SERIES 800
ROAD PAVEMENTS – UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

Contents

ROAD PAVEMENTS – UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

800 (02/16) General

1 (02/16) This Series is part of the Specification for Highway Works. Whilst this Series is particularly relevant to the subject matter in its title it must be read in conjunction with the general requirements in Series 000 and 100 and with all other Series relevant to the specification for the particular works to be undertaken.

(02/16) Unbound Mixtures for Subbase

801 (02/16) General Requirements for Unbound Mixtures

1 (02/16) Unbound mixtures shall be made and constructed to conform to BS EN 13285, the requirement categories in Table 8/1 and Clauses 802 to 807. The permitted alternatives for each part of the permanent works shall be as described in contract specific Appendix 7/1.

TABLE 8/1: (02/16) **Mixture and Grading Requirement Categories for Unbound Mixtures**

Unbound mixture	**Type 1**	**Type 2**	**Type 3 (open graded)**	**Category B (close graded)**	**Type 4 (asphalt arisings)**
Clause	803	804	805	806	807
Standard	BS EN 13285 Categories for unbound mixture properties				
Mixture requirement category					
- Designation	0/31,5	0/31,5	0/40	0/31,5	0/31,5
- Maximum fines	UF_9	UF_9	UF_5	UF_9	UF_9
- Oversize	OC_{75}	OC_{75}	OC_{80}	OC_{80}	OC_{75}
Grading requirement category					
- Overall grading	G_P	G_E	G_O	G_B	G_P

2 (02/16) Unbound mixtures placed within 500 mm, or any other distances described in contract specific Appendix 7/1, of concrete, cement bound materials, other cementitious mixtures or stabilised capping forming part of the permanent works shall conform to requirements A and B below.

A Mixtures shall conform to the following two criteria:

(i) Water-soluble sulfate (WS) content determined in accordance with BS EN 1744-1 clause 10 shall not exceed 1500 mg of sulfate (as SO_4) per litre;

(ii) Total sulfur (TS) content determined in accordance with BS EN 1744-1 clause 11 expressed as (S) shall not exceed 1% for aggregates other than air cooled blast furnace slag or 2% for air cooled blast furnace slag.

B Mixtures shall conform to at least one of the following two options:

(i) When described in accordance with BS EN 932-3 and BS EN 13242 Annex A, limestone, chalk, dolomite, blast furnace slag, steel slag or crushed concrete are predominant;

or

(ii) The sulfide content of the mixture determined in accordance with BS EN 1744-1 clause 13 is less than 0.5% (as SO_4).

When determining WS, TS or sulfide content, at least five samples of each material shall be tested. The mean of the highest two values shall be used for comparison with the limiting values. This also applies if six to nine results are available. If ten or more results are available, the mean of the highest 20% of the results shall be used for comparison with the limiting values. The pH of the mixture shall be reported.

3 (02/16) Unbound mixtures placed within 500mm, or any other distances described in contract specific Appendix 7/1, of metallic structural elements forming part of the permanent works shall conform to requirements C and D below.

C Mixtures shall conform to the following two criteria:

(i) Water-soluble sulfate (WS) content determined in accordance with BS EN 1744-1 clause 10 shall not exceed 300 mg of sulfate (as SO_4) per litre;

(ii) Total sulfur (TS) content determined in accordance with BS EN 1744-1 clause 11 expressed as (S) shall not exceed 1% for aggregates other than air cooled blast furnace slag or 2% for air cooled blast furnace slag.

D Mixtures shall conform to at least one of the following two options:

(i) When described in accordance with BS EN 932-3 and BS EN 13242 Annex A, limestone, chalk, dolomite, blast furnace slag, steel slag or crushed concrete are predominant

or

(ii) The sulfide content of the mixture determined in accordance with BS EN 1744-1 clause 13 is less than 0.06% (as SO_4).

When determining WS, TS or sulfide content, at least five samples of each material shall be tested. The mean of the highest two values shall be used for comparison with the limiting values. This also applies if six to nine results are available. If ten or more results are available, the mean of the highest 20% of the results shall be used for comparison with the limiting values. The pH of the mixture shall be reported.

The requirements in (i) and (ii) above shall not apply to metallic items protected by concrete and ancillary metallic items such as the tops of chambers and gullies.

4 (02/16) The properties of aggregates used in unbound mixtures shall comply with the selected requirements of BS EN 13242 listed in Table 8/2.

TABLE 8/2: (02/16) **Requirements for Aggregates Used in Unbound Mixtures**

Unbound mixture	**Type 1**	**Type 2**	**Type 3** (open graded)	**Category B** (close graded)	**Type 4** (asphalt arisings)
Clause	**803**	**804**	**805**	**806**	**807**
Standard	BS EN 13242 Categories for aggregate properties				
Crushed, or broken and totally rounded particles – crushed rock, crushed manufactured and crushed recycled aggregates – see NOTE 1	$C_{90/3}$	$C_{90/3}$	$C_{90/3}$		$C_{90/3}$
– crushed gravel	$C_{50/10}$ – see NOTE 2	C_{NR} (no requirement)	Not permitted		Not permitted
Resistance to fragmentation – Los Angeles test	LA_{50}	LA_{50}	LA_{30}		LA_{50}
Resistance to wear – micro-Deval test	M_{DE}NR (no requirement). The supplier shall state the value for the aggregate used.				
Resistance to freezing and thawing – magnesium sulfate soundness	MS_{35}				
Water absorption	WA_{24}NR (no requirement). The supplier shall state the value for the aggregate used.				
Volume stability of blast furnace slags	Free from dicalcium silicate and iron disintegration.				
Volume stability of steel (BOF and EAF) slags	V_5		Not permitted		V_5
All other BS EN 13242 aggregate requirements	Category $_{NR}$ (no requirement).				
NOTES: 1. BS EN 13242 assumes that crushed rock aggregates comply with category $C_{90/3}$ without further testing. 2. Where permitted by contract specific Appendix 7/1.					

5 (02/16) Where recycled coarse aggregate or recycled concrete aggregate is used in unbound mixtures in accordance with Clauses 802 to 807 as appropriate, it shall have been tested in accordance with Clause 710. Recycled coarse aggregate and recycled concrete aggregate used in unbound mixtures in accordance with Clauses 803, 804 and 807 shall also comply with the additional requirements of Table 8/3.

TABLE 8/3: (02/16) **Additional Requirements for Recycled Coarse Aggregate and Recycled Concrete Aggregate Used in Type 1, Type 2 and Type 4 Unbound Mixtures**

Unbound Mixture	**Type 1**	**Type 2**	**Type 4 (asphalt arisings)**
Component Identified by Clause 710	**Maximum Permitted Content** (% by mass)		
Asphalt (Class Ra)	50	50	100
Glass (Class Rg)	25		
Other materials (Class X), including wood, plastic and metal	1		

6 (02/16) When required by contract specific Appendix 7/1 and Clauses 803 and 804 as appropriate, the unbound mixture shall satisfy the minimum CBR requirement of contract specific Appendix 7/1 when tested in accordance with clause 7 of BS 1377-4, with surcharge discs. The specimens shall be tested in a soaked condition. The mixture shall be tested at the density and moisture content likely to develop in equilibrium field conditions which shall be taken as being the density relating to the uniform air voids content of 5% and the value of optimum water content declared when tested as required by BS EN 13285.

(02/16) **Frost Heave**

7 (02/16) Subject to the tolerances given in Table 7/1 and unless otherwise stated in contract specific Appendix 7/1, material shall not be frost susceptible if it is used within 450 mm of the designed final surface of a road or paved central reserve, or 350 mm if the Mean Annual Frost Index (MAFI) of the site is less than 50.

8 (02/16) Material shall be classified as non-frost-susceptible if the mean heave is 15 mm or less, when tested in accordance with BS 812-124. Comparator specimens in accordance with Annex B of BS 812-124 shall be used.

802 (02/16) Transport, Laying, Compaction and Trafficking of Unbound Mixtures

(02/16) **Transporting**

1 (02/16) Unbound mixtures shall be protected from drying out and segregation both during transit to the point where it is to be laid and whilst awaiting tipping.

(02/16) **Laying**

2 (02/16) Unbound mixtures in a frozen condition shall not be incorporated in the works but may be used, if acceptable, when thawed. Unbound mixtures shall not be laid on any surface which is frozen or covered with ice.

3 (02/16) All unbound mixtures shall be placed and spread evenly. Spreading shall be undertaken either concurrently with placing or without delay. Unbound mixtures shall be spread using a paving machine or a suitable spreader box and operated with a mechanism which levels off the material to an even depth.

4 (02/16) Except where otherwise stated in contract specific Appendix 7/1, material up to 225 mm compacted thickness shall be spread in one layer so that after compaction the total thickness is as specified. Material of compacted thickness greater than 225 mm shall be laid in two or more layers and the minimum compacted thickness of any such layer shall be 110 mm. Where the layers of unbound mixtures are of unequal thickness, the lowest layer shall be the thickest layer.

(02/16) **Compaction**

5 (02/16) Compaction shall be completed as soon as possible after the mixture has been spread and in accordance with the requirements for the individual mixtures.

6 (02/16) Full compaction shall be obtained over the full area including in the vicinity of both longitudinal and transverse joints.

7 (02/16) Compaction of unbound mixtures shall be carried out by a method specified in Table 8/4, unless the Contractor demonstrates at site trials that a state of compaction achieved by an alternative method is equivalent to or better than that using the specified method.

8 (02/16) The surface of any layer of material shall on completion of compaction and immediately before overlaying, be well closed, free from movement under construction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted.

9 (02/16) For the purposes of Table 8/4 the following shall apply:

(i) The number of passes is the number of times that each point on the surface of the layer being compacted shall be traversed by the item of compaction plant in its operating mode (or struck, in the case of power rammers).

(ii) The compaction plant in Table 8/4 is categorised in terms of static mass. The mass per metre width of roll is the total mass on the roll divided by the total roll width. Where a smooth-wheeled roller has more than one axle, the category of the machine shall be determined on the basis of the axle giving the highest value of mass per metre width.

(iii) For pneumatic-tyred rollers the mass per wheel is the total mass of the roller divided by the number of wheels. In assessing the number of passes of pneumatic-tyred rollers the effective width shall be the sum of the widths of the individual wheel tracks together with the sum of the spacings between the wheel tracks provided that each spacing does not exceed 230 mm. Where the spacings exceed 230 mm the effective width shall be the sum of the widths of the individual wheel tracks only.

(iv) Vibratory rollers are self-propelled or towed smooth-wheeled rollers having means of applying mechanical vibration to one or more rolls:

(a) The requirements for vibratory rollers are based on the use of the lowest gear on a self-propelled machine with mechanical transmission and a speed of 1.5-2.5 km/h for a towed machine or a self-propelled machine with hydrostatic transmission. If higher gears or speeds are used an increased number of passes shall be provided in proportion to the increase in speed of travel.

(b) Where the mechanical vibration is applied to two rolls in tandem, the minimum number of passes shall be half the number given in Table 8/4 for the appropriate mass per metre width of one vibrating roll but if one roll differs in mass per metre width from the other, the number of passes shall be calculated as for the roll with the smaller value. Alternatively the minimum number of passes may be determined by treating the machine as having a single vibrating roll with a mass per metre width equal to that of the roll with the higher value.

(c) Vibratory rollers operating without vibration shall be classified as smooth-wheeled rollers.

(d) Vibratory rollers shall be operated with their vibratory mechanism operating at the frequency of vibration recommended by the manufacturer. All such rollers shall be equipped, or provided with devices indicating the frequency at which the mechanism is operating and the speed of travel. Both devices shall be capable of being safely read by an inspector alongside the machine.

(v) Vibrating-plate compactors are machines having a base-plate to which is attached a source of vibration consisting of one or two eccentrically-weighted shafts:

(a) The mass per square metre of base-plate of a vibrating-plate compactor is calculated by dividing the total mass of the machine in its working condition by its area in contact with compacted material.

(b) Vibrating-plate compactors shall be operated at the frequency of vibration recommended by the manufacturer. They shall normally be operated at travelling speeds of less than 1 km/h but if higher speeds are necessary, the number of passes shall be increased in proportion to the increase in speed of travel.

(vi) Vibro-tampers are machines in which an engine driven reciprocating mechanism acts on a spring system, through which oscillations are set up in a base-plate.

(vii) Power rammers are machines which are actuated by explosions in an internal combustion cylinder; each explosion being controlled manually by the operator. One pass of a power rammer shall be considered to have been made when the compacting shoe has made one strike on the area in question.

(viii) Combinations of different types of plant or different categories of the same plant will be permitted; in which case the number of passes for each shall be such proportion of the appropriate number in Table 8/4 as will together produce the same total compactive effort as any one operated singly, in accordance with Table 8/4.

TABLE 8/4: (02/16) **Compaction Requirements for Unbound Mixtures**

Type of Compaction Plant	Category	Number of passes for layers not exceeding the following compacted thicknesses:		
		110 mm	150 mm	225 mm
Smooth-wheeled roller (or vibratory roller operating without vibration)	Mass per metre width of roll:			
	over 2700 kg up to 5400 kg	16	unsuitable	unsuitable
	over 5400 g	8	16	unsuitable
Pneumatic-tyred roller	Mass per wheel:			
	over 4000 kg up to 6000 kg	12	unsuitable	unsuitable
	over 6000 kg up to 8000 kg	12	unsuitable	unsuitable
	over 8000 kg up to 12000 kg	10	16	unsuitable
	over 12000 kg	8	12	unsuitable
Vibratory roller	Mass per metre width of vibrating roll:			
	over 700 kg up to 1300 kg	16	unsuitable	unsuitable
	over 1300 kg up to 1800 kg	6	16	unsuitable
	over 1800 kg up to 2300 kg	4	6	10
	over 2300 kg up to 2900 kg	3	5	9
	over 2900 kg up to 3600 kg	3	5	8
	over 3600 kg up to 4300 kg	2	4	7
	over 4300 kg up to 5000 kg	2	4	6
	over 5000 kg	2	3	5
Vibrating-plate compactor	Mass per square metre of base plate:			
	over 1400 kg/m² up to 1800 kg/m²	8	unsuitable	unsuitable
	over 1800 kg/m² up to 2100 kg/m²	5	8	unsuitable
	over 2100 kg/m²	3	6	10
Vibro-tamper	Mass:			
	over 50 kg up to 65 kg	4	8	unsuitable
	over 65 kg up to 75 kg	3	6	10
	over 75 kg	2	4	8
Power rammer	Mass:			
	100 kg-500 kg	5	8	unsuitable
	over 500 kg	5	8	12

(02/16) **Use of Surfaces by Construction Plant and Other Traffic**

10 (02/16) Construction plant and other traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

11 (02/16) Where the Contractor proposes to use the unbound mixture layers for construction plant he shall improve these layers where necessary, to accommodate the method of construction and the type of plant and vehicles which he proposes to use, in order to avoid damage to the laid layer(s), any capping and the subgrade. Any permanent thickening shall be across the whole width of the pavement. Temporary thickening shall not impede drainage of any layer or the subgrade.

(02/16) **Trafficking Trial**

12 (02/16) When required by contract specific Appendix 7/1, the Contractor shall undertake a Trafficking Trial incorporating the unbound mixture proposed for use in the permanent works. A trial area shall be constructed, trafficked and assessed in accordance with the procedure described in sub-Clauses 13 to 18 of this Clause. The mean vertical deformation after 1000 equivalent standard axles shall be less than 30 mm when measured in accordance with the procedure stated in sub-Clause 17 of this Clause.

Proposals for trafficking trials shall be submitted to the Overseeing Organisation for review and acceptance five days in advance of construction.

(02/16) **Trial Procedure**

13 (02/16) The trial area shall be located on a formation prepared 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 is demonstrated to comply with sub-Clause 12 of this Clause.

14 (02/16) The trial area shall be at least 60 m long, and of sufficient width that when trafficked, the wheel paths of the test vehicle shall be at least 1 m from either edge of the top of the unbound mixture layer. The unbound mixture layer shall be compacted to the thickness specified in contract specific Appendix 7/1. The formation shall extend for a further 1 m either side of the unbound mixture layer.

15 (02/16) A sufficient run off/run on area shall be constructed at each end of the trial area of the same width, and compacted to the same level, as the trial area, to ensure correct tracking by the test vehicle and minimise dynamic effects of the vehicle bouncing on its springs. Suitable guidance shall be given to assist the driver in maintaining the same track in each pass and to achieve channelled trafficking. Examples of suitable guides would be a string or painted line.

(02/16) **Mixtures**

16 (02/16) The unbound mixture used in the trial shall be transported, laid and compacted using the equipment proposed for use in the works.

17 (02/16) Maximum vertical deformation shall be measured in both wheel tracks using optical or laser levels at pre-determined monitoring points on five transverse lines spaced equally along the length of the trial bay. The transverse lines at the ends of the trial area shall be at least 5 m from the run off/run on areas. The average deformation of the two wheel tracks after 1000 standard axles shall be recorded.

(02/16) **Reporting and Acceptance of Trafficking Trial Area**

18 (02/16) The Contractor shall provide the Overseeing Organisation, for acceptance, with a report on the Trafficking Trial, stating how the use of the unbound mixture was validated. The main construction of the permanent works shall not start until the Trafficking Trial area has been accepted by the Overseeing Organisation within two working days of receiving the Trafficking Trial area report.

803 (02/16) Type 1 Unbound Mixtures

1 (02/16) Type 1 unbound mixture shall be made from crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic shale and may contain up to 10% by mass of natural sand that passes the 4 mm test sieve. Where permitted by contract specific Appendix 7/1, crushed gravel complying with sub-Clause 803.7 may be used.

2 (02/16) The mixture shall comply with BS EN 13285 and the requirements of Table 8/1. The grading requirements for the mixture are summarised in Table 8/5.

TABLE 8/5: (02/16) **Summary Grading Requirements for Type 1 and Type 4 Unbound Mixtures**

Sieve size, mm	Percentage by mass passing		
	Overall grading range	**Supplier declared value grading range**	**Tolerance on the supplier declared value**
63	100		
31.5	75 – 99		
16	43 – 81	54 – 72	± 15
8	23 – 66	33 – 52	± 15
4	12 – 53	21 – 38	± 15
2	6 – 42	14 – 27	± 13
1	3 – 32	9 – 20	± 10
0.063	0 – 9		
Grading of individual batches – differences in values passing selected sieves			
Retained sieve size, mm	Passing sieve size, mm	Percentage by mass passing	
		Not less than	Not more than
8	16	7	30
4	8	7	30

3 (02/16) The properties of aggregates used in the mixture shall be in accordance with BS EN 13242 and the requirements of Table 8/2.

4 (02/16) The size fraction of the unbound mixture passing the 0.425 mm size test sieve shall be non-plastic as defined by BS 1377-2 and tested in compliance therewith.

5 (02/16) Where the mixture contains recycled coarse aggregate or recycled concrete aggregate, it shall comply with sub-Clause 801.5.

6 (02/16) The mixture shall be transported, laid and compacted without drying out or segregation.

(02/16) **Additional Requirements for Mixtures Containing Crushed Gravel**

7 (02/16) For the purposes of this Clause, gravel is defined as aggregate derived from a natural, unconsolidated, coarse-grained sedimentary deposit consisting of water-worn rock fragments. Crushed gravel aggregate shall be derived from natural cobbles retained on the 63 mm test sieve and comply with the crushed, broken and totally rounded particles requirement in Table 8/2.

8 (02/16) Where required by contract specific Appendix 7/1, mixtures containing crushed gravel coarse aggregate shall comply with the minimum CBR requirement in sub-Clause 801.6. Where required by contract specific Appendix 7/1, mixtures containing crushed gravel coarse aggregate shall be assessed using a trafficking trial complying with sub-Clause 802.12.

804 (02/16) Type 2 Unbound Mixtures

1 (02/16) Type 2 unbound mixture shall be made from natural sands, gravels, crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic shale.

2 (02/16) The mixture shall comply with BS EN 13285 and the requirements of Table 8/1. The grading requirements for the mixture are summarised in Table 8/6.

TABLE 8/6: (02/16) **Summary Grading Requirements for Type 2 Unbound Mixtures**

Sieve size, mm	Percentage by mass passing		
	Overall grading range	**Supplier declared value grading range**	**Tolerance on the supplier declared value**
63 31.5 16 8 4 1 0.063	100 75 – 99 50 – 90 30 – 75 15 – 60 0 – 35 0 – 9	No requirement	No requirement
Grading of individual batches – differences in values passing selected sieves			
Retained sieve size, mm	Passing sieve size, mm	Percentage by mass passing	
		Not less than	Not more than
8 4	16 8	5 5	35 35

3 (02/16) The properties of aggregates used in the mixture shall be in accordance with BS EN 13242 and the requirements of Table 8/2.

4 (02/16) The size fraction of the unbound mixture passing the 0.425 mm size test sieve when tested in compliance with BS 1377-2 shall have a plasticity index of less than 6.

5 (02/16) Where the mixture contains recycled coarse aggregate or recycled concrete aggregate, it shall comply with sub-Clause 801.5.

6 (02/16) Where required by contract specific Appendix 7/1, the mixture shall satisfy the minimum CBR requirement when tested in accordance with sub-Clause 801.6.

7 (02/16) The mixture shall be transported, laid and compacted without drying out or segregation, at a moisture content within the range 1% above to 2% below the declared value of optimum water content when tested as required by BS EN 13285.

805 (02/16) Type 3 (open graded) Unbound Mixtures

1 (02/16) Type 3 (open graded) unbound mixture shall be made from crushed rock, crushed blast furnace slag or recycled concrete aggregate. When tested in accordance with Clause 710, recycled concrete aggregate used in Type 3 (open graded) unbound mixtures shall not contain more than 5% asphalt (Class Ra) and not more than 1% other materials (Class X).

2 (02/16) The mixture shall comply with BS EN 13285 and the requirements of Table 8/1. The grading requirements for the mixture are summarised in Table 8/7.

3 (02/16) The properties of aggregates used in the mixture shall be in accordance with BS EN 13242 and the requirements of Table 8/2.

4 (02/16) The size fraction of the unbound mixture passing the 0.425 mm size test sieve shall be non-plastic as defined by BS 1377-2 and tested in compliance therewith.

5 (02/16) The mixture shall be transported, laid and compacted without drying out or segregation.

TABLE 8/7: (02/16) **Summary Grading Requirements for Type 3 (open graded) Unbound Mixtures**

Sieve size, mm	Percentage by mass passing		
	Overall grading range	**Supplier declared value grading range**	**Tolerance on the supplier declared value**
80	100		
40	80 – 99		
20	50 – 78		
10	31 – 60	58 – 70	± 8
4	18 – 46	39 – 51	± 8
2	10 – 35	26 – 38	± 8
1	6 – 26	17 – 28	± 7
0.500	0 – 20	11 – 21	± 5
0.063	0 – 5	5 – 15	± 5
Grading of individual batches – differences in values passing selected sieves			
Retained sieve size, mm	Passing sieve size, mm	Percentage by mass passing	
		Not less than	Not more than
10	20	10	25
4	10	10	25
2	4	7	20
1	2	4	15

806 (02/16) Category B (close graded) Unbound Mixtures

1 (02/16) Category B (close graded) unbound mixture shall be made from crushed rock, crushed blast furnace slag or recycled concrete aggregate. When tested in accordance with Clause 710, recycled concrete aggregate used in Category B (close graded) unbound mixtures shall not contain more than 5% asphalt (Class Ra) and not more than 1% other materials (Class X).

2 (02/16) The mixture shall comply with BS EN 13285 and the requirements of Table 8/1. The grading requirements for the mixture are summarised in Table 8/8.

TABLE 8/8: (02/16) Summary Grading Requirements for Category B (close graded) Unbound Mixtures

Sieve size, mm	Percentage by mass passing		
	Overall grading range	**Supplier declared value grading range**	**Tolerance on the supplier declared value**
63	100		
31.5	80 – 99		
16	55 – 85	63 – 77	± 8
8	35 – 68	43 – 60	± 8
4	22 – 60	30 – 52	± 8
2	16 – 47	23 – 40	± 7
1	9 – 40	14 – 35	± 5
0.500	5 – 35	10 – 30	± 5
0.063	0 – 9		
Grading of individual batches – differences in values passing selected sieves			
Retained sieve size, mm	Passing sieve size, mm	Percentage by mass passing	
		Not less than	Not more than
8	16	10	25
4	8	10	25
2	4	7	20
1	2	4	15

3 (02/16) The properties of aggregates used in the mixture shall be in accordance with BS EN 13242 and the requirements of Table 8/2.

4 (02/16) The size fraction of the unbound mixture passing the 0.425 mm size test sieve shall be non-plastic as defined by BS 1377-2 and tested in compliance therewith.

5 (02/16) The mixture shall be transported, laid and compacted without drying out or segregation.

807 (02/16) Type 4 (asphalt arisings) Unbound Mixtures

1 (02/16) Type 4 unbound mixture shall be made from recycled aggregates containing asphalt arisings, and may contain crushed rock, crushed slag, crushed concrete or well burnt non-plastic shale and up to 10% by mass of natural sand that passes the 4 mm size test sieve.

2 (02/16) Asphalt arisings shall be either asphalt road planings or granulated asphalt, but excluding materials contaminated with tar or tar-bitumen binders. Asphalt planings are defined as materials derived from the asphalt layers of the pavement using a mobile machine fitted with milling cutters. Granulated asphalt is defined as asphalt bound material recycled from roads under reconstruction or surplus asphalt material destined for bound pavement layers, but unused, which has been granulated.

3 (02/16) Type 4 unbound mixture shall have an asphalt (Class Ra) content greater than 50% when tested in accordance with Clause 710, and the recovered bitumen content of the asphalt shall be not more than 10% when tested in accordance with BS EN 12697-1.

4 (02/16) Type 4 unbound mixture shall comply with BS EN 13285 and the requirements of Table 8/1. The grading requirements for the mixture are summarised in Table 8/5.

5 (02/16) The properties of aggregates used in the mixture shall be in accordance with BS EN 13242 and the requirements of Table 8/2.

6 (02/16) The size fraction of the unbound mixture passing the 0.425 mm size test sieve shall be non-plastic as defined by BS 1377-2 and tested in compliance therewith.

7 (02/16) Where the mixture contains recycled coarse aggregate or recycled concrete aggregate, it shall comply with sub-Clause 801.5.

8 (02/16) The mixture shall be transported, laid and compacted without drying out or segregation, at a moisture content within the range 1% above to 2% below the declared value of optimum water content when tested as required by BS EN 13285. The moisture content shall be determined by oven drying at a reduced temperature setting of 45ºC to 50ºC.

9 (02/16) Where required by contract specific Appendix 7/1, Type 4 unbound mixtures shall be assessed using a trafficking trial complying with sub-Clause 802.12.

808 and 809 (02/16) Not Used

(02/16) Cement and Other Hydraulically Bound Mixtures

810 (02/16) General Requirements for Cement and Other Hydraulically Bound Mixtures

1 (02/16) Cement and other hydraulically bound mixtures (HBM) shall be produced, constructed and tested in accordance with the following Clauses. The permitted alternatives for each part of the works shall be as described in contract specific Appendix 7/1.

2 (02/16) Attributes shall be deemed to have a "No requirement" classification unless stated otherwise.

3 (02/16) The terms listed below shall apply to the HBM Clauses of this specification:

ASS	air cooled steel slag
CBGM	cement bound granular mixture
CBR	California bearing ratio
CFA	cement treated fly ash
E	modulus of elasticity
FA	fly ash (also known as 'pulverized fuel ash')
FABM	fly ash bound mixture
G_{vxx}	volumetric expansion category
GBS	granulated blast furnace slag
ggbs	ground granulated blast furnace slag
HBM	hydraulically bound mixture
HRB	hydraulic road binder (factory blended hydraulic binder for road use)
HRBBM	'hydraulic road binder' bound mixture
IBI	immediate bearing index
Imm_{xx}	immersion category
IPI_{xx}	immediate bearing index category
LA	Los Angeles coefficient
LFA	lime treated fly ash
MCV	moisture condition value
NR	no requirement
OWC	optimum water content
PTR	Pneumatic tyred roller
$Pulv_{xx}$	pulverisation category
R_c	compressive strength
R_t	direct tensile strength
R_{it}	indirect tensile strength
R_tE	method of performance classification based on the combination R_t and E. Classes of R_tE are designated T0 to T5, in BS EN 14227, where T designates R_tE and the number indicates the performance class
SBM	slag bound mixture
SC	soil treated by cement
SFA	soil treated by fly ash
SHRB	soil treated by hydraulic road binder
SS	soil treated by slag
t	time (hours) at constant temperature in defining maturity for calculating the construction period
TºC	ambient air temperature in defining maturity for calculating construction period
W_{xx}	water content category

4 (02/16) HBM shall be tested in accordance with Clause 870 and the test methods specified in the following Clauses.

5 (02/16) Before work commences, the Contractor shall submit a statement to the Overseeing Organisation that includes:

(i) The information detailed in the 'Designation and Description' clause of the relevant BS EN Standard for the specified HBM, confirming compliance with the requirements of this Series and contract specific Appendix 7/1.

(ii) Target proportions of constituents, including water.

(iii) Mixture design details and results, in accordance with Clause 880.

(iv) Method statement for the demonstration area and the main works, in accordance with Clause 817.

6 (02/16) When required by contract specific Appendix 7/1, the coefficient of linear expansion of the mixture shall be determined in accordance with Clause 871.

811 (02/16) Binder Constituents

1 (02/16) Binder constituents shall comply with BS EN 14227 except that, unless otherwise agreed by the Overseeing Organisation:

(i) fly ash shall be siliceous fly ash complying with BS EN 14227-4;

(ii) quicklime shall comply with BS EN 14227-11 and have a grading that complies with particle size Category 1.

2 (02/16) The binder content shall comply with Table 8/9, unless otherwise agreed by the Overseeing Organisation. The mixture proportions used for production shall be based on a laboratory mixture design procedure in accordance with Clause 880.

TABLE 8/9: (02/16) **Minimum Binder or Binder Constituent Additions for HBM**

Binder or binder constituent	Application	Minimum addition for mix-in-plant method of construction using batching by mass (by dry mass of mixture)	Minimum addition for mix-in-plant method of construction using volume batching and for mix-in-place construction (by dry mass of mixture)
Lime (quicklime or hydrated lime)	when used with another binder constituent	1.5%	2%
	when used as the only binder in FABM 5	3%	4%
Cement	when used with another binder constituent	2%	3%
	when used as the only binder constituent in CBGM	The appropriate value from BS EN 14227-1, Table 1	1% + (the appropriate value from BS EN 14227-1, Table 1)
	when used as the only binder constituent in soil treated by cement (SC)	3%	4%
Ground granulated blast furnace slag (ggbs)	when used with cement	2%	3%
	when used with lime	3%	4%
Air-cooled steel slag (ASS)	when used with GBS (see Note)	2.5%	3%
Dry fly ash (FA)	when used with cement	4%	5%
	when used with lime	5%	6%
Granulated blast furnace slag (GBS)	when used with lime	6%	8%
	when used with ASS (see Note)	2.5%	3%
Wet (conditioned) fly ash (FA)	All applications	6%	8%
Hydraulic road binder	All applications	3%	4%
NOTE: When GBS and ASS are used in combination, the sum of the two shall be not less than 11%.			

812 (02/16) Storage of Constituents

1 (02/16) Aggregates shall be stored on a firm and clean substrate avoiding contamination with other constituents. Fine aggregate shall be stored at the production location for at least 24 hours before use.

2 (02/16) Lime, cement, ggbs, HRB and dry FA shall be stored in silos.

3 (02/16) Wet (conditioned) FA shall have no agglomerations greater than 10 mm size. This shall be determined by sieving samples through a 10 mm size test sieve using not more than 10 seconds of gentle agitation by hand. Wet (conditioned) fly ash shall be stored at the source or at the production location for at least 72 hours before use, and have a minimum water content of 10%.

4 (02/16) GBS and ASS shall be stored as specified in sub-Clause 812.1 and used within 3 months of delivery to the production location.

813 (02/16) General Requirements for Production and Layer Construction

1 (02/16) HBM shall be produced and laid using one of the following methods, as specified in the following mixture Clauses:

(i) mix-in-plant method of construction using batching by mass, in accordance with Clause 814;

(ii) mix-in-plant method of construction using volume batching, in accordance with Clause 815;

(iii) mix-in-place method of construction, in accordance with Clause 816.

2 (02/16) Construction of layers, including multiple lift layers, and any reworking and reuse, shall be completed within the lesser of 8 hours, the construction period specified in Table 8/10 or the mixture setting time. The time shall be measured from the addition event defined in Table 8/10 to completion of compaction.

3 (02/16) The construction period, in degree hours, shall be the summation of the products of the average air temperature above 3ºC (T ºC) and time for each period (t hours): i.e. construction period limit =Σ(T.t). The air temperature during the interval, t, shall not fluctuate by more than 4ºC.

TABLE 8/10: (02/16) **Construction Period for HBM Layers**

Binder	Addition event defining the start time for calculating maximum construction period	Maximum construction period (ºC hours)
Cement, cement with FA or cement with ggbs	Addition of cement	35
Lime with GBS or FA	Addition of lime	1,600
Lime and gypsum for FABM 5	Addition of lime and gypsum	70
GBS + ASS	Addition of ASS and GBS	3,000
Lime with ggbs	Addition of ggbs	200 if ggbs added after lime 1,600 if ggbs added before lime
HRB	Addition of HRB	Workability Period at 20°C determined in accordance with BS EN 13286-45 multiplied by 17

4 (02/16) Mixtures used in base layers shall be batched by mass and paver laid in a single lift. Construction of bases by other methods shall only be permitted in confined spaces where it is impracticable for a paver to operate, when agreed by the Overseeing Organisation.

5 (02/16) When quicklime is used, full hydration shall be complete prior to final compaction.

6 (02/16) Laying shall be carried out in a way that avoids segregation and drying of the surface. The temporary intermediate surfaces within a multiple lift layer shall be sprayed with water to prevent surface drying.

7 (02/16) The minimum compacted lift thickness in a multiple lift layer shall be 150 mm.

8 (02/16) Making-up of level after initial compaction shall not be permitted for single lift working or the uppermost lift of multiple lift working.

9 (02/16) The edge of previously compacted HBM or other material shall be vertical and straight before fresh HBM is laid against it.

10 (02/16) Compaction of HBM layers, including the intermediate lifts of multiple lift working, shall be completed without drying out and before setting of any part of the layer and shall meet the requirements for density in Clause 870.

11 (02/16) Compaction of HBM, other than FABM 5, shall be carried out by vibrating roller and/or pneumatic-tyred roller (PTR). Where vibrating roller compaction is used on mixtures specified in Clauses 830 to 835 it shall be followed by at least 8 passes of a PTR with a wheel loading of not less than 30kN. Only PTR compaction with a wheel loading of not less than 30kN shall be applied to FABM 5.

12 (02/16) On completion of compaction the surface shall be closed, free from ridges, cracks, loose material, visible voids, ruts, shear planes and other defects. All defective areas shall be rectified within the time period specified in sub-Clause 813.2. If rectification is not completed within the specified time period, the defective area shall be removed to the full thickness of the layer, and new mixture laid and compacted.

(02/16) **Cold and Wet Weather Working**

13 (02/16) During cold weather:

(i) the temperature of HBM shall not be less than 5ºC at the time of laying;

(ii) HBM shall not be laid on a frozen surface;

(iii) laying of HBM shall cease when the air temperature falls below 3ºC, and laying shall not be resumed until the rising air temperature reaches 3ºC;

(iv) the laying of HBM using binders containing less than 3% of CEM 1 cement, by dry mass of mixture, shall be restricted in use to the period from 1 May to 30 September, unless otherwise agreed by the Overseeing Organisation.

14 (02/16) In the case of heavy or persistent rain, production shall cease and any laid material shall be compacted immediately.

(02/16) **Curing, Protection and Trafficking**

15 (02/16) On completion of compaction the layer shall be cured to prevent loss of moisture by:

(i) application of a bitumen emulsion spray complying with Class C40B4, as specified in the National Foreword to BS EN 13808 to produce an even and complete coverage of at least 0.2 kg/m^2 of residual bitumen. Before spraying commences, the surface shall be free of all loose material and standing water. The curing membrane shall be protected from any damage until the construction of the overlaying layer;

(ii) application of a mist/fog/light spray of water, sufficient to keep the surface continuously wet until the specified strength of the HBM has been developed or the layer is overlaid.

16 (02/16) Trafficking of HBM layers shall comply with the requirements set out in Table 8/11 and sub-Clause 813.17. Should any HBM layer exhibit signs of damage, trafficking shall cease immediately and shall only be resumed once the layer has gained sufficient stability to resist damage.

TABLE 8/11: (02/16) **Trafficking of HBM Layers**

HBM Designation	Clause reference	Trafficking
CBGM	821, 822 and 823	Sub-Clause 813.17.
HBM	830, 831, and 835	Not restricted.
	832	Not restricted provided that the IBI requirement of sub-Clause 832.6 is satisfied.
FABM 5 with cement	834	Not permitted for 7 days unless overlaid by at least 150mm of bound material within the construction period.
FABM 5 with lime	834	Only the minimum amount of traffic required to construct the next layer is permitted.
SC, SS, SHRB and SFA	840	Not restricted provided that the IBI requirements of Table 8/13 are satisfied. For mixtures containing cohesive soil or chalk, the test specimens made at the same time as the specimens required in Clause 870 but cured under the same conditions as the insitu treated soil shall also have achieved an average strength of at least Class C0.8/1.0.

17 (02/16) CBGM shall not be trafficked for 7 days unless the layer complies with the following:

(i) the layer is compacted by both vibrating roller and PTR in accordance with sub-Clause 813.11 to comply with the requirements of sub-Clause 813.12;

(ii) the mixture contains at least 50% by mass of coarse aggregate complying with BS EN 13242, Category $C_{90/3}$ for 'crushed or broken particles';

(iii) test specimens made at the same time as the specimens required in Clause 870 but cured under the same conditions as the in-situ CBGM have achieved an average strength of at least Class C3/4.

18 (02/16) Surface contamination shall be avoided as far as is practicable and any unavoidable contamination shall be removed prior to overlaying. Reworking and re-compaction of the layer shall only be permitted within the construction period set out in Table 8/10. Reworking shall only be permitted when the water content requirements of the reworked material are maintained within the limits stated in the method statement.

19 (02/16) Before overlaying, any loose material shall be removed and replaced to the full depth of the layer or, if within the construction period set out in Table 8/10, reworked as specified in sub-Clause 813.18.

20 (02/16) Daily record sheets complying with sub-Clause 817.4 shall be submitted to the Overseeing Organisation by start of work on the next working day, detailing:

(i) spread rate/batching record results;

(ii) depth measurements;

(iii) density test measurements;

(iv) sample and test locations;

(v) construction period records showing the time(s) of mixing, water addition, completion of compaction and application of curing membrane.

814 (02/16) Mix-in-Plant Method of Construction Using Batching by Mass

1 (02/16) The HBM shall be produced in a stationary mixing plant that batches by mass and mixes in a forced-action mixer, allowing sufficient time in the mixer to produce a homogenous mixture.

2 (02/16) The mixing plant shall have an automated surveillance and data collection system.

3 (02/16) HBM shall be transported directly to the point where it is to be laid and protected from the weather during transit and whilst awaiting tipping, unless otherwise agreed by the Overseeing Organisation.

815 (02/16) Mix-in-Plant Method of Construction Using Volume Batching

1 (02/16) The HBM shall be produced in a stationary mixing plant that batches by volume and mixes in a forced action mixer, allowing sufficient time in the mixer to produce a homogenous mixture.

2 (02/16) HBM shall be transported directly to the point where it is to be laid and protected from the weather during transit and whilst awaiting tipping, unless otherwise agreed by the Overseeing Organisation.

3 (02/16) Dispensing accuracy shall be verified by reconciliation between constituent deliveries and the area and depth of completed layer for each 5000 m^2 of work, or part thereof, during each day's operations.

816 (02/16) Mix-in-Place Method of Construction

1 (02/16) Mixed-in-place HBM shall be produced by an in-situ pulverizing-mixing process with the added mixing water injected directly into the mixture during the mixing process. The pulverizing-mixing process shall be repeated until a homogenous mixture is produced.

2 (02/16) When binder constituents are dispensed onto the surface to be pulverized-mixed, the rate of spread shall be confirmed by site checks carried out in accordance with Clause 870. For each group of 5 readings the mean rate of spread of material shall be within ±10% of the stated target rate and each individual value shall be within ±15% of the mean value of the group of 5 readings.

3 (02/16) The accuracy of the system used to dispense binder constituents shall be verified by reconciliation between constituent deliveries and the area and depth of completed layer for each 5000 m^2 of work, or part thereof, during each day's operations.

4 (02/16) Mixing of fresh material shall ensure a minimum overlap of 200 mm with previously mixed material.

5 (02/16) Where lime is used to granulate cohesive soils it shall be added and mixed with the soil using at least two passes of the pulverizer-mixer between 24 and 96 hours before the subsequent addition of cement, FA, HRB or ggbs. The surface of the layer shall be sealed by rolling immediately after adding and mixing lime. The MCV during this period, known as the mellowing period, shall comply with Clause 840.

817 (02/16) Method Statement and Demonstration Area

(02/16) **Method Statement**

1 (02/16) At least 10 days prior to constructing the demonstration area specified in sub-Clause 817.5, the Contractor shall provide a full method statement for the approval of the Overseeing Organisation. The statement shall detail the operatives, plant, materials and procedures for the construction of demonstration area(s) and of the works, including procedures. The statement shall also include procedures for induced cracking, if required by contract specific Appendix 7/1, and the procedures to be applied during inclement weather, plant breakdowns and other unscheduled events.

2 (02/16) The method statement shall include the intended mixture proportions with supporting data from trial mix results and/or historic records to justify the proportions, the water content (or MCV) limits and (if applicable) spread rates for all stages of the work.

3 (02/16) Where multiple lift working is used, the method statement shall detail the methods used to assure that bond between the individual lifts is achieved. The method statement shall also detail the procedures to be used to confirm that bond has been achieved in the demonstration area and in the works.

4 (02/16) The method statement shall include a sample record sheet for the submission of the data required by sub-Clause 813.20.

(02/16) **Demonstration Area**

5 (02/16) Prior to the commencement of the main works, the Contractor shall construct a demonstration area of at least 800 m^2 conforming to the submitted method statement. The demonstration area shall include a transverse end-of-day joint and (if appropriate) multiple lift working. The demonstration area may be accepted into the permanent works, where agreed by the Overseeing Organisation. Where the Contractor can produce documentary evidence of similar work carried out to this specification during the previous 6 months, the Overseeing Organisation may allow the works to proceed without the demonstration area.

6 (02/16) Where multiple lift working is used, the demonstration area shall confirm the effectiveness of the procedures used to assure that bond between the individual lifts can be achieved.

7 (02/16) Where induced cracking is required, the demonstration area shall include crack induction at the specified spacing. The effectiveness of the procedure used shall be checked within 28 days of construction, by recovering four evenly spaced 150 mm dia cores from the line of the induced cracks and assessing each core for compliance with sub-Clause 818.2.

8 (02/16) The mixture constituents, proportions, laying and compaction plant and construction procedures used for the demonstration area shall not be changed unless the Contractor lays a further demonstration area or the changes are agreed by the Overseeing Organisation.

818 (02/16) Induced Cracking of HBM

1 (02/16) Where required by contract specific Appendix 7/1, transverse cracks shall be formed at the specified spacing with a tolerance of ± 150 mm. Where the pavement is made up of two or more layers of HBM with induced cracks, the cracks in the overlying HBM layer shall align with the induced cracks in the layer below with a tolerance of ± 100 mm.

2 (02/16) Cracks shall be induced in fresh material after initial compaction. The transverse cracks shall be induced by grooving the fresh material to form straight vertical grooves not more than 20 mm wide, to a depth of between one half and two thirds of the layer thickness over the full width of the pavement. Bitumen emulsion shall be poured or sprayed into the grooves prior to final compaction, to form a crack inducing membrane. The bitumen emulsion shall comply with Class C40B4, as specified in the National Foreword to BS EN 13808. During final compaction of the mixture, the surface of the groove shall be fully closed throughout its full length. The bitumen in the groove shall be fully encased and remain continuous, with not less than 70% of the sides of the groove coated with bitumen.

3 (02/16) Where required by contract specific Appendix 7/1, longitudinal cracks shall be induced using the procedure specified in sub-Clause 818.2.

819 (02/16) Not Used

820 (02/16) Aggregates

1 (02/16) The aggregates used in HBM shall comply with BS EN 13242 and the selected requirements listed in Table 8/12. Where recycled coarse aggregate or recycled concrete aggregate is used in HBM, it shall also be tested in accordance with Clause 710 and comply with the additional requirements for the proportion of the components listed in Table 8/12.

2 (02/16) When required by contract specific Appendix 7/1, an existing pavement layer that is to used to produce HBM shall be tested to confirm compliance with sub-Clause 820.1.

TABLE 8/12: (02/16) **Aggregate Requirements for HBM**

Clause reference	821	822	823	830	831	832	835
HBM designation	**CBGM A**	**CBGM B**	**CBGM C**	**FABM 1 HRBBM 1**	**SBM B2, FABM 2 HRBBM 2**	**SBM B3, FABM 3 HRBBM 3**	**SBM B1-1, B1-2, B1-3 & B1-4**
Categories for aggregate properties, BS EN 13242							
Crushed or broken particles and totally rounded particles in coarse aggregate	C_{NR} (Note 1)	C_{NR} unless otherwise specified in contract specific Appendix 7/1		$C_{90/3}$ or $C_{50/30}$, as specified in contract specific Appendix 7/1 (Note 2)		C_{NR} (Note 1)	$C_{90/3}$ or $C_{50/30}$ as specified in contract specific Appendix 7/1
Resistance to fragmentation of coarse aggregate	LA_{NR}	LA_{50} or LA_{60} as specified in contract specific Appendix 7/1	LA_{50}	LA_{50} or LA_{60} as specified in contract specific Appendix 7/1	LA_{50}	LA_{NR}	LA_{50}
Acid-soluble sulfate content (Note 3)	Air-cooled blast-furnace slag – $AS_{1,0}$						
	Other aggregates – $AS_{0,2}$						
Total sulfur content (Note 3)	Air-cooled blast-furnace slag – S_2						
	Other aggregates – S_1						
Other requirements, BS 1377-2							
Fines quality (Note 4)	NR (Note 1)	*Non-plastic*				NR (Note 1)	*Non-plastic*
Proportion of components, Clause 710							
Maximum glass content (ClassRgG)	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Maximum impurities content (Class X)	*5*	*3*	*3*	*3*	*3*	*5*	*3*

NOTES:
1. The suffix $_{NR}$ denotes that the 'No requirement' category applies.
2. C_{NR} if FABM 1 contains at least 3% CEM 1 cement by dry mass of the mixture and trafficking is prevented for 7 days.
3. Where the Contractor is able to provide evidence of mixture stability over an extended period then the Overseeing Organisation may consider the use of higher limits.
4. Where required, the size fraction of the aggregate passing the 0.425 mm size test sieve shall be non-plastic as defined by and tested in compliance with BS 1377-2.

821 (02/16) Cement Bound Granular Mixtures A (CBGM A)

1 (02/16) Cement bound granular mixtures A (CBGM A) shall comply with BS EN 14227-1 and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregate shall comply with the requirements of Clause 820 and shall have a combined grading that complies with Envelope A from BS EN 14227-1, Figure 1.

3 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

4 (02/16) The method of construction shall be in accordance with Clause 813 and either Clause 814, Clause 815 or Clause 816.

5 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

822 (02/16) Cement Bound Granular Mixtures B (CBGM B)

1 (02/16) Cement bound granular mixtures B (CBGM B) shall comply with BS EN 14227-1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregates shall comply with the requirements of Clause 820 and shall have a combined grading that complies with Envelope B from BS EN 14227-1, Figure 1. Alternatively, the total mixture grading shall comply with the grading envelope Category G2 from BS EN 14227-1, Annex B, Figure B2.

3 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

4 (02/16) The method of construction shall be in accordance with Clause 813 and Clause 814.

5 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

823 (02/16) Cement Bound Granular Mixtures C (CBGM C)

1 (02/16) Cement bound granular mixtures C (CBGM C) shall comply with BS EN 14227-1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregates shall comply with the requirements of Clause 820 and shall have a total mixture grading that complies with grading envelope Category G1 from BS EN 14227-1, Annex B, Figure B2 for 0/20 size mixtures, Figure B3 for 0/14 mm size mixtures or Figure B4 for 0/10 mm size mixtures.

3 (02/16) The compacity of the mixture shall be at least 0.8, when calculated in accordance with BS EN 14227-2, Annex C. The maximum dry density value used for the calculation shall be determined in accordance with BS EN 13286-50, using the modified Proctor (4.5 kg rammer) procedure from BS EN 13286-2.

4 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

5 (02/16) The method of construction shall be in accordance with Clause 813 and Clause 814.

6 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

824 to 829 (02/16) Not Used

830 (02/16) Fly Ash Bound Mixture 1 (FABM 1) and Hydraulic Road Binder Bound Mixture 1 (HRBBM 1)

1 (02/16) The mixture shall comply with the requirements of BS EN 14227-3 for Fly Ash Bound Mixture 1 or the requirements of BS EN 14227-5 for Hydraulic Road Binder Bound Mixture 1, as specified in contract specific Appendix 7/1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregate shall comply with the requirements of Clause 820.

3 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

4 (02/16) The method of construction shall comply with Clause 813 and Clause 814.

5 (02/16) The laboratory mechanical performance shall comply with the contract specific requirements of Appendix 7/1, when sampled and tested in accordance with Clause 870.

831 (02/16) Slag Bound Mixture B2 (SBM B2), Fly Ash Bound Mixture 2 (FABM 2) and Hydraulic Road Binder Bound Mixture 2 (HRBBM 2)

1 (02/16) The mixture shall comply with the requirements of BS EN 14227-2 for Slag Bound Mixture B2 or the requirements of BS EN 14227-3 for Fly Ash Bound Mixture 2 or the requirements of BS EN 14227-5 for Hydraulic Road Binder Bound Mixture 2, as specified in contract specific Appendix 7/1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregate shall comply with the requirements of Clause 820.

3 (02/16) SBM B2 shall have a total mixture grading that complies with grading envelope Category G1 or G2 from BS EN 14227-2, Figure 5 for 0/20 size mixtures, Figure 6 for 0/14 mm size mixtures or Figure 7 for 0/10 mm size mixtures.

4 (02/16) FABM 2 shall have a total mixture grading that complies with grading envelope Category G1 or G2 from BS EN 14227-3, Figure 3 for 0/20 size mixtures, Figure 5 for 0/14 mm size mixtures or Figure 7 for 0/10 mm size mixtures.

5 (02/16) HRBBM 2 shall have a total mixture grading that complies with grading envelope Category G1 or G2 from BS EN 14227-5, Figure 2 for 0/20 mm size mixtures, Figure 3 for 0/14 mm size mixtures and Figure 4 for 0/10 mm size mixtures

6 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

7 (02/16) The method of construction shall be in accordance with Clauses 814 and 813.

8 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

832 (02/16) Slag Bound Mixture B3 (SBM B3), Fly Ash Bound Mixture 3 (FABM 3) and Hydraulic Road Binder Bound Mixture 3 (HRBBM 3)

1 (02/16) The mixture shall comply with the requirements of BS EN 14227-2 for Slag Bound Mixture B3 or the requirements of BS EN 14227-3 for Fly Ash Bound Mixture 3 or the requirements of BS EN 14227-5 for Hydraulic Road Binder Bound Mixture 3, as specified in contract specific Appendix 7/1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregate shall comply with the requirements of Clause 820.

3 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

4 (02/16) The method of construction shall be in accordance with Clause 813 and either Clause 814, Clause 815 or Clause 816.

5 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

6 (02/16) The mixture design procedures specified in Clause 880 shall include the determination of the immediate bearing at the target water and binder content. The mixture shall comply with Immediate Bearing Index Category IPI_{40}. When approved by the Overseeing Organisation, and where the mixture is not subject to direct trafficking, the mixture shall comply with Immediate Bearing Index Category IPI_{25}.

7 (02/16) The requirements of Clause 832.6 shall not apply if the mixture contains at least 3% cement by mass of the dry mixture and traffic is not permitted to use the layer for the first 7 days.

833 (02/16) Not Used

834 (02/16) Fly Ash Bound Mixture 5 (FABM 5)

1 (02/16) The mixture shall comply with BS EN 14227-3 for Fly Ash Bound Mixture 5, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

3 (02/16) For lime-treated fly ash mixtures with gypsum added as an additional constituent, the method of construction shall be in accordance with Clause 813 and 814. For other mixtures, the method of construction permitted shall comply with Clause 813 and either Clause 814, Clause 815 or Clause 816.

4 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

835 (02/16) Slag Bound Mixtures B1-1, B1-2, B1-3 and B1-4 (SBM B1)

1 (02/16) The mixture shall comply with BS EN 14227-2 for SBM B1-1, SBM B1-2, SBM B1-3 or SBM B1-4, as specified in contract specific Appendix 7/1, and have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Aggregates shall comply with the requirements of Clause 820.

3 (02/16) The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 880.

4 (02/16) The method of construction shall be in accordance with Clause 813 and 814.

5 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

836 to 839 (02/16) Not Used

840 (02/16) Soil Treated by Cement (SC), Soil Treated by Slag (SS), Soil Treated by Fly Ash (SFA) and Soil Treated by Hydraulic Road Binder (SHRB)

1 (02/16) The mixture shall be as specified in contract specific Appendix 7/1 and comply with the appropriate requirements selected from Table 8/13 and the following:

(i) BS EN 14227-10, for soil treated by cement (SC);

(ii) BS EN 14227-12, for soil treated by slag (SS);

(iii) BS EN 14227-13, for soil treated with hydraulic road binder (SHRB)

(iv) BS EN 14227-14, for soil treated by fly ash (SFA).

The mixture shall also have binder constituent proportions complying with the requirements of Clause 811.

2 (02/16) Not less than 95% of the soil shall pass the 63 mm size test sieve when tested in accordance with BS EN 933-1 and the maximum particle size of the soil shall not exceed 25% of the layer depth.

3 (02/16) When tested in accordance with BS EN 1744-1 clause 10, soil with a total potential sulfate (TPS) content less than 0.25% sulfate (as SO_4) shall be deemed suitable for treatment, if the laboratory mixture design procedure confirms that the mixture complies with the 'resistance to water' requirements specified in Table 8/13. Soil with a total potential sulfate (TPS) equal to or greater than 0.25% sulfate (as SO_4) shall only be deemed suitable for treatment where agreed by the Overseeing Organisation.

4 (02/16) The method of construction shall be in accordance with Clause 813 and either Clause 814, Clause 815 or Clause 816.

5 (02/16) The laboratory mechanical performance shall comply with the requirements of contract specific Appendix 7/1, when sampled and tested in accordance with Clause 870.

TABLE 8/13: (02/16) **Requirements for Soil Treated by Cement (SC), Slag (SS) and Fly Ash (SFA)**

<table>
<tr><th rowspan="2">Mixture parameter</th><th colspan="2">Requirement Category</th><th rowspan="2">BS EN 14227 -10, -12, -13, -14 reference</th></tr>
<tr><th>Non-cohesive soil mixtures</th><th>Cohesive soil mixtures and chalk mixtures</th></tr>
<tr><td rowspan="2">Minimum water content

(Expressed as a proportion of the optimum water content, determined in accordance with BS EN 13286-4, Vibrating hammer method)</td><td>$W_{0,9}$</td><td rowspan="2">W_{NR}
(Note 1)</td><td rowspan="2">Table 1</td></tr>
<tr><td>$W_{1,0}$
for mixtures containing quicklime</td></tr>
<tr><td>Degree of Pulverization
(Determined in accordance with BS EN 13286-48)</td><td>$Pulv_{NR}$
(Note 1)</td><td>$Pulv_{60}$</td><td>Table 2</td></tr>
<tr><td>Immediate Bearing Index (Note 2)

(Determined in accordance with Clause 880)</td><td>IPI_{40}
(Note 3)</td><td>IPI_{15}</td><td>Table 3</td></tr>
<tr><td>Moisture Condition Value

(Determined in accordance with BS EN 13286-46)</td><td>MCV_{NR}
(Note 1)</td><td>$MCV_{8/12}$
at final mixing and compaction (Note 4)</td><td>Table 4</td></tr>
<tr><td>Laboratory mechanical performance

(Compressive strength or tensile strength)</td><td colspan="2">R_c or $R_t E$,
as specified in contract specific Appendix 7/1</td><td>Table 6 for R_c

Figure 1 for $R_t E$</td></tr>
<tr><td>Resistance to water – strength after immersion

(R_i/R ratio, determined in accordance with Clause 880)</td><td colspan="2">$I_{0,8}$</td><td>Table 7</td></tr>
<tr><td rowspan="2">Resistance to water – volumetric swelling

(Determined in accordance with BS EN 13286-49)</td><td rowspan="2">NR
(Note 1)</td><td>SC - G_{V5}</td><td>Table 9
(BS EN 14227-10)</td></tr>
<tr><td>SS, SRB and SFA – G_V to be not greater than 5%</td><td>Clause 9.1.4
(BS EN 14227-12, -13 and -14)</td></tr>
<tr><td colspan="4">NOTES:
1. The suffix $_{NR}$ denotes that the 'No requirement' category applies.
2. Where SC is not to be trafficked within 7 days, IPI_{NR} may be used.
3. IPI_{25} where the mixture is not subject to direct trafficking.
4. For cohesive soil mixtures, the requirement also applies during the mellowing period.</td></tr>
</table>

841 to 869 (02/16) Not Used

870 (02/16) Testing, Control and Checking of HBM

(02/16) **General**

1 (02/16) Tests, controls and checks shall be carried out in accordance with the requirements in Table 8/14 and the following sub-Clauses at locations determined by the Overseeing Organisation, unless otherwise stated in contract specific Appendix 1/5. Where the Overseeing Organisation is satisfied that a consistent quality of work is being achieved it may order the frequency of testing to be reduced to half that required in Table 8/14. Where a test reference is shown in Table 8/14, the testing shall be carried out in compliance with the requirements of Clause 105 and be undertaken by an organisation accredited in accordance with BS EN ISO/IEC 17025 for the test method.

(02/16) **Sampling**

2 (02/16) Sampling shall be in accordance with BS 1924-1. Where a bulk sample of HBM is taken from a layer, it shall be taken from the full depth of the layer, used without further mixing, and not combined with other bulk samples.

(02/16) **Spread Checks for the Mix-in-Place Method of Construction**

3 (02/16) The rate of spread of added constituents shall be determined by weighing the amount of material retained on five trays (or mats) of known area laid in the path of the spreading machine. The trays (or mats) shall be positioned at points equally spaced along a diagonal bisecting line the area of coverage so as to assess the full width of discharge from the spreading machine.

(02/16) **Depth of Mixing for the Mix-in-Place Method of Construction**

4 (02/16) The depth of mixing shall be checked by excavation and inspection on completion of each stage of the pulverizing-mixing process. The depth of mixing shall be referenced to the design levels for the pavement by precise leveling of the stabilized soil interface (or other techniques approved by the Overseeing Organisation) to ensure that the level at the underside of the stabilized layer is in accordance with the specified requirements.

(02/16) **Standardisation of Nuclear Density Gauges and Measurement of In-situ Wet Density**

5 (02/16) The in-situ wet density of a compacted mixture shall be measured using a calibrated nuclear density gauge in accordance with BS 1924-2 and the following sub-Clauses, except that each test shall consist of at least 3 measurements at 120 degrees to each other using the same source rod hole and the density taken as the average of the higher 2 results.

6 (02/16) The operation, warming-up period if any, and standardisation of the gauge shall be carried out in compliance with the manufacturer's recommendations. The gauge shall be calibrated in accordance with BS 1924 immediately prior to the construction of the demonstration area and at least once every 28 days thereafter.

7 (02/16) The gauge shall be used in the direct transmission mode of operation with the source rod lowered to within 25 mm of the bottom surface of the layer. The in-situ wet density shall be determined within two hours of completing compaction.

8 (02/16) The in-situ wet density of a subbase layer shall be taken as the average value of five determinations equally spaced along a line that bisects each 1000 m^2 or part thereof laid each day. The first and fifth positions shall be located 300 mm from the edges of the laid area, or other positions agreed by the Overseeing Organisation.

9 (02/16) For a subbase layer, the average in-situ wet density of the area specified in sub-Clause 870.8 shall be not less than 95% of the average wet density of the test specimens taken to determine the laboratory mechanical performance of the same area.

10 (02/16) For a base layer, the average in-situ wet density of the area specified in sub-Clause 870.8 shall be not less than 95% of the wet density of the HBM at its optimum moisture content, measured using the vibrating hammer method detailed in BS EN 13286-4. The result of each single determination of in-situ wet density shall be not less than 92% of the wet density of the HBM at its optimum moisture content.

(02/16) **Laboratory Mechanical Performance**

11 (02/16) A bulk sample of HBM shall be taken from each of the locations in sub-Clause 870.8, after the in-situ wet density has been determined. Test specimens used to determine laboratory mechanical performance shall be made using vibratory hammer compaction, in accordance with BS EN 13286-51. Where cubes are used for the determination of compressive strength, the specimens shall be 150 mm size, unless agreed otherwise by the Overseeing Organisation.

TABLE 8/14: (02/16) **Requirements for Testing, Control and Checking of HBM**

Test/control/check	Test frequency	Test reference
Water content of aggregate or soil sources on site	3 per 1000 m^2	BS 1924-1, Clause 7.1
Grading of aggregate or soil sources on site	1 per 1000 m^2	Aggregates: BS EN 1097-5 Soils: BS 1924-1, Clause 7.1
Plasticity of aggregate or soil sources on site	1 per 1000 m^2	BS 1924-1, Clause 7.3
Constituents sourced off-site	Aggregates – Results of routine control tests from the factory production control system required by BS EN 13242, Annex C to be provided weekly. Cement – Certificates to be provided monthly for each cement type, in accordance with BS EN 197-1, National Annex NB. Slag – Certificates to be provided weekly to confirm the declared values required by BS EN 14227-2, Clause 5. Fly ash – Certificates to be provided weekly to confirm compliance with the requirements of BS EN 14227-4. Other constituents – certificates to be provided weekly to confirm compliance with the specification agreed as part of the factory production control system for the mixture.	–
Batching records for 'mix-in-plant' method of construction using batching by mass	Continuously using the automated surveillance and data collection system	–
Batching records for 'mix-in-plant' method of construction using batching by volume and mix-in-place	Dispensing accuracy shall be verified by reconciliation between constituent deliveries and the area and depth of completed layer for each 5000m^2 of work, or part thereof, during each day's operation	–
Spread checks for 'mix-in-place' method of construction at each stage of the mixing process (sub-Clause 870.3)	1 determination per 1000 m^2 but not less than 4 per day	–
Mixture grading, including binder	1 per 1000 m^2 but not less than 3 per day	BS EN 933-1
Water content at final compaction	1 per 1000 m^2 but not less than 3 per day	BS 1924-2, Clause 1.3
MCV at mixing and final compaction and, in the case of cohesive mixtures, during the mellowing period	3 per 1000 m^2 but not less than 4 per day	BS EN 13286-46
Pulverization (cohesive mixtures only)	2 per 1000 m^2 but not less than 4 per day	BS EN 13286-48
Depth of mixing for 'mix-in-place' method of construction at each stage of the mixing process (sub-Clause 870.4)	5 per 1000 m^2 but not less than 4 per day	–
In-situ wet density	5 per 1000 m^2 or part thereof laid each day (measured at the locations detailed in sub-Clause 870.8)	Sub-Clause 870.5
Laboratory mechanical performance	5 per 1000 m^2 or part thereof laid each day (with test specimens prepared from a bulk sample taken from each of the locations detailed in sub-Clause 870.8)	As required by Table 8/15
Strength after immersion in water	Laboratory mixture design procedure	As required by Clause 880

TABLE 8/15: (02/16) **Laboratory Mechanical Performance Testing Requirements for HBM**

Clause	Mixture	Curing regime	Curing temperature	Test method	Age at test
821, 822 & 823	GBGM A, CBGM B and CBGM C	Regime A from, BS EN 14227-1, Annex C	20°C	R_C – BS EN 13286-41	28 days – or other age agreed by the Overseeing Organisation (see Note)
830, 831, 832 & 835	SBM, HRBBM and FABM, (except FABM 5)	BS EN 13286-51	40°C		
834	FABM 5 treated with lime	BS EN 13286-51	40°C	R_{it} – BS EN 13286-42	
	FABM 5 treated with cement	BS EN 13286-51	20°C		
840	SC	Regime A1 from BS EN 14227-10, Annex B	20°C	E_c – BS EN 13286-43	
	SS & SFA	BS EN 13286-51	40°C		

NOTE:
For site control purposed, HBM may be assessed on the basis of 7 days strength (or other agreed age) where the Contractor so requests, provided that a robust correlation is established between 7 days and 28 days strength using representative samples of the aggregates and binder used in the works.

12 (02/16) Compliance of the area specified in sub-Clause 870.8 shall be assessed using the results for test specimens that are cured and tested in accordance with Table 8/15 using either compression or indirect tensile testing as appropriate to the class of mechanical performance specified in contract specific Appendix 7/1. Assessment shall be made using the following criteria:

(i) Compressive strength:

The requirement specified in contract specific Appendix 7/1 shall be deemed to be satisfied if the average compressive strength of the group of specimens in Table 8/14 is equal to or greater than the minimum for the specified R_c class and no individual test result is less than 67% of the minimum strength requirement for the R_c class.

(ii) Indirect tensile strength:

The requirement specified in contract specific Appendix 7/1 shall be deemed to be satisfied if the average indirect tensile strength of the group of specimens in Table 8/14 is equal to or greater than the minimum requirement and no individual result is less than 67% of the minimum requirement appropriate to the E value determined during the laboratory mixture design procedure specified in Clause 880.

For the purposes of this specification, any reference to 'characteristic strength' in BS EN14227-1 shall be superseded by the requirements of this sub-Clause.

871 (02/16) Determination of the Coefficient of Linear Thermal Expansion

(02/16) **Scope**

1 (02/16) The test method described in this Clause shall be used to determine the coefficient of linear thermal expansion of HBM within the normal range of temperature for pavement layers. The test method shall be carried out using hardened specimens.

(02/16) **Apparatus**

2 (02/16) The following apparatus shall be used:

(i) A water bath with sufficient capacity to accommodate three test specimens and capable of maintaining predetermined temperatures between 15ºC and 60ºC.

(ii) A device capable of measuring linear dimensions of not less than 275 mm to an accuracy of ± 0.002 mm, with a known temperature correction factor.

(iii) Vibrating hammer compaction apparatus capable of producing 150 mm diameter cylindrical test specimens, in accordance with BS EN 13286-51. The apparatus shall be suitably modified to manufacture 300 mm long test specimens.

(02/16) **Test procedure**

3 (02/16) The following test procedure shall be followed:

(i) Compact three 150 mm diameter test specimens, 300 mm in length, in accordance with BS EN 13286-51 but using six layers, each with a nominal depth of 50 mm.

(ii) Mark each specimen with 3 pairs of permanent reference points, aligned longitudinally. One of each pair shall be at opposite ends of the specimen. Each pair shall be located at 120º around the circumference of the specimens, aligned parallel to the axis, and not more than 30 mm from each end of the specimen.

(iii) Cure the specimens using the procedure specified for the determination of mechanical laboratory performance in Table 8/15.

(iv) Saturate the test specimens, either at atmospheric pressure or under vacuum, until the increase in the surface dried mass of each specimen, determined using two readings taken at least 24 hours apart, is less than 1%.

(v) Immerse the specimens in the water bath at a constant temperature (T1), maintained to an accuracy of ± 2ºC, for 24 ± 2 hours. Then measure the length (L1) of each test specimen at the locations defined by the three pairs of reference points. Repeat the measurement of length every 24 hours, until the change in length between successive measurements is less than 0.004 mm.

(vi) Raise the temperature of the water bath by at least 30ºC and record the temperature (T2). T2 shall not exceed 55ºC. Maintain the temperature at T2 ± 2ºC for 24 ± 2 hours and measure the length (L2) using the procedure in (v).

(vii) Lower the temperature of the water bath by at least 30ºC and record the temperature (T3). Maintain the temperature at T3 ± 2ºC for 24 ± 2 hours and measure the final length (L3) using the procedure in (v).

(02/16) **Calculations**

4 (02/16) Calculate the Coefficient of Linear Thermal Expansion (C_{LE}) as follows:

(i) For each pair of reference points for the heating sequence calculate:

$C_{LE}' = (L2 – L1) / (T2 – T1)$, giving 9 results in total.

(ii) Reject the highest and lowest results and record the mean value of C_{LE}' for the remaining 7 results.

(iii) For each pair of reference points for the cooling sequence calculate:

$C_{LE}'' = (L2 – L3) / (T2 – T3)$, giving 9 results in total.

(iv) Reject the highest and lowest results and record the mean value of C_{LE}'' for the remaining 7 results.

(v) Calculate:

C_{LE} = 0.5 ((Mean value of C_{LE}') + (Mean value of C_{LE}'')).

(vi) Check that the mean values of C_{LE}' and C_{LE}'' lie in the range $0.95C_{LE}$ to $1.05C_{LE}$. If the mean values lie outside this range, repeat the procedure in sub-Clause 871.3.

(02/16) **Reporting of Results**

5 (02/16) Report the value of C_{LE} using units of $m.10^{-6}/ºC$, expressed to the nearest whole number.

872 to 879 (02/16) Not used

880 (02/16) Laboratory Mixture Design Procedure

1 (02/16) Prior to the commencement of the work or any change in mixture constituents, the Contractor shall determine the target proportions of the constituents, including water, for the specified HBM, based on the mixture design procedure described in this Clause.

2 (02/16) The mixture design procedure shall determine the properties of the HBM at a minimum of 3 values of binder contents, and a minimum of 2 values of water content for each value of binder content.

(02/16) **Immediate Stability**

3 (02/16) When required, the mixture design procedure shall include the determination of the immediate bearing index (IBI) at the selected design water and binder content, measured in accordance with BS EN 13286-47. The IBI value shall be taken as the average value for a set of 3 test specimens.

(02/16) **Resistance to Water – Strength After Immersion**

4 (02/16) The strength after immersion in water shall be assessed by comparing the average strength and condition of:

(i) 3 specimens initially cured in a sealed condition for 14 days at the test temperature; and then removed from their moulds and immersed in aerated water for 14 days at the same test temperature.

(ii) 3 specimens cured in sealed condition for 28 days at the same test temperature.

The immersed specimens shall be unconfined and have water in contact with all surfaces. On completion of the immersion stage of the test the specimens shall show no signs of cracking or swelling.

5 (02/16) For mixtures containing less than 3% by dry mass of the mixture of cement, the test temperature shall be (40 ± 2)ºC. For mixtures containing 3% or more cement, the test temperature shall be (20 ± 2)ºC.

(02/16) **Resistance to Frost Heave**

6 (02/16) HBM shall be deemed resistant to frost heave where the compressive strength class is C3/4 or greater or R_{it} is greater than 0.25 MPa, when cured in accordance with Table 8/15.

SERIES NG 800
ROAD PAVEMENTS – UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

Contents

ROAD PAVEMENTS – (02/16) UNBOUND, CEMENT AND OTHER HYDRAULICALLY BOUND MIXTURES

NG 800 (02/16) General

1 (02/16) 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 EN 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 7.1.2).

(02/16) Unbound Mixtures for Subbase

NG 801 (02/16) General Requirements for Unbound Mixtures

1 (02/16) 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 (02/16) 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 (02/16) Table 8/1 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 (02/16) 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 (02/16) 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 601.14 and Clause NG 644.

6 (02/16) 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.

(02/16) **Aggregates Used in Unbound Mixtures**

7 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) In previous editions, blast furnace and steel slags were identified separately from other materials. The requirements for these materials 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 field tests and experience.

(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.

(02/16) **Recycled Aggregates**

12 (02/16) 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 (02/16) 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 (02/16) 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.

(02/16) **Unbound Mixtures Produced as Part of The Works**

15 (02/16) BS EN 13242 (see Annex C) and BS EN 13285 (see Annex C) 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.

(02/16) **Frost Heave**

16 (02/16) 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 (02/16) 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 (02/16) 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 (DMRB 7.2.2).

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

Met. Office Customer Centre
FitzRoy Road
Exeter
Devon
EX1 3PB
United Kingdom

Tel No: 0370 900 0100
Fax No: 0370 900 5050
E-mail: enquiries@metoffice.gov.uk

NG 803 (02/16) Type 1 Unbound Mixtures

1 (02/16) 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 (02/16) 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.

3 (02/16) 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 (02/16) 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-Clause 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 (02/16) 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.

(02/16) **Mixtures Containing Crushed Gravel Aggregates**

6 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) Type 2 Unbound Mixtures

1 (02/16) 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 trial.

2 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) 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 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. BS EN 13286-4 also includes a test method for the determination of optimum moisture content which was developed specifically for graded aggregates and gives more reproducible results than the vibrating hammer test for these materials.

NG 805 (02/16) Type 3 (open graded) Unbound Mixtures

1 (02/16) 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 (02/16) 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 Annex B (informative) of BS EN 13285, the use of tolerances does not change the overall grading range.

3 (02/16) 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 (02/16) 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-Clause 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 (02/16) 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 (02/16) Category B (close graded) Unbound Mixtures

1 (02/16) 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 (02/16) 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 (02/16) 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 (02/16) 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-Clause 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 (02/16) 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 (02/16) 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.

NG 807 (02/16) Type 4 (asphalt arisings) Unbound Mixtures

1 (02/16) Trafficking trials of mixtures containing a high proportion of asphalt arisings 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 contract specific Appendix 7/1.

2 (02/16) 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. Type 4 (asphalt arisings) unbound mixtures should, therefore, be compacted at moisture contents close to the declared value of optimum water content discussed in sub-Clause 807.8.

3 (02/16) 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.

4 (02/16) 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.

5 (02/16) 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.

6 (02/16) The performance of unbound mixtures in subbase layers 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 temperatures at the time of compaction, the temperature at the time of testing and the duration of loading. However, as the grading envelope ensures that at least 19% of the mixture is retained on the 16 mm test sieve, it can be assumed without test that the material will have an adequate CBR value. Contract specific Appendix 7/1 can be used to require a trafficking trial, if the additional assurance of performance is required.

Cement and Other Hydraulically Bound Mixtures

NG 810 (02/16) General Requirements for Cement and Other Hydraulically Bound Mixtures

(02/16) General

1 (02/16) Cement and other hydraulically bound mixtures; collectively referred to as 'HBM', form a sub-series of Series 800 of the specification. The term 'mixtures' is used in preference to 'materials' to conform to BS EN 14227 Hydraulically bound mixtures, Specifications. The Parts of BS EN 14227 provide specifications for mixture composition and laboratory mechanical performance but do not cover production and construction methods. Series 800 Clauses provide options from which mixtures may be selected to suit design requirements and provide specifications for the construction of the pavement layers. The variety of terms introduced within the HBM family has prompted the inclusion of a glossary in Clause 810.

2 (02/16) Throughout BS EN 14227 there are options, from which the designer and compiler may choose. Where the designer wishes to use materials covered by BS EN 14227 but not included in Series 800, the use of such materials should be referred to the Overseeing Organisation for approval under the Departure from Standards procedure

3 (02/16) BS EN 14227 is published in Parts to allow the specification of mixtures with different types of hydraulic binder. Separate part numbers are used for mixtures made with granular aggregates and for mixtures made with soil. Hydraulically bound mixtures (HBM) are grouped within Series 800 by reference to their aggregate type and their binder type as indicated in Table NG 8/1. The mixtures are then defined by their strength. Test methods for HBM are published in the Parts of BS EN 13286.

(02/16) HBM Grading Characteristics

4 (02/16) Cement bound granular mixture (CBGM) is relatively fast setting, in comparison with most other types of HBM. It also generally contains less binder for a specified strength. Because of this, the mass of the binder has less influence on the total grading than it does for other types of HBM. This means the grading of CBGM is generally defined for the aggregate alone. However, where CBGM is required to take early trafficking, or where special considerations of shrinkage or density apply, it may be specified using the mixture grading, including the binder. This can be done by specifying CBGM C using Clause 823 or by specifying the alternative mixture grading for CBGM B in Clause 822.

5 (02/16) The mass of material added to FABM, HRBBM and SBM as a binder and/or activator can be relatively large. These types of HBM are usually required to carry site traffic and in-service traffic before they have developed their full strength. This means that the mixture should have some initial mechanical stability to prevent rutting and to allow the formation of cementitious bonds. Therefore grading is specified for the complete mixture, including the binder and any activators

6 (02/16) In order to provide initial mechanical stability, the grading tolerances are more important for FABM, HRBBM and SBM than for CBGM A or CBGM B, unless the latter are to be trafficked early. The particular grading characteristics of FABM, HRBBM and SBM are discussed further in NG 830 to NG 835. The quantity of binder in FABM, HRBBM and SBM is often dictated more by the need to produce a smooth grading curve than mechanical performance considerations.

7 (02/16) FABM has slightly different mixture gradings dependent upon whether the fly ash is siliceous or calcareous. Highways England's experience is predominantly with usage of siliceous fly ash and hence the use of calcareous ash is currently prohibited.

TABLE NG 8/1: (02/16) Cement and Other Hydraulically Bound Mixtures – Classification

HBM designation	General description	Principal binder or binder constituent	SHW Clause number	BS EN 14227: – Specification part reference
CBGM A	Mixtures with broad grading envelope	Cement	821	-1: Cement bound granular mixtures
CBGM B	Graded aggregate mixture		822	
CBGM C	0/20 mm, 0/14 mm or 0/10 mm well graded mixture with compacity requirement		823	
FABM 1	0/31,5 mm Graded mixture	Fly ash	830	-3: Fly ash bound mixtures
HRBBM 1		Hydraulic road binder		-5: Hydraulic road binder bound mixtures
SBM B2	0/10 mm, 0/14 mm, 0/20 mm well graded mixture with compacity requirement	Ground granulated, or granulated, blast furnace slag	831	-2: Slag bound mixtures
FABM 2		Fly ash		-3: Fly ash bound mixtures
HRBBM 2		Hydraulic road binder		-5: Hydraulic road binder bound mixtures
SBM B3	0/6,3 mm mixture	Ground granulated, or granulated, blast furnace slag	832	-2: Slag bound mixtures
FABM 3		Fly ash		-3: Fly ash bound mixtures
HRBBM 3		Hydraulic road binder		-5: Hydraulic road binder bound mixtures
FABM 5	Treated fly ash	Fly ash	834	-3: Fly ash bound mixtures
SBM B1-1, B1-2, B1-3 and B1-4	Graded mixtures with low fines content	Granulated blast furnace slag	835	-2 Slag bound mixtures
SC	Soil or aggregate	Cement	840	-10: Soil treated by cement
SS		Ground granulated blast furnace slag		-12: Soil treated by slag
SFA		Fly ash		-14: Soil treated by fly ash
SHRB		Hydraulic road binder		-13: Soil treated by hydraulic road binder

(02/16) **Strength Classification**

8 (02/16) Two methods of strength classification are included in Series 800 for all granular and soil mixtures. Classification by compressive strength using unconfined cylindrical or cubic specimens and measured in accordance with BS EN 13286-41 is the more commonly applied. However, classification by tensile strength in combination with elastic modulus (R_t,E) provides a modelling regime closer to the performance of bound pavement layers.

9 (02/16) The R_t,E classification requires that materials be placed into tensile strength/elastic stiffness category envelopes. Tensile strength can be measured on cylindrical specimens either by direct tensile testing in accordance with BS EN 13286-40 or indirect (cylinder-splitting) testing in accordance with BS EN 13286-42. Elastic modulus (*E*) is measured in accordance with BS EN 13286-43, either in direct compression or tension or in indirect tension tests. Measurement of tensile strength in indirect tension and *E* in direct compression is considered to be adequate for the purposes of classification and compliance testing.

10 (02/16) The mechanical performance class will be determined by the design requirements. Further guidance is given in HD 25 (DMRB 7.2.2) and HD 26 (DMRB 7.2.3).

11 (02/16) Contract specific Appendix 7/1 should show the allowable alternatives of strength and the associated layer thickness. The designation should be the mix specification name followed by the appropriate strength class in BS EN 14227. For example, for a CBGM A mixture with C5/6 class the designation should be 'CBGM A C5/6'. For a mixture defined using the R_tE system, an equivalent designation may be 'CBGM A T2'.

12 (02/16) Wherever possible, curing times longer than 28 days should be used in order to establish a robust relationship between early age strength and the strength at 360 days. For site control purposes, HBM may be assessed at ages earlier than 28 days where the Contractor so requests, provided that a robust correlation is established between strength test results at the required age and results at 28 days using representative samples of the aggregates and binder used in the works.

13 (02/16) When assessing the acceptability of the aggregate grading for fast setting mixtures such as CBGM, allowance should be made for the grading of the added binder. This is usually 100% by mass passing the 0.063 mm test sieve.

14 (02/16) The specification allows the use of mixtures with a compressive strength below 3 MPa. Because this value is considered to be the lowest strength at which frost heave resistance is always likely to be achieved within a reasonable time, other factors should be considered if a mixture is not expected to have a compressive strength of 3 MPa before the 1st November. The factors to be considered should include:

(i) the frost penetration depth, as discussed in sub-Clause 801.7;

(ii) whether a sufficient depth of overlying layers will give protection against temperatures less than 0ºC;

(iii) the position of the water table;

(iv) the nature of any seal to the surface of the HBM layer;

(v) the indirect tensile strength of the mixture – this should be greater than 0.25 MPa at the time of the first frost.

NG 811 (02/16) Binder Constituents

1 (02/16) Care should be taken when mixing HBM when the proportion of binder or binder constituent is very low, as it may be difficult to obtain complete dispersion throughout the mixture.

2 (02/16) HBM has been mixed successfully using volume batching and in-situ stabilisation with the total binder content at, or close to, the minimum values shown in Table 8/9. Success at such low cement contents depends on:

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

(ii) close control of the binder addition rates;

(iii) efficiency of the binder dispenser or spreader;

(iv) mixing efficiency.

3 (02/16) The minimum binder requirements of Table 8/9, particularly for cement based HBM, may be relaxed if recent and well-documented evidence shows that consistent mixing can be achieved with the same plant and operators using similar soils or aggregates. If evidence is not available, a trial should be carried out over a period of not less than 5 full working days, covering a total area of not less than 3000 m^2. The success of the trial should be judged on the cubes or cylinders made from samples taken at a minimum of 10 evenly spaced locations per day and tested for strength after not less than 7 days curing. A trial should normally be considered successful if the results showed consistent compliance with the specification, after adjusting the test results to reflect the age of test specimens using a laboratory correlation of strength against age. A successful trial may be incorporated into the permanent works.

4 (02/16) The minimum values for binder additions given in Table 8/9 for FABM, HRBBM and SBM are related firstly to the need for a smooth grading curve to allow use by site traffic, and secondly long-term mechanical performance. Usually, if the first criterion is satisfied the second will also be met.

5 (02/16) 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 the operatives change.

NG 813 (02/16) General Requirements for Production and Layer Construction

1 (02/16) Three methods of blending and mixing are recognised in Clause 813; in-plant mixing with batching by mass, in-plant mixing with batching by volume, and in-situ mixing for which batching can only be carried out by volume. Continuous mixing plants, where the mass of the aggregate and binder are constantly recorded using load cells or similar devices, are considered to be mass batching plants. Where a mixture is mixed insitu and then excavated and transported to the point of laying, the construction requirements for in-situ mixing should apply. This technique has advantages over normal insitu methods because it can improve the consistency of mixing, aid compliance with surface level tolerances and help to disperse potentially harmful minerals.

2 (02/16) The values of construction period in Table 8/10 allow for the variation in the rate of hydration of different types of HBM binder with temperature. Until further research indicates otherwise, no hydration is assumed at temperatures below 3ºC. Although this is an established figure for cement it may be that other hydraulic binders have higher threshold temperatures and/or may have strength temperature development curves that cannot be approximated by a linear relationship. Where problems related to this factor are of concern (e.g. for a binder without local or independently documented performance data) laboratory trials should be carried out.

3 (02/16) For the mix-in-plant method of construction, the mixture can be placed using a grader, a dozer or a paver. If pavement foundation layers are constructed in 2 lifts, the depth of the lower lift should be compatible with the strength of the subgrade. A thicker first lift is needed over a weak subgrade, to enable effective compaction of the first lift without damage to itself or the subgrade beneath it. The thicker first lift will also minimise movement during the construction of the second lift, particularly if the first is still workable. This helps to ensure proper compaction. It will also prevent degradation of the lower lift when the construction of the second lift takes place after the lower one has set.

4 (02/16) Care should be taken during spreading to control the depth of uncompacted mixture so that trimming can be undertaken quickly and effectively within the construction period. The trimming of over-thick layers can also result in segregation.

5 (02/16) Clause 813.4 requires base layer mixtures to be laid using a paver, to assure consistent compaction and compliance with surface level tolerance. The Overseeing Organisation may permit the use of other laying methods, if the Contractor can confirm satisfactory performance using a method statement and demonstration area, as required by Clause 817.

6 (02/16) If any quick lime in a mixture has not fully hydrated, it will subsequently hydrate and may disrupt the compacted layer. Such disruption is possible with lime-based mixtures where the water content of the HBM is on the dry side of the OWC or the MCV is greater than 12, particularly when the time between lime addition and compaction is just a few hours. The risk of disruption is usually minimised by controlling the moisture content so that it is on the wet side of the OWC or MCV curve, and by using fine quick lime with a high reactivity. The characteristics of quicklime are controlled by Clause 811.1, which uses the requirements of BS EN 14227-11 to

specify the use of high reactivity quick lime with Grading Category 1. The potential for disruption can be avoided by using hydrated lime instead of quick lime.

7 (02/16) The Contractor is responsible for protecting the works from weather damage. To protect HBM from drying or wetting during transport, it is normally necessary to sheet delivery vehicles. Some slow setting HBM is suitable for stockpiling and for hauling over a long distance. Care is needed to avoid surface or local drying and segregation when a mixture is stockpiled or double handled in any way. If a visual inspection or test confirms that the water content is variable, the load or stockpile should be rejected or reprocessed through a mixing plant, adding water if necessary.

8 (02/16) Segregation can be seen as zones of coarse aggregate without enough fine aggregate to fill the gaps between the larger particles. It should be avoided because it leads to an increase in the proportion of air voids. Large air voids can fill with water, giving rise to a large reduction in strength of the mixture and destruction of local inter-layer bond. Coarse and rounded aggregates and non-cohesive mixtures are prone to segregation. When a mixture is found to be prone to segregation, consideration should be given to reducing the specified aggregate size. Clause 823 for CBGM C mixtures also has a requirement for compacity. Compliance with the compacity requirement requires close control of the volume of air and free water in the mixture. This usually results in a mixture that is less prone to segregation.

9 (02/16) Segregation can occur with the mix-in-plant methods if an all-in aggregate is used, because segregation often occurs in the aggregate stockpile prior to mixing. Segregation at the mixing stage can be minimised by using a number of aggregate fractions, each with a separate aggregate feed hopper.

10 (02/16) To assure layer integrity, the surface must be free of surface shearing and aggregate degradation. Fine graded and uniformly graded mixtures are often prone to surface shearing, when a thin plate of compacted mixture becomes detached from the top surface. Surface shearing can be mitigated by using a combination of vibratory compaction followed by a pneumatic tyred roller (PTR). Aggregate degradation by the crushing of weaker particles in some aggregates such as sandstone, limestone, chalk or recycled aggregate can also be reduced by the use of pneumatic tyred rollers.

11 (02/16) Surface shearing with fine mixtures with a long construction period such as FABM 5 has been avoided by constructing the compacted layer 30 to 40 mm high and then trimming to remove the excess without further compaction. The trimmed material can be used in the works, provided this is carried out within the workability period of the mixture.

12 (02/16) The water content in the top part of the layer can be adversely affected by high temperatures and/or low humidity, particularly when associated with a high wind speed. This makes compaction difficult and can prevent setting and hardening in the top part of the layer. In order to maintain the water content, it may be necessary to spray water on the surface during compaction and start the curing stage immediately on completion of compaction.

13 (02/16) A good bond between the lifts of a multi-lift layer is an important factor in achieving the expected pavement stiffness and durability. Because of this, Clause 817 requires the Contractor's method statement and demonstration area to include multi-lift working when necessary, and the methods of assuring and checking that a good bond has been achieved. Bond can usually be encouraged by making sure that the lower lift is not allowed to dry out before the upper lift is placed. It may also be necessary to scarify the surface of the lower lift.

14 (02/16) The rate of hydration of HBM binders slows down at low temperatures and hydration can stop if the mixture temperature falls to close to 0°C. If freezing occurs in a mixture which has yet to attain full strength it may disrupt the bond between the binder and the aggregate. The formation of ice lenses can also displace aggregate from some HBM mixtures. The HBM mixture chosen by the Contractor should develop sufficient tensile strength to resist internal freezing, if it is likely to be subject to temperatures close to 0°C. Strength develops relatively quickly in a HBM mixture with a cement content of at least 3%, so it is unlikely to be affected by low temperatures. When a HBM mixture has a cement content of less than 3%, there is a danger of hardening taking place so slowly that the integrity of the mixture is put at risk by low temperatures. Construction using HBM mixtures with a cement content of less than 3% is usually not allowed in the winter, particularly if the layer is to be left exposed. However, where rapid construction of the overlaying layers is proposed, the overlaying layers can provide adequate insulation to enable the winter working restrictions to be relaxed. The Contractor should use a risk assessment approach to evaluate and define appropriate weather and construction time criteria for the HBM layers by considering:

(i) the depth of cover provided by the overlying layers;

(ii) the type and durability of the aggregates used in the mixture;

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

(iv) the site location (TRL Report RR 45 provides guidance on the influence of location);

(v) the likely construction date.

15 (02/16) Rain can degrade HBM mixtures, particularly if the mixture has a high proportion of fine aggregate or if the mixture is to be trafficked soon after laying. Because of this, Clause 817 requires the Contractor's method statement to clearly define the action to be taken to mitigate any adverse effects caused by rain. If the rain is light, it may be possible to continue laying by adjusting the amount of water added during production of the mixture. Fly Ash Bound mixtures are particularly vulnerable to rain in the fresh state prior to compaction, so the works must be carefully planned.

16 (02/16) Early trafficking of the pavement may be permitted, if the traffic is well controlled. It should be noted that:

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

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

(iii) subject to performance when compacted using a PTR and provided the IBI is greater than 50, well graded mixtures with not less than 50% crushed hard aggregate should be suitable for immediate trafficking;

(iv) subject to performance when compacted using a PTR and provided the IBI is greater than 40, mixtures with a high proportion of fine aggregate should be suitable for immediate trafficking.

NG 814 (02/16) Mix-in-Plant Method of Construction Using Batching by Mass

1 (02/16) Forced action mixers should be used so that relatively small proportions of binder or activator are distributed and thoroughly mixed with the aggregates or soils. This forced action is normally produced by one of the following methods:

(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;

(b) a continuous mix system where horizontal pairs of counter rotating helical blades blend and then mix the constituents as they are fed into the mixer.

2 (02/16) The free flow of constituents into the mixer is essential for the production of a mixture with consistent characteristics. With fine graded, silty or clayey constituents, it is usually necessary to use hoppers with a number of design features that assist free flow, such as vibrators and friction reducing internal coatings.

3 (02/16) Further advice about the mix-in-plant construction method can be found in CCIP-009 available from the Concrete Centre (www.concretebookshop.com) and in TRL611 available from the Transport Research Laboratory (www.trl.co.uk).

NG 815 (02/16) Mix-in-Plant Method of Construction Using Volume Batching

1 (02/16) Batching by volume assumes that the mixture constituents are fed into the mixer at a constant rate that is varied in a predictable way by changing the settings of the control system. This means that any variation in the density and flow characteristics of a mixture component will affect the consistency of the HBM mixture. Because of this potential variability, Clause 813 does not permit volume batching for mixtures used in base layers.

2 (02/16) The guidance given in NG 814 also applies to volume batching.

NG 816 (02/16) Mix-in-Place Method of Construction

1 (02/16) Mix in place methods can produce high quality mixtures when the process is carefully controlled. It is essential that the pulveriser-mixer used has sufficient power to fully pulverise cohesive and bound agglomerations at a water content high enough to comply with the Moisture Condition Values (MCV) specified in contract specific Appendix 7/1. It is also essential that water is introduced into the mixture in a controlled way so that a consistent mixture is produced. The required degree of pulverisation and MCV limits must be rigorously maintained if full integration and activation of binder(s) is to be effective. Thorough dispersion of sufficient mixing water is necessary to ensure rapid slaking of quick lime, if used. This is needed to promote satisfactory reactions between the lime and clay, and helps to prevent long-term volume stability problems. The introduction of mixing water from a spray bar under the mixing hood is currently the only effective method of adding water in a reliable enough way for pavement construction.

2 (02/16) Binders and activators are usually laid in front of the pulveriser-mixer by a separate metered spreader but can be distributed directly by some types of pulveriser-mixer. The second method can be particularly helpful on sites when fine powdered materials could cause a dust nuisance.

3 (02/16) Uniformity of binder distribution and depth of pulverisation and mixing are important factors in achieving the expected pavement stiffness and durability. Because of this, sub-Clause 870.4 requires the excavation of trialpits to check the depth of mixing. It is essential that the binder be distributed to the full depth of pulverisation to avoid the formation of a residual layer of loosed unbound soil.

4 (02/16) Further advice about the mix-in-place construction method can be found in CCIP-009, available from the Concrete Centre (www.concretebookshop.com) and in TRL Report TRL611, available from the Transport Research Laboratory (www.trl.co.uk).

NG 817 (02/16) Method Statement and Demonstration Area

1 (02/16) The method statement prepared by the Contractor should describe the proposed method of working for the demonstration area and for the main works. It should contain a description of all stages of construction, including:

(i) facilities for storing of constituents;

(ii) plant to be used for mixing, transport and laying;

(iii) estimated time durations and intervals between the main stages of the work;

(iv) site preparation details prior to laying the HBM layer;

(v) lime flocculation stage, control and timing;

(vi) mixing method, time of residence in mixer, output, etc;

(vii) transport, journey time, protection during transport etc;

(viii) compaction and levelling;

(ix) curing and protection;

(x) action to be taken during inclement weather

(xi) production control checks including:

- (a) site preparation;
- (b) powder spreading;
- (c) mixing and pulverization;
- (d) water addition;
- (e) batching and mixing records;

(f) controlling MCV;

(g) depth of mixing;

(h) compaction;

(i) in-situ density measurement;

(j) level control for bottom and top of layer;

(k) procedures to assure and check the integrity of any multiple lift layers.

NG 818 (02/16) Induced Cracking of HBM

1 (02/16) The need for inducing transverse and longitudinal cracks in HBM is determined by the design requirements. Further guidance is given in HD 25 (DMRB 7.2.2) and HD 26 (DMRB 7.2.3).

NG 820 (02/16) Aggregates

1 (02/16) Table 8/12 gives requirements for aggregates using the Categories from BS EN 13242.

2 (02/16) For some HBM mixtures, a Category for the proportion of crushed or broken particles in coarse aggregate is specified. This is because crushed rock aggregate will support construction and in-service traffic better than rounded aggregate with the same grading curve. HBM with slow setting binders may need a well graded crushed aggregate to support site traffic whilst allowing the development of the expected strength and stiffness. The specification for the mixtures in Clauses 830, 831 and 835 can require either Category $C_{90/3}$ or Category $C_{50/10}$. Compilers of contract specific Appendix 7/1 should not routinely specify Category $C_{90/3}$ if that selection inhibits the use of local or recycled aggregate. However, Category $C_{90/3}$ should be specified when heavy early traffic loads are anticipated, as is often the case in maintenance works.

3 (02/16) The Los Angeles coefficient of coarse aggregate is a measure of its resistance to fragmentation and an indicator of mechanical strength. A lower value indicates greater resistance. The selection of Category LA_{50} is appropriate for HBM layers subject to heavy traffic, particularly if the layer is used by site traffic before an overlying pavement layer is constructed.

4 (02/16) Requirements for Categories that specify acid-soluble sulfate content and total sulfur content are introduced to the current edition, pending the results of continuing research into correlation of sulfate and sulfur swelling induced damage to the loss of strength after immersion tests. Feedback on the performance of sulfate bearing aggregates in the immersion tests and, where appropriate, in the works would be welcomed by Highways England Pavement Engineering Group, even when the acid-soluble sulfate and total sulfur contents are below the critical values.

The upper limits stated in Table 8/12 for wood and other impurities have been set to encourage the use of processed recycled aggregates and aggregates from secondary sources. A separate requirement is given for the maximum proportion of glass for similar reasons.

5 (02/16) It is often difficult to determine the characteristics of the aggregate components of an existing bound pavement layer before it is recycled. If the site investigation indicates that there are no problems with durability or chemical characteristics, it is usual to assume that aggregates derived from an existing pavement will comply with the requirements of Clause 820 and Table 8/12. If necessary, additional testing of the processed recycled aggregate before it is used in a mixture can be specified in contract specific Appendix 7/1.

Further guidance about recycling existing pavement layers can be found in TRL Report TRL611, available from the Transport Research Laboratory (www.trl.co.uk).

NG 821 (02/16) Cement Bound Granular Mixtures A (CBGM A)

1 (02/16) The grading curve for the aggregates for CBGM A is specified using Envelope A from BS EN 14227-1, Figure 1. This grading envelope covers a wide range of readily available aggregates from 0/2 (*MP*) size fine aggregate to 0/32 size all-in aggregate.

NG 822 (02/16) Cement Bound Granular Mixtures B (CBGM B)

1 (02/16) The grading curve for the aggregates for CBGM B is specified using Envelope B from BS EN 14227-1, Figure 1. Envelope B covers a more restricted range of available aggregates when compared to those permitted for CBGM A. It has much lower limits for the proportion of particles passing the 2 mm size and 0.063 mm size test sieves.

2 (02/16) As an alternative, a 20 mm size mixture may be specified using the mixture grading envelope from BS EN 14227-1, Figure 2 (Category G2). This grading envelope applies to the whole mixture, including the binder.

3 (02/16) As explained in NG 820.2, resistance to traffic can be improved by ensuring a high proportion of crushed or broken particles by specifying Category $C_{90/3}$ in contract specific Appendix 7/1.

NG 823 (02/16) Cement Bound Granular Mixtures C (CBGM C)

1 (02/16) Clause 823 allows the option of specifying a CBGM that can be expected to have enhanced and more consistent structural and trafficking properties when compared to CBGM A and CBGM B.

2 (02/16) The grading curve for the aggregates for CBGM C are specified using the mixture grading envelopes from BS EN 14227-1, Figure 2 (Category G1). The specified grading envelopes allow a choice of 0/20 mm size, 0/14 mm size and 0/10 mm size mixtures, each with a tightly controlled grading curve and a compacity requirement to control the proportion of air voids. The grading curve applies to the whole mixture, including the binder.

3 (02/16) Compliance with the tightly controlled grading curve will usually require a mixing plant with a number of aggregate feed hoppers so that different aggregate sizes can be added to the mixer in a controlled way.

4 (02/16) As explained in NG 820.2, resistance to traffic can be improved by ensuring a high proportion of crushed or broken particles by specifying Category $C_{90/3}$ in contract specific Appendix 7/1.

(02/16) NG 830, NG 831, NG 832, NG 834 and NG 835 Slag, Fly Ash Bound Mixtures and Hydraulic Road Binder Bound Mixtures

(02/16) General

1 (02/16) Slag bound mixtures (SBM) can be made with slag binder derived from either air-cooled steel slag (ASS) or from blast furnace slag. There are three types of blast furnace slag binder - granulated blast furnace slag (GBS), ground granulated blast furnace slag (ggbs) and partially ground blast furnace slag (pgbs). ASS binders harden by a reaction that produces carbonates whilst blast furnace slag binders harden by hydraulic reaction.

2 (02/16) Granulated blast furnace slag (GBS) is a sand size granulate that must be activated by lime (quicklime or hydrated lime). Fine-grained air-cooled steel slag can also be used as an activator because it is a source of lime. The setting process and the consequent gain in strength happen slowly.

3 (02/16) Ground granulated blast furnace slag (ggbs) is a powder that is activated by lime (quicklime or hydrated lime) or by cement. Hardening is more rapid than with ASS or GBS. Mixtures activated by lime develop strength only slightly less rapidly than those activated by cement. There is little experience with the use of partially ground blast furnace slag (pgbs) in the UK.

4 (02/16) Fly ash bound mixtures (FABM) are made with fly ash that is activated either by lime (quicklime or hydrated lime) or by cement. The setting time for lime-activated mixtures is longer than that of cement activated mixtures.

5 (02/16) As a consequence of the various combinations of binder and activator, slag and fly ash bound mixtures have a range of setting times. This means that the performance of the mixture under traffic loading will often not depend on setting and hardening but on the grading of the mixture. This means that crushed aggregate will be required for mechanical stability and resistance to traffic loads. If the mixture is not mechanically stable, satisfactory long-term performance will not be achieved.

(02/16) **Fly Ash Bound Mixture 1 (FABM 1) and Hydraulic Road Binder Bound Mixture 1, Clause 830**

6 (02/16) FABM 1 and HRBBM 1 are well-graded 0/31.5 mm mixtures with a grading envelope defined by BS EN 14227-3 or BS EN 14227-5, as appropriate. The grading is similar to that for a 0/31,5 mm size CBGM B mixture.

(02/16) **Slag Bound Mixture B2 (SBM B2), Fly Ash Bound Mixture 2 (FABM 2) and Hydraulic Road Binder Bound Mixture 2 (HRBBM 2), Clause 831**

7 (02/16) Group 2 graded mixtures differ from the mixtures specified using Clause 831 and Clause 835 because both BS EN 14227-2, BS EN 14227-3 and BS EN 14227-5 have a requirement for a minimum compacity of 0.80.

8 (02/16) Compacity is a measure of the voids occupied by air and free water (water that is not needed for hydration) in compacted specimens. It limits the amount of water available to lubricate compaction and indirectly constrains the amount of binder. Mixtures designed to comply with compacity limits will usually have a better balance between grading, drying shrinkage and workability than mixtures specified by grading and binder content alone.

9 (02/16) The use of a compacity limit permits the use of smaller aggregate sizes. This can reduce segregation in transport and laying, and give enhanced in-service performance. BS EN 14227-2, BS EN 14227-3 and BS EN 14227-5 set out grading envelopes for 0/20 mm size, 0/14 mm size and 0/10 mm size mixtures. However, the Standards have an additional requirement for the 0/10 mm size mixtures. They must have an immediate bearing index (IBI) of not less than 50 to allow use by site traffic. The IBI is determined using a version of the California Bearing Index test.

(02/16) **Slag Bound Mixture B3 (SBM B3), Fly Ash Bound Mixture 3 (FABM 3) and Hydraulic Road Binder Bound Mixture 3, Clause 832**

10 (02/16) Group 3 mixtures allow the use of mixtures with a large proportion of fine aggregate. The grading requirements for Group 3 mixtures in BS EN 14227-2, BS EN 14227-3 and BS EN 14227-5 are the same, with at least 85% of the particles in the mixture must pass the 6.3 mm size test sieve. Both Standards limit the proportion passing the 0.063 mm size test sieve (including the binder) to a maximum of 35%.

11 (02/16) In order to accommodate immediate use by traffic, a minimum value of immediate bearing index (IBI) is specified using Category IPI_{40}. This requirement may be relaxed to Category IPI_{25}, if the mixture is not to be used by site traffic.

(02/16) **Fly Ash Bound Mixture 5 (FABM 5), Clause 834**

12 (02/16) FABM 5 is a mixture where fly ash is used as both the main aggregate and, together with added activator, the binder. The activator can be cement, lime (quicklime or hydrated lime), or lime and gypsum.

13 (02/16) Good compaction of FABM 5 requires close control of moisture content. As explained, in NG811.11, care must also be taken to minimise surface shearing. Lime activated mixtures are prone to damage, so the next layer should be constructed within their construction period. This provides some re-compaction of the FABM 5 mixture and heals any surface cracks. The overlying layer should preferably be one that can be laid without direct trafficking of the FABM 5 layer.

(02/16) **Slag Bound Mixtures B1 (SBM B1), Clause 835**

14 (02/16) BS EN 14227-2 sets out grading envelopes for four sub-types of SBM B1. SBM B1-1 is 0/22,4 mm size; SBM B1-2 and SBM B1-4 are 0/31,5 mm size; and SBM B1-3 is 0/45 mm size.

15 (02/16) The grading envelopes limit the proportion of the mixture (including the binder) passing the 0,063 mm size test sieve to not more than 6%. This means that GBS is usually used as a binder instead of ggbs. The grading curves give mixtures that are often relatively permeable. This means the mixtures are suitable for use in inclement and winter conditions. However, their mechanical properties are not usually as good as those for the mixtures specified using Clause 830 and Clause 831.

NG 840 (02/16) Soil Treated by Cement (SC), Soil Treated by Slag (SS), Soil Treated by Fly Ash (SFA) and Soil Treated by Hydraulic Road Binder (SHRB)

1 (02/16) European experience and research carried out at TRL in full-scale trials has shown that satisfactory foundation layers that are suitable for direct trafficking can be made using hydraulically bound mixtures with a compressive strength of about 1 MPa. It has also been shown that hydraulic binders can be used with types and sizes of aggregates and soil (including cohesive soil) that are not routinely used to produce subbase layers. More details can be found in HA 74 (DMRB 4.1.6).

2 (02/16) Clause 840 gives requirements for soil treated by cement (SC), soil treated by slag (SS), soil treated by fly ash (SFA) soil treated by hydraulic road binder (SHRB). These mixtures are often known as stabilised soil. Use of this technique often gives environmental and economic benefits by minimising the need to transport aggregates and by using fly ash or slag as the major part of the binder. The need to dispose of surplus soil from excavations can also be minimised.

3 (02/16) The requirements for cohesive soils in Table 8/13 assume a minimum of 15% by mass passing the 0.063 mm test sieve and a plasticity index (PI) greater than 10.

4 (02/16) When cohesive soils are stabilised, a two stage process is required. The first step is flocculation with lime to give a more granular soil. This then allows efficient mixing with a second binder to develop the specified strength. Traditionally cement has been used for the second stage, but experience has shown that fly ash and ground granulated blast furnace slag binders can produce layers with greater tolerance of sulphates than layers made with cement.

5 (02/16) The limiting value for Total Potential Sulfate (TPS) has been chosen to control the risk of problems due to oxidation of reduced sulfur compound such as pyrite. If the TPS is in excess of the specified limit, reference should be made to the Overseeing Organisation. The soil should be tested to determine the form of the sulfur species present and the associated risk evaluated. More details can be found in BS EN 1744-1and HA 74 (DMRB 4.1.6).

6 (02/16) Many overconsolidated clays and some alluvial sands and gravels contain significant concentrations of sulfates and sulfides, which could affect the stabilization process. The occurrence of sulfate and sulfide minerals in the UK is summarised in Appendix B of HA 74 (DMRB 4.1.6).

7 (02/16) Where the TPS exceeds the limiting value, its effect can be modelled by volumetric expansion tests with samples of soil and the proposed proportions of the intended binder combinations prepared as mixed and cured specimens. As sulfur bearing minerals are not uniformly distributed in natural soil care needs to be taken that tested samples model the true level of the relevant minerals. Specimens should be analysed on completion of the tests to determine their individual TPS values to check that they correctly modelled the site conditions.

8 (02/16) The volumetric expansion test is preferred to the CBR swell test. The presence of sulfate or potential sulfate may not mean that the soil is unable to be permanently stabilised, but it could mean that special measures need to be taken. These could include additional mixing, mellowing, temperature limitations, and a limited choice of binder types.

9 (02/16) Current best practice for the stabilisation of sulfate and sulfide bearing soils can be found in Britpave document BP/16, ‘Stabilisation of sulfate-bearing soils’, obtained from www.britpave.org.uk

10 (02/16) The general notes in NG 830, NG 831, NG 832, NG 834 and NG 835 about the different rates of strength gain for different binder and activator combinations also apply to treated soil.

11 (02/16) There are no limitations on the level of individual impurities in treated soils, because unacceptable 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 the immersion test and alkali aggregate susceptibility will need to be investigated. Where the receptor soil is 'made ground', secondary or recycled material, the aggregate requirements given in Table 8/12 for Clause 832 mixtures can be taken as a guide to the level of impurities likely not to be deleterious to the performance of treated soil.

NG 870 (02/16) Testing, Control and Checking of HBM

1 (02/16) HBM specified using BS EN 14227 are tested using the test methods in the relevant Parts of BS EN 13286. The scope of the test methods is restricted to mixture tests and tests on specimens made from mixtures. Tests for water content and plasticity are found in BS 1924-1, grading in BS EN 933-1, and in-situ density in BS 1924-2.

NG880 (02/16) Laboratory Mixture Design Procedure

1 (02/16) A schedule of testing similar to that shown in Table NG 8/2 should be used for each combination of binder and water content.

TABLE NG 8/2: (02/16) Suggested Schedule of Testing for Laboratory Mechanical Performance of One Combination of Binder and Water Content

HBM Type	Curing Temperature	Age of Sealed Specimens at Time of Test (3 Specimens for Each Test Age)					
		7 days	14 days	28 days	56 days	91 days	1 year
Without cement	40°C	✓	✓	✓	–	–	–
	20°C	–	–	✓	✓	✓	✓
With cement	20°C	✓	✓	✓	✓	✓	✓

NOTES:
1. Testing at ages beyond 28 days is optional.
2. For mixtures using binders without cement, cylindrical specimens compacted to refusal, 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.
3. For mixtures using binders containing cement, cylindrical or cube specimens compacted to refusal, 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 (02/16) The Contractor should provide evidence of strength development over a minimum of 28 days. This information should be used by the Contractor to declare the age of testing for site control purposes.