Road Pavements - Concrete and Cement Bound Materials

NG 1001 Grades and Constituents of Concrete

1 Clauses 1001 and 1002 give the requirements for materials and limits for mix proportions for designed concrete mixes in the form required in BS 5328.

2 In addition to Portland cement (PC) the term 'cement' includes blends of PC and pulverised-fuel ash (PFA,), whether they are blended on site or manufactured by blending or intergrinding.

3 For durability it is necessary to have a water/cement ratio below 6.45 for a pavement surface slab. The water/cement ratio is defined as the ratio of free water to total cement content of the mix.

4 PC/PFA concrete has a long term increase in strength greater than PC concretes for the same 28-day strength and provide greater durability and resistance to chemical attack. If PFA is included in the mix it permits lower water/cement ratios for a required workability, so providing denser concrete of lower permeability and greater durability.

Admixtures

5 Air entraining agents are essential in pavement surface slabs to reduce permeability and frost damage. They also have a plasticising effect. They are not necessary in roadbase concrete unless the concrete is to be exposed to frost before the surfacing is applied. A small loss in strength is to be expected with air entrained concrete compared with plain concrete with the same mix proportions.

6 Plasticisers can be used to reduce water in the mix, increase strength and maintain workability at the required level. They can be beneficial in mixes with blends of PC with PFA, as the water reduction partially compensates for the loss of early strength.

7 Where low water/cement ratios are used to obtain C40 strength, retarders can be used in high summer temperatures, to ensure that the finishing processes can be completed in time.

Aggregates

8 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.

9 Popouts can occur in the surface of the concrete slab when frost-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 frost, close to transverse and longitudinal joints.

10 The use of aggregate with high water absorption values is not desirable. In addition to frost damage due to absorption of water there is a higher risk of alkali silica reaction in the presence of moisture in the porous aggregates. Details of the required tests should be scheduled in Appendix 1/5.

11 The soundness test should be used for source approval for aggregates, the durability of which the Engineer considers questionable. It is not intended as a mandatory test for known durable aggregates. The water absorption test can be used as a routine check test of such aggregates.

NG 1003 Density

1 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. lb 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 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.

3 As a rough rule for assessment of strength, 1% reduction in density equates to a 5% loss of strength of concrete.

4 Calculation of the theoretical maximum dry density (TMDD) of the concrete, for comparison with cores, should take into account the bound water due to the hydration of the cement. This will vary with the age of the concrete. In calculating the TMDD the mass of hydrated cement is found by multiplying the mass of cement in the fresh cement mix by a time factor (F) determined from the following Table NG 10/1.

Table NG 10/1: Time Factor (F) for Hydrated Cements and Cement Blends

Age (Days)	*PC*	*PC/PFA*
1-3	1.13	1.11
>3-7	1.15	1.14
> 7-91	1.19	1.17
> 91-365	1.22	1.22

The theoretical maximum dry density (TMDD) of the concrete shall be calculated from the formula:

$$\text{TMDD} = \frac{[(F \times W'i + W' + W'J \times 1000}{\frac{W}{pi} + \frac{W^4}{JJ4} + \frac{W}{} + W^a}$$

Where:

F = time factor for hydration of cement from Table NG 10/1
W' = mass of cement (kg)
W- = mass of total water (in aggregate + added)(kg)
W* = mass of oven-dry fine aggregate (kg)
W^4 = mass of oven-dry coarse aggregate (kg)
P' = relative density of cement
F = apparent relative density of fine aggregate
P^4 = apparent relative density of coarse aggregate

Note:

(i) The apparent relative density and moisture content shall be determined in accordance with the method described in BS 812 : Part 2.

(ii) Where more than one size of coarse aggregate is used then:

$$W' = W' + W- + W' + \qquad W''$$

and

$$\frac{W^4}{} \quad \frac{W''}{p.} \quad \frac{W^b}{p.,} \quad \frac{W<}{p} + \ldots \quad \frac{W''}{P''}$$

Where W" is the mass of oven-dry aggregate of a certain fraction and P^n is the apparent relative density of that certain fraction.

(iii) Where blends of PC and PFA are used then:

$$W^1 = W + W''$$

and

$$\frac{W^1}{P'} \quad \frac{W''}{p} \quad \frac{W''}{p_p}$$

where suffix = PC
" = PFA

values of P° = 3.12
P^p = 2.00 are recommended

Table NG 10/2 gives a worked example of the determination of the theoretical maximum dry density (TMDD).

NG 1004 Quality Control of Concrete Strength

1 BS 5328 : Part **4** is used as the basis for control testing of pavement concrete but the rate of sampling and testing has been modified.

2 The 7-day strengths are used to give early warning of the possibility of low results and any need for additional cement after 7 days can be verified by the test results at 28 days. The ratio between 7 and 28 days should be established on laboratory trial mixes, but once paving has started this ratio can be updated from the most recent test results of 7 and 28 days on the same batches.

3 When two radically different mixes are used in the slab in two-layer construction, the statistical check on strength results should be carried out on the mixes separately.

4 The average value of **4** results represents 300 nr of work at the minimum specified rate of testing. If the Contractor wishes to reduce the area of pavement at risk he may wish to arrange with the Engineer for a higher rate of testing.

5 Cores may be taken and tested in compression and assessed in accordance with BS 6089 in order to assess whether (and how much) concrete should be rejected in the event of compression strengths of representative batches not meeting the specified value. The number and position of cores should be agreed with the Contractor before cores are taken.

Table NG 10/2: **Density of Concrete**

Constituent	*Batch J Weight kg*	*Moisture Content %*	*Water in Aggregate kg*	*Oven Dry Weight kg*	*Relative Density glcm**	*Absolute Volume m'*	*Mass of Partially Hydrated Material kg*
Cement	336			336	3.12	0.108	386.4**
Water	137					0.191|t	
Fine Agg	689	4.7	30.9	658.1	2.63*	0.250	658.1
Coarse 40-20	657	1.2	7.8	649.2	2.60*	0.250	649.2
20-10	330	1.9	6.2	323.8	2.60*	0.125	323.8
10-5	221	4.1	8.7	212.3	2.62*	0.081	212.3
			53.6			1.005	2229.8

Apparent Relative Density
tf Volume of total water (water in aggregate + water added at mixer)
** Time Factor (F) of 1.15 used

Theoretical Maximum Dry Densitv (TMDD) $= \frac{\quad}{1.005} = 2219$ kg/m'

Minimum dry density requirement of 97<# = 2219 x 0.97 = 2152 kg/m'
(non-air entrained concrete)

Minimum dry density requirement of 93# # = 2219x0.93 = 2064 kg/m³
inon-air entrained concrete)

Notes: t **In practice the batch weights for air entrained and non-air entrained concretes are unlikely to be the same**
92^**r for** 20 **mm maximum size**

NG 1005 Workability

1 The compacting factor (CF) is a suitable workability test for most of the stiff mixes required for machine paving, because it can be carried out alongside the paver. The volumetric method for the CF test as in BS DD90 or the Vebe, or other vibrating tests should be used on trial mixes of cohesive mixes, e.g. when PFA is used, to measure the effect of vibration for a range of CF values.

2 The optimum compacting factor at the paver will need to be re-assessed at intervals depending on the climatic conditions.

3 Workability should be constant. A useful check on whether the workability 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.

4 The target values for CF will vary with the mixes and materials used and with the weather. Approximate values are:

(i) single layer construction 0.80 - 0.85

(ii) two layer construction
top layer 0.80 - 0.83, bottom layer 0.75 - 0.78

Low workabilities are required in the concrete to ensure that inserted dowel bars are retained in position. Higher workabilities are 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.

5 As consistently correct workability 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.

NG 1006 Trial Mixes

1 Unless suitable data is offered to and accepted by the Engineer, trial mixes are required for each source of material to be used. Cements from different sources used with the same mix will have varying effects on the strength and workability of the concrete.

2 The trial mix in the laboratory should be assessed, not only for strength but also for workability and the effects of vibration. It should be used to assess the rate of gain of strength between 7 and 28 days. It is important to know what the ratio will be during the trial length as 28 day results may not be available before normal working is likely to commence.

3 Trial mixes should be used to obtain the rate of gain of strength of concrete to assess the time when the pavement layer may be used by traffic. The tests should be completed in advance of the start of urgent work such as reconstruction or widening existing roads.

NG 1007 Separation Membrane

1 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.

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 When fixed height supports are used, e.g. rings of standard mesh reinforcement, it is necessary to ensure a good surface regularity to the sub-base or roadbase on which the reinforcement is laid.

3 When pre-fabricated 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 pre-fabricated sheets at the position of the laps.

NG 1009 Transverse Joints

1 Transverse joints are normally contraction or expansion joints. Warping joints are retained in Clause 1009 for special cases, e.g. for extra joints in long narrow or tapered unreinforced concrete 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 Expansion joints can be omitted in summer and this period can be extended at the discretion of the Engineer to enable paving to be completed, provided the mid-day air temperature does not fall below 10°C. Expansion joints should be included in kerbs, channels or hard strips which are constructed in winter or a different paving season from the main pavement, and which are tied to the pavement.

3 Structures below the pavement can be isolated by at least 150 mm of granular fill and the pavement continued over them. Structures within the pavement depth should be isolated by expansion joints or fully flexible construction with at least 25 m of flexible construction on either side of the structure.

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 When it is intended to add in the future an additional lane or hard shoulder, provision should be made to tie the new and old slab together. This can be done by the inclusion of cranked tie bars in the edge of the old concrete slab at the time of its construction. This requires the addition to the specification in Clause 1010 of an additional sub-clause such as "The longitudinal (inner/outer) edge of concrete slab, excluding the edges to slip road tapers, shall have cranked tie bars as in Clause 1012", and a further addition in Clause 1012 such as "Tie bars to (inner/outer) edges of concrete slabs shall be cranked and embedded into the concrete slab with a cover of 15 mm. The cranked section of bar shall be covered by a protective coating against corrosion." A drawing showing a typical configuration should be included in the contract drawings.

NG 1011,1012, 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 lb 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 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 10/5. It will be necessary to reinstate with a 1 m long reinforced slab as a full depth repair. Alternatively the penultimate joint in a day's work could be selected for the dowel ahgnment check. The remaining concrete in the last slab is then discarded before work starts again.

5 Dowel bars, tie bars and transverse reinforcement across a longitudinal joint need to be protected from corrosion. Thin flexible plastic sleeves have been found to be effective for dowel bars. Suitable bituminous protective paint is allowed for reinforcement. Tie bars should be protected by bonded polymeric coatings.

NG 1013 Joint Grooves

1 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. 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 With wet-formed joint grooves with bottom crack inducers 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 The joint groove must form a complete discontinuity across the slab, so that the concrete will crack along the joint position.

5 In normal summer work in unreinforced concrete 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.

NG 1015 Joint Filler Board

1 Expansion joint filler board should have a pointed ridge and 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.

NG 1016, 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:

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

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

(c) 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.

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.

4 With all sealants 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.

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.

The sub-base and 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. The Engineer should ensure that precautions are 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 Delivery, Storage and Batching of Concreting Materials

1 The requirement for **8** hours storage of materials containing sands is to ensure that moisture contents are stabilised so reducing batch variability in the mixed concrete.

2 Checks should be made on the method of delivery and forming stockpiles to prevent segregation and accumulation of moisture. Aggregates can be contaminated during stockpiling, by 'dozing' or digging into the soil at the base of the stockpile.

NG 1022, 1023 Mixing, Transport and Delivery of Concrete

1 A constant supply of concrete with consistent workability is essential to maintain steady progress in paving. Disruption to this steady progress inevitably results in loss of workability making finishing difficult and leading to bad riding quality. To maintain an adequate supply to the paver, pavement quality concrete should be mixed on site in a batch type mixer with an output greater than the capacity of the paver when proceeding at the average planned speed.

2 Supplies from off-site mixing can be very dependent on local traffic conditions outside the Contractor's control, but they may be permitted for small works or other areas at the Engineer's discretion.

The variability of concrete mixed in truck mixers may be greater than that mixed in batch mixers so they are unlikely to be suitable

for large quantities of pavement quality concrete. Truck mixers may be permitted to mix pavement quality concrete for small individual slabs, otherwise they may be used only as agitators, the concrete having been mixed at the central batching and mixing plant. Tb maintain constant workability and consistent concrete its temperature should be kept as constant as possible during the day. In high ambient temperatures there is a considerable advantage in cooling the mixing water. Similarly in cold weather heated water is often necessary, but in both cases the temperature of the mixing water should not be excessive.

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 (HMSO 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 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 workability of the mix may be necessary.

3 With slip-form pavers there is a tendency for edge slump in the concrete immediately after leaving the paver. If this occurs, fixed side forms are required where concrete being placed has to be matched to another section of pavement, e.g. 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.

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 finish can be achieved. 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 Surface Texture

1 It is important that a uniform texture is achieved both along and across the slab. It is therefore necessary to take full account of the workability 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 workability of the concrete.

2 From experience a suitable texture 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 If the texture depth is over 1.25 mm it will produce unacceptable tyre noise. Trial lengths should be closely monitored and if the texture depth is outside the limits, adjustments should be made to the workability of the concrete mix, 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 Where the surface texture 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 Isolated areas less than 6 m in length need not be treated unless the texture 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 The use of tentage will 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.

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

NG 1028 Trial Lengths

1 The Engineer may only approve machinery and plant which is known or proved to be capable of constructing a pavement to meet the Specification. 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 can be rectified with the agreement and to the satisfaction of the Engineer.

2 The Engineer should notify the Contractor as soon as any deficiency is apparent and not necessarily await the full 10 days allowed for assessing concrete strength. The Engineer may allow normal working within 10 days of laying the last trial length if it is satisfactory in all respects, other than strength, and if he is satisfied from experience gained in earlier trial lengths that the strength can be easily achieved with the mix used.

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 1035 General Requirements for Cement Bound Materials

General

1 Lean concrete has been renamed Cement Bound Material Category 3 (CBM3). A new and stronger category, CBM4, has been included for higher traffic category roads.

Mix Design for Cement Bound Materials

2 Cement-bound materials are mixtures of raw material and cement that have a moisture content compatible with compaction by rolling. If the requirements for surface level, regularity and surface finish are to be achieved, compaction will need to be carried out at or close to optimum moisture content (omc). The compaction tests described in BS 1377 : Part 4 can be used to determine omc or alternatively Clause 2.1.5 of BS 1924 : Part 2 : 1990. Difficulty in determining the exact omc for clean gravel mixtures is sometimes experienced due to the lack of fines present which allows the cement/water paste to be pumped out under vibration. However a sufficiently accurate estimate of omc can usually be made from the results obtained.

3 Using the value of omc, the cement content needed to achieve the required strength can be determined by establishing the compressive strength of the CBM over a range of cement contents.

4 With some aggregates the strength requirements of CBM3 and CBM4 can be met with very low quantities of cement. Ratios of aggregate to cement greater than 24:1 are unlikely to result in an acceptable homogeneous mix and if permitted should be closely monitored throughout the works.

5 PFA may be used in combination with PC as cementitious binder for CBM. The strength gain for such mixes after 7 days is likely to be higher than for mixes using PC alone. The Contractor may wish to take account of this when using PFA blends, and this may be achieved by testing at 28 days rather than 7 days, subject to the approval of the Engineer. It will be necessary for the Contractor to show from trial mixes that the 28-day strength of the blended cement mix compares with that of the PC mix which meets the Specification requirements at 7 days. The curing period before use by traffic and overlaying should be extended to ensure that the specified 7-day strength is reached. The pozzolanic reaction of PFA requires the products of hydration of PC before it can take effect. Care will be necessary in mixes where the amount of PC is very low, due to the difficulty of dispersion of the PC during mixing. This can lead to local variations in strength with the risk of very weak patches. When using blended cements in winter there is an increased risk of frost damage if the early strength of the CBM is very low.

Delivery and Storage of Materials

6 It is important to prevent contamination and degradation of materials. The deposition of stockpiles of materials and subsequent extraction from them should be carried out in such a way that segregation is minimised.

Mix-in-plant Method of Construction

7 In this method the material, cement and water are mixed in a central plant with the resulting mixture being transported to the point of laying and spreading.

8 To ensure completed distribution of the relatively small quantities of cement, mixing should preferably be carried out in a forced action mixer of either the batch or continuous type, carefully selected such that the plant can process the material and produce a uniform CBM to the requirements of Table 10/8. If the Contractor proposes a mixer other than a forced action mixer the Engineer should ensure during the trials that a satisfactory mixing is achieved. The mixer should have an output to satisfactorily meet the demands of the spreading and compacting operations.

9 Vehicles transporting mixed CBM should be of sufficient number and capacity to meet both the output of the mixer and spreading and compacting operations.

Laying

10 The formation of satisfactory joints between adjacent areas of CBM or other material and of longitudinal joints is vital to the performance of the layer. When laying against compacted cement-bound or other material, cut back vertical joints prevent wedges of CBM which may crack or allow the riding up of one area on another.

Compaction

11 When CBM has begun to harden it is important that the matrix is not disturbed, hence the requirement that compaction must be completed

within two hours of the addition of the cement. However, some cement-bound materials are more critical than others in this respect. Equally the weather conditions at the time of construction affect this particular aspect. In all circumstances the two hour requirement should be adhered to unless site trials indicate a tightening or relaxation of this limit. Great care must be exercised when compacting CBM at joints to ensure that compaction plant does not bear on previously compacted CBM after the two hour period until the specified 7-day cube strength has been reached.

Use by Traffic

12 CBM is susceptible to overstressing if traffic is permitted to run on it before it has obtained its specified strength. Use by traffic earlier than the specified times may be permitted once the specified strength has been achieved, which may be obtained by high cement contents or special mixes. Alternatively, if high density CBM's using PFA as a filler to reach densities above 97% of theoretical density are used, early use by traffic to lay subsequent layers may be permitted.

Preliminary Trial

13 The size of the preliminary trial relates to larger areas of CBM. Where small areas are to be laid the Engineer should consider allowing trial areas of less than 400 m^2.

NG 1038,1039 Cement Bound Materials

1 The aim is to achieve a uniform layer meeting the strength and density requirements of the Specification. This is particularly important with CBM where the cement content is relatively low, and mixing and quality control need to be adequate so as to produce a homogeneous mix. The correct application of the trial and test regime clauses is most important to ensure that this is being achieved in the field and the Engineer should consider increasing the rate of testing in cases of non-uniformity.

NG 1040 Testing of Cement Bound Materials

1 Cubes for strength testing for all cement-bound materials are effectively compacted to refusal when made in the specified manner. The cube strengths are consequently higher than would be expected from cubes compacted at field density. Field density requirements are met by comparing in situ measurements with those of the strength cubes.

2 Nuclear density gauges can be operated in either direct transmission or backscatter mode. As the backscatter mode only measures the density of the top 50 mm - 60 mm of the layer, the direct transmission mode is used for CBM.

NG 1041 Use of Nuclear Density Gauges With Cement Bound Materials

1 Nuclear density gauges utilise radioactive substances and unless used in accordance with the manufacturer's instructions may be hazardous to the health of users. Regulations cover the use, transportation and storage of gauges (see NG 123). Gauge suppliers and manufacturers will usually advise on these regulations. Supervisory staff need to be familiar with the appropriate regulations and the manufacturer's operating instructions. In exceptional circumstances, where nuclear gauges cannot be used for the measurement of in situ wet density, the sand replacement method given in BS 1924 may be used as an alternative with the approval of the Engineer. The tests should be made between 4 hours and 24 hours of completion of compaction of the layer.

2 A preliminary check is included because Transport and Road Research Laboratory Report No. LR 1109 indicates that certain materials can give biased results when tested with nuclear density gauges. This is due to the radiation absorption characteristics of the material and is allowed for by re-calibration of the gauge or adjustment of the displayed result. It may be necessary to repeat the preliminary check from time to time where the materials used for CBM are variable. The mass of each block may be determined by weighing the concrete in batches before it is placed into the mould, providing accuracy is maintained.

NG 1043 Foamed Concrete for Backfilling Excavations

1 Foamed concrete is a lightweight material produced by incorporating a preformed foam into a base mix of cement paste or mortar, using standard or proprietary mixing plant.

2 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 mix is suitable for transport by road, foamed concrete may be delivered to site entirely ready-mixed.

3 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 mix 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 sites 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 Construction of Concrete Pavement with Exposed Aggregate Surface

1 Sub-Clause 1044.11 specifies that the depth of the mortar layer cover to the selected aggregate shall be uniform. Variable mortar layer cover to the selected aggregate should be avoided as this will result in unacceptable surface depressions after exposure.