 1025 Construction by Small Paving Machines or Hand Guided Methods

1 If sufficient internal vibration is provided and truss type finishing screeds with multi-vibration points are used together with scraping straight edge and bull floats where necessary, a well compacted slab with a satisfactory level and finish can be achieved. There is no technical restriction on the lengths of pavement which can be constructed in this manner, which is suitable for short bypasses, urban areas, widening or slip roads. More even distribution of the concrete is obtained if auger spreaders are fitted to the screeds.

2 Slip road tapers adjacent to a concrete pavement should always be of a similar construction for the full length of the taper, which is adjoining the concrete slab, in order to keep the same depth of construction across the whole pavement width. If the remainder of the junction or roundabout is of flexible construction, a standard transverse transition slab should be included at the end of the taper after the slip road has diverged and is separate from the carriageway. The slip road taper slab should not be tied longitudinally to the main carriageway after the point where the traffic lanes of the slip road leave the main carriageway, as this is the point at which changes in level and direction of movement of the slabs can occur. Joints in that part of the slip road taper which is tied to the carriageway and constructed at the same time can be normal to the axis of the main carriageway and in the same line of the main carriageway joint.

NG 1026 Finished Surface Requirements

1 (11/03) It is important that a uniform macrotexture is achieved both along and across the slab. It is therefore necessary to take full account of the consistence of the concrete at the time of brushing and the operator must have the ability to gauge the optimum time for brushing after compaction and finishing of the concrete. Care should be taken to minimise variations which may occur with differences in ambient conditions and the consistence of the concrete.

Brushed Concrete Surface Finish

2 (11/02) From experience a suitable macrotexture can be obtained by using a wire brush made of 32 gauge tape wires grouped together in tufts and initially 100 mm long. The brush should have two rows of tufts. The rows should be 20 mm apart and the tufts in one row should be opposite the centre of the gap between tufts in the other row. The brush should be replaced when the shortest tuft wears down to 90 mm long.

3 (11/03) If the macrotexture depth is over 1.25 mm it will produce unacceptable tyre noise. Trial lengths should be closely monitored and if the macrotexture depth is outside the limits, adjustments should be made to the consistence of the concrete, or to the pressure on the brush, or to the time when brushing is carried out after compaction, or the type of brush changed. Thereafter spot checks should be made on the concrete surface as necessary.

4 (11/02) Where the surface macrotexture from the average of ten results has been found to be deficient or excessive the areas to be rectified can be assessed from the individual measurements. If necessary, additional measurements can be made in a particular lane to decide the limit of treatment. If four or more successive individual measurements are deficient or excessive, the area relating to those measurements should be treated across the full lane (or lanes) width.

5 (11/02) Isolated areas less than 6 m in length need not be treated unless the macrotexture has been omitted altogether or riding quality is impaired. If such areas are close or occur in a regular pattern or chain, they should not be left untreated.

6 Measurements should be carried out in sufficient time before opening to general traffic to allow the Contractor to complete remedial works, taking into account the effect of wear of heavy construction traffic.

7 The depth of grooved texture (hardened concrete) should be measured by means of a tyre tread gauge.

NG 1027 Curing

1 Curing is essential to provide adequate protection from evaporation and against heat loss or gain by radiation and so permit the concrete to achieve its designed strength. The retention of moisture is particularly important with cement or cement blends which have a slow rate of increase in strength. Without moisture the hydration process cannot be completed. Without adequate curing the concrete strength could be half the strength of the corresponding cubes cured in water in the laboratory.

2 (05/02) The best form of curing is to keep the concrete constantly damp. This can be achieved by covering the concrete with plastic sheeting, or by a sprayed plastic material which hardens into a plastic sheet, which can be removed by traffic, or by an aluminised curing compound. For small bays or patches, wet hessian covered by plastic sheeting is satisfactory. For concrete slabs a waterproof bituminous spray is normally sufficient.

3 Plastic sheeting or sprayed plastic film will avoid the risk of damage by rainfall and the consequent cost of rectification by surface grinding, retexturing or relaying. The use of tentage will also reduce the risk of rain damage but unless closed at sides and ends it could cause a wind-tunnel effect which would reduce the curing. Where tentage is used measures should be taken to prevent drips falling on to unhardened concrete. Tentage covers should overlap by a minimum of 500 mm. Remedial works leave a generally patchy, aesthetically unpleasant surface. The rate of progress of fixed form paving plant makes the provision of tentage feasible, but with the higher output of slip form pavers tentage is generally uneconomical, and without rails there could be damage to the sides of the pavement. Sprayed plastic film allows paving to continue in wet weather, except in heavy storms.

4 Thermal insulation blankets provide accelerated curing and an increased rate of strength development.

NG 1028 Trial Lengths

1 Trials to prove new or modified machinery should be carried out off Site or below pavement level. The Contractor is permitted to choose whether he lays the trial as part of the pavement or elsewhere, but if the former, he is not allowed to proceed with other trials or further paving at pavement surface level until any defective trial lengths have been removed, or rectified to comply with the Specification.

NG 1029 Texturing of Hardened Concrete

1 Experience has shown that grooving, with the grooves at an irregular spacing and of average size 3 mm wide by 4 mm deep as required, produces less tyre noise than surface dressing. It is the only acceptable method of retexturing the surface of concrete pavements as it will provide a long life texture.

Grooving across joints should be avoided as this could lead to minor spalling and damage to the seal. In order to obtain the minimum depth of 3 mm the setting of the machine should take into account the transverse irregularity of the surface. Isolated areas of substandard texture less than 1 m in length along the carriageway would be unlikely to require treatment except in special circumstances.

NG 1030 Wet Lean Concrete

1 (11/04) Wet lean concrete is the term describing lower strength concretes which, using present pavement design, are suitable only for sub-bases. Four classes of wet lean concrete have been selected. These provide a range of strengths sufficient to enable the Contractor to choose a concrete stronger than the minimum specified to permit early access onto a sub-base after laying.

The inclusion of wet lean concrete in the Specification allows the Contractor to choose alternative methods of laying the sub-base most suited to the size and location of the contract; as a workable concrete via paving plant or by hand guided methods.

NG 1043 (05/01) Foamed Concrete

1 (11/03) Foamed concrete is a lightweight material produced by incorporating a preformed foam or an air entraining agent into a base mix of cement paste or mortar, using standard or proprietary mixing plant.

2 (11/03) Foamed concrete is normally prepared on site, either from basic constituents, or using ready-mixed base mortar delivered to site. However, subject to experience gained by prior development that the material is suitable for transport by road, it may be delivered to site entirely ready-mixed.

3 (11/03) Foamed concrete should be prepared in accordance with a mix formulation proven, by prior development testing, to yield a compressive strength within the required range. The wet density corresponding to the specified strength should be determined in the development testing.

4 The wet density of the foamed concrete should be checked prior to and during placement or as agreed.

5 On any site presenting special drainage or groundwater problems, the foamed concrete should be formulated to have a permeability not less than that of the surrounding ground. Alternatively a backfill layer of pea gravel, of 100 mm minimum thickness and surrounded by a geotextile filter fabric where appropriate, may be considered to offer an equivalent drainage potential.

6 Foamed concrete flows very easily and may infiltrate, and block, any damaged drainage or ducting existing within, or immediately adjacent to, the excavation. Unguarded reinstatements can represent a drowning hazard for children.

NG 1044 Pavements with an Exposed Aggregate Concrete Surface

1 Guidance to the requirements specified in Clause 1044 is contained in Chapter 3 of HD 38.

2 Methods and construction requirements for this type of surface should be based on the general requirements of Series 1000.

3 (05/01) The PSV and AAV requirements of the coarse aggregate in the surface layer concrete are dependent on the traffic category and should be specified in Appendix 7/1. Guidance on the PSV and AAV requirements is given in Chapter 2 of HD 36.

4 (11/03) Attention is drawn to the flakiness index requirement in Clause 1044 for the coarse aggregate in the top layer concrete. This is Flakiness Index category FI_{15}, rather than the more common FI_{20}.

5 Sub-Clause 1044.5.(iv) specifies that at least 60% of the concrete (total mass of the constituents excluding water) should consist of the coarse aggregate specified in Appendix 7/1. This is to ensure that sufficient coarse aggregate is presented at the surface after brushing the laitance to expose the aggregate.

6 Hardness and durability of the coarse aggregate should be as described in sub-Clause 901.2.

7 (11/03) The compiler should specify in Appendix 7/1, coarse aggregate size and appropriate macrotexture depth requirements using Table NG 10/2. A high speed road has an 85 percentile speed of traffic exceeding 90 km/h (55 miles/hour). The compiler should assess if the in-use traffic speed of the road is anticipated to be above this level.

8 The Contractor should be required to submit at the time of tender a completed Appendix 10/1, containing details of his proposed plant and equipment to achieve the required surface.

9 The Contractor is required to submit to the Overseeing Organisation for their consent a detailed method statement one month prior to the commencement of site trials. In the UK trials have been successfully concluded using conventional rail mounted paving equipment, but in the rest of Europe and elsewhere contractors have normally chosen to use slipform paving equipment.

TABLE NG 10/2 (11/03) **Grading and Macrotexture Depth Requirements**

CATEGORY OF ROAD	COARSE AGGREGATE SIZE (mm)	MACROTEXTURE DEPTH REQUIREMENTS		
		AVERAGE	MAXIMUM	MINIMUM
High Speed Roads (> 90 km/h)	6.3/10	1.5 mm ± 0.25 mm	1.80 mm	1.20 mm
Low Speed Roads (≤ 90 km/h)	4/8	1.0 mm ± 0.20 mm	1.30 mm	0.75 mm

NG 1045 (05/01) Weather Conditions for Laying of Cementitious Materials

1 Thermal insulation blankets laid on the finished concrete can enhance the rapidity of curing by the retention of heat. This is of benefit not only in cold weather, but also at other periods to accelerate the curing of the concrete slab.

NG 1048 (05/01) Use of surfaces by Traffic and Construction Plant

1 (11/03) Where there is a need to open a section of concrete pavement or base to traffic early after placing the concrete, high strength concretes may be used. To estimate the time when the required strength may be achieved trial mixes should be tested at various early periods to establish a rate of strength development. These times can be confirmed by testing cubes which were placed alongside the pavement in moulds insulated around the sides. However, such results can only be used as an expedient for the purpose and not for compliance with the Specification.

NG SAMPLE APPENDIX 10/1: (05/01) PLANT AND EQUIPMENT FOR THE CONSTRUCTION OF EXPOSED AGGREGATE CONCRETE SURFACE

The Contractor shall insert details below of the methods, plant and equipment he intends to use in the Works to construct an exposed aggregate concrete road surface to Clause 1044 and **shall submit this Appendix with his Tender.**

No. of Layers *[1044.3]*	a) One b) Two		....
Paving Equipment *[1044.6]*	a) Fixed Form b) Slip Form	i) Two Separate pavers ii) Two layer paver i) Two Separate pavers ii) Two layer paver	....
Retarder Type *[1044.12]*	a) Manufacturer b) Type reference		....
Brushing Details *[1044.8]*	a) Wet b) Dry		....
Brushing Equipment *[1044.23]*	a) On Slab b) Spanning Slab		....

Retarder Protection Method *[1044.16]* ....