SERIES NG 800
ROAD PAVEMENTS - (11/04) UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

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ROAD PAVEMENTS - (05/01) UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

NG 800 (05/01) General

1 (11/04) Advice on design and construction of subbases and bases (roadbases) is published in the Design Manual for Roads and Bridges (DMRB) Volume 7. The Clauses in Series 800 refer to BS EN 13285, 'Unbound mixtures – Specification' and Parts 1 to 5 and 10 to 14 of BS EN 14227, 'Hydraulically bound mixtures – Specifications' which cover other hydraulically bound mixtures and now form the sub-Series 800. The cement bound Clauses of Series 1000 have been moved to Series 800. These are now part of sub-Series 800 referred to above. BS EN 13285 applies to unbound mixtures of natural, manufactured aggregates such as slags and recycled aggregates. The different parts of BS EN 14227 require aggregates to conform to BS 13242 which apply to aggregates obtained by processing natural or manufactured or recycled materials. DMRB also includes advice on the use of recycled materials, see HD 35 (DMRB 7.2.1).

(11/04) Unbound Mixtures for Subbase

NG 801 (11/04) General Requirements for Unbound Mixtures

1 (11/04) BS EN 13285 specifies the requirements for unbound mixtures used for the construction and maintenance of roads and other trafficked areas. All unbound mixtures used should comply with BS EN 13285. The requirements for the properties of aggregates used in unbound mixtures are defined by appropriate cross-reference to BS EN 13242.

2 (11/04) Because BS EN 13285 aims to satisfy differing custom and practice across many Member States (MS) of the European Economic Area (EEA), the standard contains many choices, which are set out in tables. The structure of the tables allows the user to choose an appropriate category for each mixture property. None of the combinations of categories from BS EN 13285 give a mixture that is directly equivalent to the established types of granular subbase material specified in previous editions of Specification for Highway Works (SHW).

3 (11/04) After detailed review of established practice and the capability of UK suppliers, the unbound mixtures in Table 8/1 have been chosen. The Table defines each mixture using a combination of categories for:

i) designation - in terms of lower sieve size (d) and the upper sieve size (D). The lower size sieve (d) = 0 for all unbound mixtures defined by BS EN 13285.

ii) maximum fines - as measured by the percentage by mass passing the 0.063 mm size sieve.

iii) oversize - in terms of the percentage by mass of particles passing a sieve size two times the upper sieve size ($2D$) and retained on the upper sieve size (D).

iv) overall grading - the combination of overall grading category and designation define the grading envelope.

For some mixtures, the overall grading category defines additional requirements to control the grading of individual batches, as detailed in Tables 8/5, 8/6, 8/7 and 8/8.

4 (11/04) It is unlikely that a single source of supply will routinely comply with the requirements for all four of the mixtures. Compliance depends upon the type of aggregate and the capability of the production process. Other BS EN 13285 mixtures not detailed in Table 8/1 should only be used after consultation with the Overseeing Organisation.

5 The limiting values for sulfate characteristics in sub-Clauses 801.2 and 801.3 have been chosen to ensure that problems do not occur due to oxidation of reduced sulfur compounds such as pyrite. Further guidance is given in sub-Clause NG 601.8.

6 The scope of BS EN 13285 is limited to the properties of unbound mixtures at the point of delivery; it does not include water content or the properties of the finished layer. To assist in the selection of an appropriate source and to help control compaction, the system of factory production control required for the unbound mixture includes an annual declaration of a typical value of laboratory dry density and optimum water content for each unbound mixture.

Frost susceptibility, plasticity, CBR and trafficking trials are outside the scope of BS EN 13285. The requirements of Series 800 apply to these mixture properties.

Aggregates Used in Unbound Mixtures

7 BS EN 13285 requires the aggregates used in unbound mixtures to comply with BS EN 13242, Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction. Because BS EN 13242 aims to satisfy differing custom and practice across many member states of the EEA, the standard contains many choices, which are set out in tables. The structure of the tables allows the user to choose an appropriate category for each required aggregate property. BS EN 13242 also permits the use of the category "No requirement" for properties that are not relevant to a particular end use or origin of the mixture, in the interest of efficiency and economy. Further guidance on the use of BS EN 13242 is given in the Published Document PD 6682-6 'Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction - Guidance on the use of BS EN 13242' published by BSI.

8 (11/04) The requirements for aggregates in Table 8/2 have been chosen after detailed review of established practice and the characteristics of UK aggregates. The Table defines each aggregate used in the mixture as a combination of categories for:

i) **Crushed or broken particles - to ensure adequate aggregate interlock.** Crushed rock aggregates should be assumed to be in Category C90/3 without further testing. Where permitted, the use of Category C50/10 for crushed gravels ensures that not more than 10% of the particles are fully rounded.

ii) **Los Angeles coefficient - to control resistance to fragmentation.** The Los Angeles test replaces the Ten Percent Fines (TPV) and the Aggregate Impact Value (AIV) tests. The Los Angeles test can only test aggregate in a dry condition. There is not a direct correlation between the Los Angeles test and the BS 812 tests it replaces.

iii) **Magnesium sulfate soundness - to ensure resistance to freezing and thawing.** Category MS_{35} provides a level of resistance that is directly equivalent to the BS 812-121 value of greater than 65.

9 The micro-Deval test is used in some countries, notably France, to measure the resistance of aggregate particles to the abrasion caused when interlocking particles are subjected to repeated loading in the presence of water; particularly in thinner pavements with greater strains in the lower layers. The property measured by the micro-Deval test is not normally specified so Category M_{DE}NR (no requirement) is used. The supplier of the mixture is required to monitor micro-Deval values as part of the system of factory production control required by BS EN 13242. The value for the aggregate used should be stated to aid comparison between sources and so that the potential for the future use of this property can be reviewed.

10 Water absorption is not normally specified so Category WA_{24}NR (no requirement) is used. The supplier of the mixture is required to monitor water absorption values as part of the system of factory production control required by BS EN 13242. The value for the aggregate used should be stated. If necessary, the value may be used to provide a baseline for routine water absorption tests on delivered material. If any result from the tests on routine deliveries exceeds the declared value (d) by more than 0.5% further investigation will be required. Routine water absorption tests are not generally required for aggregates with a declared value of 2.0% or less.

11 In previous editions, blast furnace and steel slags were identified separately from other materials. The requirements for these materials, including those in BS 1047, are now incorporated into BS EN 13242. Table 8/2 defines requirements using categories for:

i) Volume stability for blast furnace slags - in terms of disintegration tests based on established UK requirements from BS 1047.

ii) Volume stability of steel (BOF and AEF) slags - in terms of a steam expansion test for which there is limited UK experience. Where permitted, the specified category is the most onerous. Evidence of recent satisfactory use of steel slag aggregate from the same source should also be obtained.

Recycled Aggregates

12 BS EN 13285 includes manufactured (such as slags and ashes) and recycled aggregates within its scope without specific mention in the requirement clauses. The approach adopted is blind to the source of the aggregate used in the mixture. The suitability of mixtures containing manufactured and recycled aggregates for use in subbase should be assessed in accordance with the requirements of the Series 800 Clauses.

13 The test procedure adopted in Clause 710 for identifying and quantifying constituent materials in recycled coarse aggregate and recycled concrete aggregate is a qualitative method. Where constituents other than those deemed to comply with the particle density requirements by the qualitative classification can be shown to be of a higher particle density, they

may be included within these higher density fractions provided that written agreement has been given by the Overseeing Organisation.

14 (11/04) Sub-Clauses 803.4, 804.4, 805.4 and 806.4 describe requirements for material passing the 0.425 mm sieve. Were the foreign materials component of recycled coarse aggregate or recycled concrete aggregate to be 'clay lumps', the material may fail these tests and hence fail to meet the Specification.

Unbound Mixtures Produced as Part of The Works

15 BS EN 13242 (see Annex C) and BS EN 13285 (see Annex D) specify the operation of a factory production control system to confirm conformance with the relevant requirements of the standards. Although unbound mixtures produced on site as part of the Permanent Works are not placed on the market, a factory production control system (or a quality plan with equivalent requirements) is still required to provide the necessary level of assurance.

Frost Heave

16 (11/04) The frost heave test described in BS 812-124 is costly and time consuming and is not suitable for routine control checks on Site. The test has been developed from earlier test methods to overcome problems of repeatability and reproducibility. The test is primarily intended as a method to establish whether or not an aggregate from a particular source is likely to be frost-susceptible when used in an unbound condition within that part of the road pavement subject to frost penetration. Material for the frost heave test should be representative of the source and comply with all other requirements of the Specification otherwise the test is superfluous. Once a material has been established as non-frost-susceptible the test need only be repeated if the material varies from the original sample, or where the source is changed.

17 Clause 6 of BS 812-124 sets down the procedure for adjusting the water level in the self-refrigerated unit (SRU). A possible problem has been identified that with the tolerances given to the dimensions for the cradle and specimen carriers it is possible for the porous discs in the specimen carriers to be located incorrectly in relation to the water level. In order to guard against this it is recommended that before testing commences the cradle and specimen carriers be put into the SRU without samples. A check is then made to ensure that discs are set at the level specified in the above-mentioned standard.

18 The requirement for material to be non-frost susceptible within 450 mm of the surface of a road or paved central reserve may be reduced to 350 mm if the Mean Annual Frost Index (MAFI) of the site is less than 50. The Frost Index is a measure of the severity of a period of cold weather and provides a means of assessing likely penetration of frost into a road. Frost index is measured in 'degree days Celsius below zero' and is calculated by taking the mean air temperature for each twenty four hour period and adding those values together. Frost penetration into a modern road in the British Isles may be estimated using the formula $x = 40\sqrt{I}$ where x is the approximate penetration in mm and I is the frost index for the freezing spell. The Annual Frost Index is the frost index accumulated over a year commencing September 1st. Mean Annual Frost Index (MAFI) is the average of all the frost index values computed for each year since September 1959. The MAFI for a site is determined using records from one or more meteorological stations close to the site, taking account of local geographical variation, such as high ground or frost hollows. Different requirements for different parts of a contract length may be used.

Further information on the MAFI can be found in HD 25.

Advice relating to any site, including the MAFI calculated for that site, may be purchased from:

Customer Centre
The Met. Office
Powell Duffryn House
London Road
Bracknell
Berks
RG12 2SY

Tel. No: 0845 300 0300
Fax No: 0845 300 1300
E-mail: climate@meto.gov.uk

NG 803 (11/04) Type 1 Unbound Mixtures

1 The inclusion of up to 10% natural sand passing the 4 mm test sieve is permitted at the discretion of the supplier to adjust the material grading. Maximum limits of material content are included for asphalt and foreign material in recycled coarse aggregate and recycled concrete aggregate.

2 (11/04) BS EN 13285 details additional requirements to control individual batches of unbound mixtures with an overall grading Category G_P, within a system of factory production control. Table 8/5 in Clause 803 illustrates this. The supplier should nominate a supplier declared value for the intermediate sieves in the grading envelope as part of the system of factory production control for the mixture. The nominated value should lie within the supplier declared value grading range in Table 8/5. Individual batches are then assessed using the tolerances in Table 8/5, applied to the supplier declared values. As explained in Annex B (informative) of BS EN 13285, the use of tolerances does not change the overall grading range.

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3 Table 8/5 also includes requirements for the calculated difference between the values of percentage by mass passing selected adjacent sieves. These requirements are taken from BS EN 13285 and ensure a 'well graded' mixture by controlling the continuity of the grading curve.

4 Because the requirements for aggregates used in the unbound mixtures now refer to the requirements of BS EN 13242, confirmation of conformity with the categories for Los Angeles coefficient and magnesium sulfate soundness can be obtained from the CE Mark Certificate for the aggregates used in the mixture. If a CE Mark Certificate is not available to confirm the suitability of the source, test certificates should be provided from a testing laboratory accredited by an appropriate organisation accredited in accordance with sub-Clauses 105.3 and 105.4 for the test, showing a value in excess of the minimum specified and dated not more than 6 months prior to the start of the contract.

5 Whilst there is no specified moisture content for laying and compacting unbound mixtures to Clause 803, in order to satisfy the requirements of sub-Clauses 802.8 and 803.7 it will be necessary to carry out these operations at optimum moisture content or thereabouts.

Mixtures Containing Crushed Gravel Aggregates

6 Previous editions of Clause 803 excludes all gravels from granular subbase material Type 1 but crushed gravel aggregate is permitted by BS EN 13285. Where local experience indicates that mixtures containing crushed gravel materials can be used successfully, the Overseeing Organisation may permit their use.

7 This edition of Clause 803 incorporates the requirements for crushed gravel subbase materials previously published as Clause 850SE. Trafficking trials of crushed gravel subbases used in Scotland have produced rut depths well within the upper limit (30 mm) recommended by the Transport Research Laboratory for the assessment of subbase materials if laid on Works contracts provided that:

(i) strict control over the grading is maintained; and

(ii) the crushed, broken and totally rounded particles requirements are met.

8 (11/04) No limiting value of design traffic has been imposed for Type 1 unbound mixtures containing crushed gravel. However their use on roads designed to carry more than 1500 commercial vehicles per lane per day should be clearly identified in the As-Built Records.

9 (11/04) For flexible roads with Type 1 unbound mixtures containing crushed gravel and carrying a traffic loading of more than 2 msa, the subbase strength should be at least an equivalent of CBR 30%. Further guidance about CBR is given in Clause NG 804. A trafficking trial should be considered for flexible roads carrying a traffic loading of more than 2 msa.

NG 804 (11/04) Type 2 Unbound Mixtures

1 (11/04) Current design requirements exclude Type 2 unbound mixtures from flexible roads carrying a traffic loading of more than 5 msa. Where local experience indicates that these materials can be used successfully at higher traffic levels, the Overseeing Organisation may require that a Substitute Clause should be written to permit their use. Mixtures containing a high proportion of asphalt arisings have been shown to perform well at design traffic levels higher than 5 msa, but performance should be assessed using a trafficking trail.

2 Table 8/6 in Clause 804 includes requirements for the calculated difference between the values of percentage by mass passing selected adjacent sieves. These requirements are taken from BS EN 13285 and ensure a 'well graded' mixture by controlling the continuity of the grading curve.

3 The value of CBR required for materials to Clause 804 will depend upon traffic loading. For flexible roads carrying a traffic loading of more than 2 msa the subbase strength should be at least an equivalent of CBR 30%. For traffic ranges below 2 msa the strength may be reduced to CBR 20%.

4 (11/04) If more than 15% of the material is retained on a 16 mm test sieve the whole material can be assumed without test to have a CBR value of 30% or more. CBR tests should be carried out (when necessary) on specimens which are compacted at a density and moisture content which represent equilibrium conditions under the completed pavement. In most cases the moisture content and density specified in sub-Clause 804.7 will apply but where this is not so it will be necessary to specify separately the required values of density and moisture content for the CBR test. The density relating to a particular air voids content can be calculated using the formula given in BS 1377-4. Compaction into the CBR mould should be carried out in such a way that the required density is obtained uniformly. The number of surcharge discs used in the CBR test should be equivalent to the weight of road construction above the subbase.

5 Although parameters related to the control of the construction of the pavement layer are outside the scope of BS EN 13285, it is appropriate to make information

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available to assist the purchaser's choice of unbound mixture. BS EN 13285 requires the laboratory dry density and optimum water content of an unbound mixture to be declared at least once each year, as part of the system of factory production control. BS EN 13285 permits choice from a list of four test methods for these properties, reflecting the range of mixtures and techniques used across Europe. In the UK, it is recommended that the vibrating hammer test (BS EN 13286-4) is used. This method is very similar to the established UK method defined in BS 1377-4. BS EN 13286-4 also includes a test method similar to that developed as BS 5835. That test procedure for the determination of optimum moisture content was developed specifically for graded aggregates and gives more reproducible results than the vibrating hammer test for these materials.

Mixtures Containing More Than 50% Asphalt Arisings

6 Trafficking trials of mixtures containing a high proportion of asphalt arisings (previously known as Type 4 granular subbase material) carried out by TRL have produced rut-depths well within the upper recommended limit of 30 mm.

However, the effects of this material on the surrounding environment should be fully assessed, and approvals from statutory bodies obtained where necessary, before including this material as a permitted option in Appendix 7/1.

7 (11/04) When dry, asphalt arisings exhibit a considerable resistance to compaction due to the friction of the bitumen coating. The addition of water has a significant effect on the state of compaction by reducing the friction between the bitumen coated particles. Mixtures containing more than 50% asphalt arisings should therefore be compacted at moisture contents close to the declared value of optimum water content discussed in sub-Clause NG 804.5.

8 The particle size distribution of asphalt arisings is best described by the term 'lump size distribution' because of the binding effect of bitumen. The grading envelope obtained will be dependent on the duration of shaking, the temperature at which the determination is carried out and the grading of the mineral particles within the asphalt arisings.

Agglomeration of lumps can occur in stockpiled material especially in hot weather or when the material is stored for long periods. It is important that, at the time of placing, the asphalt arisings comply with the specified lump size distribution and care should be taken to ensure that material taken from a stockpile is to the required grading. It may be necessary to demonstrate that the material actually placed meets the grading specification rather than to rely on tests at an earlier time.

Lumps, or individual particles of aggregate separated by the planing process, should be angular in appearance. Rounded particles that can be present when using arisings containing gravel aggregates can lead to difficulties in meeting the rutting criterion.

9 Particle durability in terms of the magnesium sulfate soundness test need not be verified for mixtures containing a high proportion of asphalt arisings as the aggregates will have been tested prior to the introduction of bitumen.

10 Particle hardness in terms of the Los Angeles test need not be verified for mixtures containing a high proportion of asphalt arisings as the test is unsuitable for materials containing bitumen and because the aggregate components will have been tested prior to the introduction of bitumen.

11 The performance of unbound mixtures in subbases is dependent on the bearing strength of the compacted material. The measurement of bearing capacity in terms of CBR should not be specified for mixtures containing a high proportion of asphalt arisings. The measurement of CBR for mixtures containing bitumen is problematical because the results are dependent upon the temperature at the time of compaction, the temperature at the time of testing and the duration of loading. However, as the grading envelope ensures that less than 10% of the material is retained on the 16 mm test sieve, it can be assumed without test that the material will have an adequate CBR value.

NG 805 (11/04) Type 3 (open graded) Unbound Mixtures

1 (11/04) Current design requirements permit the use of open graded mixtures in circumstances where a free draining layer is to be preferred. Type 3 (open graded) unbound mixtures is similar to the granular subbase materials previously known as Type 3 (Clause 850NI) and Type 1X, a grading derived by TRL.

2 (11/04) BS EN 13285 details additional requirements to control individual batches of unbound mixtures with an overall grading Category G_O, within a system of factory production control. Table 8/7 in Clause 805 illustrates this. The supplier should nominate a supplier declared value for the intermediate sieves in the grading envelope as part of the system of factory production control for the mixture. The nominated value should lie within the supplier declared value grading range in Table 8/7. Individual batches are then assessed using the tolerances in Table 8/7, applied to the supplier declared values. As explained in

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Annex B (informative) of BS EN 13285, the use of tolerances does not change the overall grading range.

3 Table 8/7 also includes requirements for the calculated difference between the values of percentage by mass passing selected adjacent sieves. These requirements are taken from BS EN 13285 and ensure a 'well graded' mixture by controlling the continuity of the grading curve.

4 Because the requirements for aggregates used in the unbound mixtures now refer to the requirements of BS EN 13242, confirmation of conformity with the categories for Los Angeles coefficient and magnesium sulfate soundness can be obtained from the CE Mark Certificate for the aggregates used in the mixture. If a CE Mark Certificate is not available to confirm the suitability of the source, test certificates should be provided from a testing laboratory accredited by an appropriate organisation accredited in accordance with sub-Clauses 105.3 and 105.3 for the test, showing a value in excess of the minimum specified and dated not more than 6 months prior to the start of the contract.

5 The chosen category for resistance to fragmentation in Table 8/2 is LA_{40}. A maximum Los Angeles coefficient of 35 is more appropriate for aggregates that have been used successfully in similar mixtures, but BS EN 13242 does not permit the choice of this value. Aggregate sources with a Los Angeles coefficient of 35 or more should be used with caution. Unless local experience indicates otherwise, aggregate sources with a Los Angeles coefficient in the range 30 to 35 should generally be considered as acceptable.

6 Whilst there is no specified moisture content for laying and compacting unbound mixtures to Clause 805, in order to satisfy the requirements of sub-Clauses 802.8 and 805.5 it will be necessary to carry out these operations at optimum moisture content or thereabouts.

NG 806 (11/04) Category B (close graded) Unbound Mixtures

1 For selected end uses where greater control of particle size distribution and consistency of performance is required than is available using the standard Type 1 unbound mixture, an unbound mixture with designation 0/31,5 and an overall grading category G_B can be used. This is known as a close graded granular mixture. The tighter tolerances of category G_B are unlikely to be achievable without special production regimes, probably involving batch blending of different aggregate sizes.

2 BS EN 13285 details additional requirements to control individual batches of unbound mixtures with an overall grading Category G_B, within a system of factory production control. Table 8/8 in Clause 806 illustrates this. The supplier should nominate a supplier declared value for the intermediate sieves in the grading envelope as part of the system of factory production control for the mixture. The nominated value should lie within the supplier declared value grading range in Table 8/8. Individual batches are then assessed using the tolerances in Table 8/8, applied to the supplier declared values. As explained in Annex B (informative) of BS EN 13285, the use of tolerances does not change the overall grading range.

3 Table 8/8 also includes requirements for the calculated difference between the values of percentage by mass passing selected adjacent sieves. These requirements are taken from BS EN 13285 and ensure a 'well graded' mixture by controlling the continuity of the grading curve.

4 Because the requirements for aggregates used in the unbound mixtures now refer to the requirements of BS EN 13242, confirmation of conformity with the categories for Los Angeles coefficient and magnesium sulfate soundness can be obtained from the CE Mark Certificate for the aggregates used in the mixture. If a CE Mark Certificate is not available to confirm the suitability of the source, test certificates should be provided from a testing laboratory accredited by an appropriate organisation accredited in accordance with sub-Clauses 105.3 and 105.3 for the test, showing a value in excess of the minimum specified and dated not more than 6 months prior to the start of the contract.

5 The chosen category for resistance to fragmentation in Table 8/2 is LA_{40}. A good resistance to fragmentation is required to ensure that a closely controlled product does not degrade excessively during handling and compaction. Aggregate sources with a Los Angeles coefficient of more than 30 should be used with caution. It may be appropriate to monitor changes in grading during laying and compaction if the Los Angeles coefficient is 35 or more.

6 Whilst there is no specified moisture content for laying and compacting materials to Clause 806, in order to satisfy the requirements of sub-Clauses 802.8 and 806.5 it will be necessary to carry out these operations at optimum moisture content or thereabouts.

(11/04) Cement and Other Hydraulically Unbound Mixtures for Subbase and Base

NG 810 (11/04) General Requirements for Cement and Other Hydraulically Bound Mixtures

Background for the Changes

1 Cement bound materials specifications have been moved from Series 1000 to Series 800. They are augmented by specifications for other hydraulically bound mixtures (HBM) and now form a collected sub-Series of the specifications under the general description of cement and other hydraulically bound mixtures for subbase and base. The term 'mixtures' is used in preference to 'materials' to conform to BS EN 14227 Parts 1 to 5 and 10 to 14, which provide specifications for mixture production as far as the point of mixture delivery.

2 Throughout BS EN 14227 there are options, from which the designer and compiler may choose.

3 Cement and other hydraulically bound mixtures are specified in BS EN 14227 with each part number applying to a unique binder type and separate part numbers for mixtures with granular aggregates and for mixtures with soil as the receptor material. The prime characteristic of hydraulically bound mixture (HBM) is the aggregate and mixtures are grouped within this specification by reference to their aggregate type and then to their binder type and as indicated in Table NG 8/1. Finally they are defined by their strength.

TABLE NG 8/1 (11/04) **Cement and Other Hydraulically Bound Mixtures - Classification**

Clause No	Desgination	Binder	Aggregate or mixture grading
821	CBGM A	Cement	Broad graded aggregate
822	CBGM B		Close grade aggregate
823	CBGM C		Graded mixture
830	SBM B1-2	Slag	0/31,5 mm graded mixture
	FABM 1	Fly ash	
	HRBBM 2	HRB	
831	SBM B2	Slag	Graded mixture with compacity requirement
	FABM 2	Fly ash	
	HRBBM 2	HRB	
832	SBM B3	Slag	0/6,3 mm graded mixture
	FABM 3	Fly ash	
	HRBBM 3	HRB	
834	FABM 3	Activator(s) only e.g. lime, cement etc.	Fly ash
840	SC	Cement	Naturally occurring soils and secondary materials without controlled grading
	SS	Slag	
	SHRB	HRB	
	SFA	Fly as	

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Application of HBM to the Chosen Pavement Designs

4 CBGM is relatively fast setting, by comparison with most of the other HBM formulations. It also generally has a lower binder demand for a given strength. Consequently the binder volume has less influence on the total grading than it does for other HBM types. Thus the CBGM grading is generally defined for the aggregate alone without regard to the total mixture proportions. The volume of fine material added to HBM, other than CBGM, as binder and/or activator can be large. Further, non-cement bound HBM is usually required to carry site traffic, and sometimes in service traffic, before it is fully set. Mechanical stability of the partially bound mixture is therefore important and the grading is specified for the complete mixture, including the binder and any activators. Where high grade cement bound mixtures (e.g., CBGM B or C) are required to take early trafficking, or where special considerations of shrinkage or density are appropriate, the mixture may be specified by mixture grading.

5 The secondary classification is by binder type. For cement bound granular mixtures three secondary classifications are provided, CBGM A which is approximately equivalent to CBM 2, and 2A and CBGM B and CBGM C which are approximately equivalent to CBM 3, 4 and 5. CBGM A, B and C cannot be directly substituted for the previous specifications without reference to the revised design method detailed in "Development of a More Versatile Approach to Flexible and Flexible Composite Pavement Design" TRL Report 615. Third classification is by strength by compressive or tensile strength, e.g., $C_{6/8}$ or T2.

6 All of the HBMs, other than CBGMs, have virtually identical specifications, other than that for the defining binder type. The mixtures are defined primarily by aggregate characteristics, secondly by binder type and thirdly by strength, in common with the GBGM approach. Mixtures with similar grading characteristics and strength classification but differing binder type cannot, necessarily, be substituted for each other due to differences in strength development with time.

7 BS EN 14227-10, -12, -13 and -14 for soil cement and treated soils are similar for each of the four principal binders and are covered by a single specification Clause. As with the granular mixtures, mixtures with similar grading characteristics and strength classification but differing binder type cannot, necessarily, be substituted for each other due to differences in strength development with time.

8 Allowable mixture specifications from the selection given in Table NG 8/2, together with their complementary layer depths should be included in Appendix 7/1, Schedules 3 and 5. The compiler may wish to include a number of options in Appendix 7/1, Schedules 3 and 5 to allow flexibility to ensure selection of the most appropriate mixture. Tenderers may be permitted to submit additional designs as alternative tenders.

9 Designs should be prepared using compressive strength class R_c, or when the R_tE design system is used the direct tensile class R_t of the mixtures. Mixtures may only be selected from those given in Table NG 8/2.

10 Frost resistance requirement was not considered previously, as the lowest design strength was sufficient to provide frost resistance. The new specifications allow the use of materials with compressive cube strength below 3 MPa, which is considered the lowest strength at which frost resistance is always likely to be achieved. Special consideration will be required where the design requirements are for mixtures, which will not have attained a compressive cube strength of 3 MPa before the 1st November. Such considerations will include:

(i) the frost penetration depth, see sub-Clause 801.7;

(ii) whether a sufficient depth of material to afford protection against temperatures less than 0ºC will cover the low strength material after the 1st November; and

(iii) The frost susceptibility of the aggregate or binder type e.g. mixtures with soft limestone aggregates will be more prone to frost degradation than mixtures with granite aggregate of a similar mixture strength. Thus in the case of a non-frost damage prone aggregate the 3 MPa limit could reasonably be reduced.

In cases of doubt reference should be made to Overseeing Organisation.

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Table NG8/2 (11/04) **Laboratory Mechanical Performance Category Permitted Options**

HBM designation	Compressive strength R_c	Direct tensile strength R_t
CBGM A	C 3/4, C 5/6, C 8/10	T1, T2, T3
CBGM B	C 8/10, C 12/15, C 16/20, C 20/25	T3, T4, T5
CBGM C	C 8/10, C 12/15, C 16/20, C 20/25	T3, T4, T5
SBM B1-2	C 6/8, C 9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
FABM 1	C 6/8, C 9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
HRBBM 1	C 6/8, C9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
SBM B2	C 6/8, C 9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
FABM 2	C 6/8, C 9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
HRBBM 2	C 6/8, C 9/12, C 12/16, C 15/20, C 18/24	T2, T3, T4
SBM B3	C 3/4, C 6/8, C 9/12, C 12/16	T1, T2, T3
FABM 3	C 3/4, C 6/8, C 9/12, C 12/16	T1, T2, T3
HRBBM 3	C 3/4, C 6/8, C 9/12, C 12/16	T1, T2, T3
FABM 5	C 3/4, C 6/8	T1, T2
SC	C 0.8/1, C 1.5/2, C3/4, C6/8, C9/12	T1, T2, T3
SS	C 0.8/1, C 1.5/2, C3/4, C6/8, C9/12	T1, T2, T3
SHRB	C 0.8/1, C 1.5/2, C3/4, C6/8, C9/12	T1, T2, T3
SFA	C 0.8/1, C 1.5/2, C3/4, C6/8, C9/12	T1, T2, T3

NG 811 (11/04) Constituents of Cement and Other Hydraulically Bound Mixtures

1 Care will be necessary when mixing HBM when the amount of binder or activator is very low, due to the difficulty of obtaining a thorough dispersion of the binder or activator during mixing. When using blended cements in winter, or other slow hardening binders on the approach of winter, there is an increased risk of freeze/thaw damage if the early strength of the mixture is very low. Care should be taken to ensure that frost protection is provided when the ground and/or air temperature falls below 2°C and until the in-situ equivalent cube strength of the in-situ layer has reached a value of 2 MPa.

2 Soil cement and GBGM A have been mixed successfully using volume batching or in-situ stabilisation at total cement contents at, or close to, the minimum in Table 8/10. Success at such low cement contents depends on:

(i) the cleanliness and grading of the soil to be stabilised;

(ii) the skill to maintain close control of the spread rates; and

(iii) the efficiency of the binder dispenser or spreader.

3 The additional cement requirements need not be applied if recent, well-documented and certified evidence can be produced of consistent mixing having been achieved with the same plant and operators on similar soils or aggregates. Unless such evidence is available a trial should be carried out over a period of not less than 5 full days work, covering a total area of not less than 3000 m^2. The success of the trial should be judged on the cubes made from samples taken at a minimum of 10 approximately evenly spaced locations per day and tested at not less than 7 days. A trial would normally be considered successful if the results for the mean strength were above the characteristic strength specified for the layer in question and no result fell below 85% of that strength, all results being adjusted to allow for the age of test on the basis of the results of job mix trials. A successful trial could be incorporated into the Permanent Works.

4 Any variation to the minimum binder content agreed by the Overseeing Organisation should be subject to reassessment if the source materials, method of working or operatives are significantly changed.

NG 813 (11/04) General Requirements for Production of HBM and Construction of HBM Layers

1 Care will be necessary when using HBM when the amount of Portland cement CEM 1 to BS EN 197-1 or activator is very low, due to the difficulty of dispersion of the CEM 1 or activator during mixing. When using blended cements in winter, or other slow hardening binders on the approach of winter, there is an increased risk of freeze/thaw damage if the early strength of the mixture is very low. It is recommended that frost protection should be provided when the ground or air temperature falls below 2ºC, until the in-situ equivalent cube strength of the in-situ layer has reached a value of 2 MPa.

2 Where a mixture is to be mixed in-situ and then excavated and transported to the site of laying the construction requirements for mix-in-place construction should apply.

3 The construction period has formerly been defined by the number of hours from the addition of the binder to the mixture until the completion of compaction. This is thought to be too restrictive in some circumstances and inadequate in other circumstances. Table 8/11 provides greater flexibility and allows for the variation in the rate of hydration of HBM binder with temperature. No hydration is assumed at temperatures below 3ºC.

4 To calculate the elapsed construction period, the temperature (in ºC) should be the recorded at hourly intervals and 3ºC subtracted from the recorded value; to give the hourly maturity value. The sum of the hourly maturity values (positive only) will give the construction period in degree hours. For slow setting binders it is reasonable to measure temperature at greater regular time intervals, but not exceeding 6 hours, and to multiply each temperature difference by the number of hours between each measurement before summating the maturity values.

5 All plant-produced mixtures are required to be paver laid in order to assure consistent levels of compaction and level tolerance. The Overseeing Organisation may permit the use of other laying systems for subbase if the Contractor can demonstrate in a site trial that satisfactory performance is achieved. Subbase level consistency, while still required to be within the specified limits, is less important than the consistency of level and compaction of the base and the Overseeing Organisation should consider this when reviewing any contractor's proposals to construct subbase using machinery other than a paver.

NG 814 (11/04) Mix-in-Plant Method of Construction Using Weigh Batching for HBM

1 Types of mixers

(i) Forced action mixers are required to distribute and thoroughly mix the relatively small proportions of binder or activator with the often fine graded aggregates or soils, which are common in HBM layers. Forced action mixers mix the components of the mixture without reliance on gravity to produce mixing by the free-fall of the aggregates. This action is normally produced by either:

(a) a batch mix system using a vertical axis rotating pan mixer with fixed location vertical blades to force the flow to the center of the pan and prevent the agglomeration of fine material at the pan wall; or

(b) a continuous process where horizontal pairs of counter rotating intermeshing helical blades mix the aggregates and binders fed into the mixer, after blending.

2 The previous specification required that the mixed material should be protected from the weather during transport. Where haul distances are short and weather condition are unlikely to dry or cause excessive wetting at the surface of loads vehicles may not need sheeting. As a first approximation the omission of sheeting could be considered by the Overseeing Organisation when the construction period is less than half of the minimum period in Table 8/11.

3 Segregation may be observed as the occurrence of single zones of coarse aggregate greater than 0.04 m^2 without continuous medium or fine aggregate between the larger particles.

4 HBM binders do not hydrate once the mix temperature falls to close to zero. Further, if freezing occurs in a unhardened mixture it will disrupt the bonding of the matrix and coarse aggregates and could displace aggregates by the formation of ice lenses. It is therefore essential that a mixture should develop sufficient tensile strength to resist the internal freezing forces before being subject to temperatures below zero. With cement bound granular mixtures, soil cement and some HBMs with slag binder systems strength develops relatively quickly and if the construction is limited as described in the clause work may continue throughout the year. Where mixtures contain less than 3% of cement there is a danger of hardening taking place so slowly that the integrity of the mixture will be put at

risk. Construction of these mixtures is, therefore, not allowed in the winter.

5 In some circumstances, where rapid construction of the overlaying layers is proposed, the overlaying layers can provide adequate insulation to enable the winter working restrictions to be waived. In general it is unlikely that a cover of less than 300 mm would provide sufficient frost protection to non-cement bound mixtures. A risk assessment should be carried out taking into consideration:

(i) the likely strength gain of the mixture prior to overlay;

(ii) the site location, TRL Report RR 45 provides guidance on the influence of location; and

(iii) the likely construction date.

6 Drying out may be observed when the capillary suction forces of the mixing water no longer hold the fine material on the surface of a layer together. This can happen particularly as a result of high winds or low air humidity even in winter conditions.

7 Early, well controlled trafficking that will not cause damage to the pavement may be permitted. This is more likely to be achieved if:

(i) well graded mixtures made with 100% crushed hard aggregate should be suitable for immediate trafficking without demonstration;

(ii) subject to performance under a PTR, well graded mixtures made with 100% crushed weak aggregate should be suitable for immediate trafficking;

(iii) subject to performance under a PTR and provided the IBI > 50, well graded mixtures with not less than 50% crushed hard constituents should be suitable for immediate trafficking;

(iv) subject to performance under a PTR and provided IBI > 40, grity flakey sand mixtures should be suitable for immediate trafficking; and

(v) all other mixtures need 7 day non-trafficked curing periods.

NG815 (11/04) Mix-in-Plant Method of Construction Using Volume Batching for HBM

1 Generally most modern batching plants dispense their materials by mass. Some continuous mixers use belt weighers and integrate the belt speed with the load on the belt that give satisfactory control of the mixture proportions.

NG816 (11/04) Mix-in-Place Method of Construction for HBM

1 Advice on the mix-in-place construction can be found in TRL Report 611.

NG819 (11/04) Coefficient of Linear Thermal Expansion

1 HD 26 (DMRB 7.1.2) for flexible composite pavement design makes assumptions for thermal warping stresses and a correlation tensile and compressive strength, which are both highly dependent upon the lithology of the coarse aggregate used in the mixture. The mixtures are designated as 'G' for gravel aggregate mixtures and 'R' for rock aggregate mixtures. As most of the gravel mixtures used in the UK use flint gravel and flint has a particularly high coefficient of linear thermal expansion, in excess of 10 x 10^{-6}/ºC, this limiting value parameter has been used to define G and R mixtures.

2 A proposed versatile deign method (TRL Report 615), will form the basis of a revision to HD 26 does not consider thermal stresses to be critical but does differentiate between G and R mixtures for CBGM equivalent mixtures. The facility to define these mixtures by coefficient of linear thermal expansion has therefore been left in the current revision of the specification in order to allow the use of the current design method and any interim advice that might be issued prior to the revision of HD 26.

NG820 (11/04) Aggregates for HBM

1 The LA value indicates the resistance of an aggregate to size fragmentation during mixing and, to a lesser extent, the mechanical strength of the aggregate particles. It is thus of greater importance in bases than in sub=bases. For the mixtures, which have a LA requirement in Table 8/13, a LA_{60} requirement should be put Appendix 7/1 for sub=bases and LA_{50} for bases.

2 CBGM mixture designs have different layer thickness depth requirements for gravel and for rock aggregate mixtures. The designs should be designated

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as gravel or rock and alternative designs provided in Appendix 7/1, Schedule 5 for mixtures with each type of aggregate.

3 The limits stated in Table 8/13 for wood, glass and other impurities have been set to encourage the use of processed recycled aggregates and aggregates from secondary sources. However, there are opportunities on many schemes to use mixtures with much higher proportions of secondary materials. If a particular source is available on or adjacent to the site it should be investigated as part of the site investigation and identified to the tenderers. Where a possible source is known it can be tested to assess the construction and environmental risks associated with its use as part of the site investigation.

NG 821, NG822, NG 823, NG830, 831, 832 and 834 (11/04) Cement and Other Hydraulically Bound Mixtures

1 The mechanical performance level should be determined from the design requirements. Mixtures should only be selected from those shown in Table NG 8/2. Mixtures of C 5/6 or T2 designation or lower should not be used in bases.

2 Appendix 7/1, Schedules 3 and 5 should show the allowable alternatives of strength and the associated required layer thickness. The designation should be, e.g., CBGM A, followed by the appropriate strength class in BS EN 14227-1, e.g., for a $C_{5/6}$ class the designation should be 'CBGM A $C_{5/6}$' or, for a mixture defined using the R_tE system, 'CBGM A T_3', as appropriate for the chosen design. Where a gravel or rock aggregate is required, 'G' or 'R' should be inserted after the class designation letter to signify the requirement. Thus a gravel aggregate mixture with a minimum characteristic compressive cube strength requirement of 20 MPa would be designated as 'CBGM B G $C_{16/20}$'.

3 It should be noted that the strength requirements is for a characteristic strength at 28 days rather than a 7 days mean strength of 5 samples as in the previous specification. For first approximation purposes it has been found, for mixtures with CEM 1 (BS EN 197-1) cement, that the 28 days characteristic cube strength has been close to the mean strength of 5 samples tested using the protocol in the previous specification. However, if it is intended to use 7 days strength for production control purposes a job specific relationship should be determined.

4 The BS EN strength and elasticity requirements are based on the 28 day characteristic strength or characteristic tensile strength and characteristic elasticity determined throughout the project. To control the contractor's risk of non-compliance, if the values of the average and minimum individual 7 day results for each successive group of five tests at which the characteristic requirement are met, the material may be deemed to satisfy the requirements of this specification. Where sufficient results are available to allow the characteristic strength or the characteristic tensile strength and elasticity to be reliably determined new 7 day compliance levels may be set that to achieve the specified 28 day characteristic strength or the 28 day characteristic tensile strength and elasticity. Where the 7 day values are not achieved the values at 28 days should be used to determine compliance.

5 During the trial mixes the Contractor should take sufficient cubes or cylinders to establish a robust relationship between the 7 day mean strengths and the 28 day characteristic strength for the mixtures being proposed for the works. This relationship may be used to control the risk of non-compliance with the requirements of this specification.

6 It is envisaged that CBGM C mixtures will only be required where early trafficking is essential or highly advantageous. Thus it is not normally intended that tender designs should be prepared for both CBGM B and GBGM C mixtures. The designer should make a choice of which mixture to specify bearing in mind the strategic needs of the scheme.

NG 840 (11/04) Soil cement (SC), Soil Treated by Slag (SS), Soil Treated by HRB (SHRB), and Soil Treated by Fly Ash (SFA)

1 It is suggested that foundation designs will be required for two binder groups, i.e., for soil cement and for the slower acting binder treated soils. The curing of test specimens for treated soils, other than soil cement, is designed to model the strength at the assumed design time of one year whereas the soil cement test results require adjustment to one-year strength as part of the thickness design process. Designs may be included for Class $C_{1.5/2.0,}$ or T2, and above.

2 Previous specifications have included requirements for soil cement subbases under the classification of CBM 1. To follow the form of the new standards, soil cement is now provided for as part of a suit of standards for soils treated with a range of hydraulic binders. The range of properties of the soil mixtures has also been expanded to allow the pavement designer sufficient options to achieve the optimum design solution for each site.

3 Research carried out at Transport Research Laboratory (TRL) and in full-scale trials has indicated that satisfactory subbases can be constructed and trafficked at lower strengths than provided in the

previous specification. Also it has been shown that aggregates and soils not commonly used, including cohesive soils, can be satisfactorily stabilised with binder combinations to produce subbase material. These techniques give environmental benefits in avoiding the use of primary aggregates and often using secondary materials such as fly ash or slag as the major part of the binder. On many schemes they can reduce the need to dispose of surplus cut soil or allow a slight lowering of grade lines.

4 Where cohesive soils are to be stabilised to form subbase they will normally require amelioration with lime to allow the efficient mixing with the second binder, which is required to develop the specified strength. Traditionally cement has been used as the second binder. However, recent experience in the use of fly ash and of ground granulated blast furnace slag has indicated that more durable subbases can be constructed than with cement and frequently at a lower cost.

5 The use of lime or hydraulic binder with some clays requires some caution and the procedures set out in HA 74 (DMRB 4.1.6) need to be followed particularly in regard to investigating the presence of sulfates. More recent work by British Research Establishment (BRE) has suggested a more thorough protocol for the investigation of sulfates. The volumetric expansion test is preferred to the CBR swell test but where the proposed receptor soil contains any sulfate and calcium carbonate reference should be made to the Overseeing Organisation before commencing the detailed investigation.

6 The presence of sulfate, or potential sulfate, need not mean that the soil is unable to be permanently stabilised but it could mean that special measures will need to be taken, which could include additional, mixing, mellowing, temperature limitations, restrictions on binder type etc.

7 Mixtures of SC or treated soil require specification details in Appendix 7/1 for the attributes listed below:

(i) Aggregates requirements:

(a) Impurities

There are no limitations on the impurities in treated soils as generally un acceptable levels of deleterious constituents will result in failure to pass the requirements of the immersion test. However, an excess of reactive glass will not be revealed by such tests and alkali aggregate susceptibility will need to be investigated as in the case for CBGM.

(ii) Laboratory mechanical performance requirements:

(a) The mechanical performance level should be determined from the design requirements. Mixtures should only be selected from those shown in Table NG 8/2 as appropriate for the design.

(b) The BS EN strength and elasticity requirements for soil cement are based on the characteristic strength or strength and elasticity determined throughout the Contract. To control the risk of non-compliance, limiting values on the minimum average and minimum individual result for each successive group of five tests at which the characteristic requirement are deemed to be satisfied are set in this specification.

(11/04) Testing, Control and Checking of Cement and Other Hydraulically Bound Mixtures

NG 870 (11/04) Testing, Control and Checking of Cement and Other Hydraulically Bound Mixtures

1 HBM produced to conform to BS EN 14227 requires testing using the complementary BS EN 13286 Parts 4, 41 to 43, 46 to 48 and 51. These standards are restricted to mixture tests and tests on specimens made from mixtures. The tests for quality in the completed pavement layer continue to be found in BS 1924 Parts 1 and 2.

2 HDM formulations without cement binder compacted to refusal to produce cylindrical specimens, cured at 40°C and tested at 28 days have been found to be at least equivalent to the 364 days strength/stiffness achieved using 20 °C curing. For mixtures using binders containing a minimum of 3% by dry mass of cement, refusal cylindrical or cube specimens cured at 20°C and tested at 28 days have been found to be equivalent to 80% of the 364 days strength at 20°C curing.

3 For mixtures using binders containing a minimum of 3% by dry mass of cement, refusal cylindrical or cube specimens cured at 20°C and tested at 28 days have been found to be equivalent to 80% of the 364 days strength at 20°C curing.

4 For mixtures using binders without cement, refusal cylindrical specimens cured at 40 °C and tested at 28 days have been found to be at least equivalent to the 360 day strength/stiffness using 20 °C curing.

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NG880 (11/04) Laboratory Mixture Design Procedure for HBM

1 A schedule of testing similar to that shown in Table NG 8/3 should be employed for each combination of binder and water content.

TABLE NG 8/3: Suggested Schedule of Testing for Laboratory Mechanical Performance of One Combination of Binder and Water Content

HBM Type	Curing Temperature	Age of Test of Sealed Specimen (X Denotes One Result)					
		7 days	14 days	28 days	56 days	91 days	1 year
Without cement	40 degrees C	XXX	XXX	XXX	-	-	-
	20 degrees C	-	-	XXX	XXX	XXX	XXX
With cement	20 degree C	XXX	XXX	XXX	XXX	XXX	XXX

NOTE: Note that for mixtures using binders without cement, refusal cylindrical specimens cured at 40°C and tested at 28 days have been found to be at least equivalent to the 360 day strength/stiffness using 20°C curing. For mixtures using binders containing cement, refusal cylindrical or cube specimens cured at 20°C and tested at 28 days have been found to be equivalent to 80% of the 360 day strength at 20°C curing.

2 The Contractor should provide evidence of strength development over a minimum of 28 days. On the basis of this information, the Contractor should declare the age of testing for site control purposes.

3 HBM complying with performance category C3/4 or T1 and greater or containing at least 8% binder addition (10% in the case of FA+lime) can be considered satisfactory as far as frost resistance is concerned without further testing.

NATIONAL ALTERATIONS OF THE OVERSEEING ORGANISATION OF SCOTLAND

NG 850SE (05/01) Crushed Gravel Sub-base Material Type 1

General

1 Trafficking trials of crushed gravel sub-bases used in Scotland have produced rut depths well within the upper limit (30 mm) recommended by the Transport Research Laboratory for the assessment of sub-base materials if laid on Works contracts provided that:

(i) strict control over the grading is maintained;

and

(ii) the crushed face requirements are met.

2 (05/01) Any unusual behaviour of the laid material under construction plant should be investigated and, if considered necessary, the Contractor's laying and compaction methods should be carefully examined. Guidance on the protection of the subgrade and sub-base is already given in NG 801.

3 (05/01) No limiting traffic design has been imposed for crushed gravel Type 1 Granular Sub-Base complying with Clause 850SE. However its use on roads designed to carry more than 1500 commercial vehicles per lane per day should be clearly identified in the As-Built Records required in accordance with SDD Circular No 27/1989.

4 (05/01) Where the soundness test is used as a means of confirming source suitability, a certificate from a testing laboratory accredited in accordance with EN 45002 by the United Kingdom Accreditation Service (UKAS) for that test, showing a value in excess of the minimum specified and dated not more than 6 months prior 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 803 or (804);

(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 2 major sites.

Routine water absorption 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.

Trafficking Trial Procedure

Introduction

5 The Transport Research Laboratory has recommended that deformation under controlled trafficking provides a suitable criterion for assessing sub-base stability. Research has indicated that 30 mm rut depth after 1000 standard axles is an acceptable limiting criterion, and this has been adopted as the basis of assessment of crushed gravels offered as alternatives to Type 1 sub-base materials.

Location

6 (i) The trial area shall be located on suitable prepared sub-formation compacted in accordance with the Specification. The trial area may be located so that it can be incorporated within the Permanent Works if the resistance to wheel track rutting complies with sub-Clause 850.9SE.

(ii) The trial area shall be not less than 60 metres long and be not less than 20 metres wide.

Materials

7 (i) If required within the Permanent Works, suitable capping layer material in sufficient quantity shall be provided to construct a platform approximately 50 metres long by 10 metres wide compacted to the thickness required in the contract.

(ii) The crushed gravel sub-base material complying with the requirements of Clause 850SE shall be provided in sufficient quantity to construct a trial area approximately 50 metres long and having a base width of 7.5 metres to 8 metres compacted to the thickness specified in the contract.

Placement

8 (i) (05/01) The materials shall be placed and compacted using the equipment proposed for use in the Works.

(ii) If required in the Contract, the capping layer material shall be placed and compacted in accordance with Clause 613 at a moisture content within the range 1% above to 2% below the optimum moisture content determined in accordance with BS 5835.

(iii) The crushed gravel sub-base material shall be placed on top of the compacted capping layer or the prepared sub-formation as appropriate and compacted in accordance with Clause 801 at a moisture content within the range 1% above to 2% below the optimum moisture content determined in accordance with BS 5835.

(iv) The trial area shall be ramped at each end and rigid beams (wooden sleepers or similar) shall be incorporated into each end of the area for a distance of approximately 5 metres and shall have their upper faces level with the surface of the compacted crushed gravel sub-base. This will assist correct tracking by the test vehicle and minimise dynamic effects of the vehicle bouncing on its springs.

Trafficking

9 (i) A convenient test vehicle is a 3-axle tipper lorry loaded to a gross mass of 24 tonnes (1 pass is equivalent to 3 standard axles). The selection of the test vehicle however shall reflect actual site conditions and the equivalent standard axle loading shall be calculated for monitoring.

(ii) Longitudinal string lines shall be laid out on the trial embankment to help the driver maintain the same track on each pass and to achieve channelled rutting. Five transverse string lines shall be laid out at equal spacing along the length, covering the full width of the trial embankment. The end string lines shall be positioned at least the length of the lorry from the rigid beams at the ends of the trial area.

(iii) Vertical deformation shall be measured in all the wheel tracks using an optical level at monitoring points on each of the 5 transverse string lines after 5, 15, 50, 100, 180 and 350 passes. The mean vertical deformations at the previously mentioned lorry passes shall be plotted against the respective passes and the vertical deformation corresponding to 1000 standard axles shall be interpolated.

(iv) The crushed gravel sub-base material shall be deemed to be an acceptable alternative to Type 1 granular sub-base materials specified in Clause 803 if the mean vertical deformation corresponding to 1000 standard axles is less than 30 mm when tested in accordance with the trafficking procedure given in this Clause.

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NATIONAL ALTERATIONS OF THE OVERSEEING ORGANISATION OF NORTHERN IRELAND

NG 801NI (05/01) General Requirements for Unbound, Hydraulically Bound and Other Materials

1 The permitted alternatives for sub-bases include Types 1, 2 and 3 granular sub-base material. For granular sub-bases under cement bound roadbases, where good drainage of the sub-base and subgrade is certain and there is no chance of water standing under cemented material, the Overseeing Organisation may, in order to make significant financial or environmental gains, such as removal of spoil heaps, accept sub-base material with a water soluble sulfate content of up to 2.2 g/litre, provided structures are isolated by 500 mm of sulfate-free material or precautions are taken to protect them (See NG 1704).

2 Sub-Clause 801.12NI(viii) permits combinations of different types of compacting equipment provided each type contributes its correct proportion of the total compactive effort. Thus if a machine when operated singly is required in Table 8/1NI to apply X passes and that same machine actually applies K passes, then the sum of the values of K/X for each of the types of plant used in combination should equal or exceed unity.

Frequency of Sampling

3 The recommended rate of sampling for the determination of grading, plasticity and quality should be one sample for every 200 tonnes of material supplied. For schemes using less than 200 tonnes one sample should be taken.

Use of surfaces by Traffic and Construction Plant

4 Under the Conditions of Contract the Contractor is responsible for care of the Works including the protection of the roadbase, sub-base and subgrade. The choice of permitted materials is intended to allow the Contractor to make the most economical use of available materials suitable for his method of construction. It will not be known when drawing up the documents what materials, plant, methods and programme the Contractor will adopt. Therefore, generally, it will not be possible to justify restriction of the choice allowed nor specify measures required specifically for construction, but where any particular circumstances are known any materials which would put the Permanent Works at risk of failure should not be included in Appendix 7/1.

5 As some unbound sub-bases are moisture susceptible and are unsuitable for construction traffic in wet periods the Contractor's choice of sub-base should be related to the time of year and his programme and method for laying the roadbase and subsequent layers. Long delays could be avoided by the use of cement-stabilised material. Traffic running on the sub-base may cause irreparable damage to the subgrade or capping. Protection of the sub-base against weather can best be achieved by laying the subsequent layers as soon as possible.

6 Some sub-base and roadbase materials degrade during normal laying and compacting operations. If there is any doubt about degradation of the material during laying and compacting then sampling points should be chosen for each material which will be representative of the quality of the laid material.

7 Under wet conditions some Type 2 granular sub-base material can rapidly deteriorate if used by construction traffic and the subgrade can be damaged by rutting, which could result in permanent soft spots. Type 2 granular sub-base material is suitable for its purpose if its moisture content is kept around the optimum. Work should preferably be programmed so that the roadbase is applied before the sub-base is wetted.

8 Any thickening shall be across the full width of that part of the pavement which is in new construction. If temporary haul roads are laid and later removed they must be placed so that drainage of the formation and sub-base surface is not impeded.

Frost Heave

9 The frost heave test described in BS 812 : Part 124 : 1989 is costly and time consuming and is not suitable for routine control checks on Site. The test has been developed from earlier test methods to overcome problems of repeatability and reproducibility. The test is primarily intended as a method to establish whether or not an aggregate from a particular source is likely to be frost-susceptible when used in an unbound condition within that part of the road pavement subject to frost penetration. Material for the frost heave test must be representative of the source and comply with all other requirements of the Specification otherwise the test is superfluous. Once a material has been established as non-frost-susceptible the test need only be repeated if the material varies from the original sample, or where the source is changed.

10 Clause 6 of BS 812 : Part 124 : 1989 sets down the procedure for adjusting the water level in the self-refrigerated unit (SRU). A possible problem has been identified that with the tolerances given to the dimensions for the cradle and specimen carriers it is possible for the porous discs in the specimen carriers to be located incorrectly in relation to the water level. In order to guard against this it is recommended that before testing commences the cradle and specimen carriers be put into the SRU without samples. A check is then made to ensure that discs are set at the level specified in the above-mentioned standard.

11 The requirement for material to be non-frost susceptible within 450 mm of the surface of a road or paved central reserve may be reduced to 350 mm if the Mean Annual Frost Index (MAFI) of the site is less than 50. The Frost Index is a measure of the severity of a period of cold weather and provides a means of assessing likely penetration of frost into a road. Frost index is measured in 'degree days Celsius below zero' and is calculated by taking the mean air temperature for each twenty four hour period and adding those values together. Frost penetration into a modern road in the British Isles may be estimated using the formula $x = 40\sqrt{I}$ where x is the approximate penetration in mm and I is the frost index for the freezing spell. The Annual Frost Index is the frost index accumulated over a year commencing September 1st. Mean Annual Frost Index (MAFI) is the average of all the frost index values computed for each year since September 1959. The MAFI for a site is determined using records from one or more meteorological stations close to the site, taking account of local geographical variation, such as high ground or frost hollows. Different requirements for different parts of a contract length may be used.

Further information on the MAFI can be found in HD 25.

Advice relating to any site, including the MAFI calculated for that site, may be purchased from:

Customer Centre
The Met. Office
Powell Duffryn House
London Road
Bracknell
Berks
RG12 2SY

Tel. No: 0845 300 0300
Fax No: 0845 300 1300
E-mail: climate@meto.gov.uk

NG 851NI Filter Layer

1 Crushed rock or sand filter layers of 50 mm minimum thickness should be provided immediately below carriageway sub-bases where cohesive materials occur within the top 150 mm of the sub-grade to prevent the ingress of cohesive particles into the sub-base.

Where a capping layer is provided, no filter layer is required at the sub-base or capping layer interfaces but the thickness of the capping layer should be increased by 75 mm if the sub-grade contains cohesive materials.

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