TECHNICAL GUIDELINES

HBM AND STABILISATION

2 The design and specification of RESIDENTIAL AND COMMERCIAL ROAD PAVEMENTS

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The British In-situ Concrete Paving Association

This publication provides design and specification guidelines for clients, designers and contractors wishing to use hyrdraulically bound mixtures for residential and commercial road pavements.

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HBM and stabilisation 2

The design and specification of residential and commercial road pavements

Contents

Glossary

Surface course	previously known as wearing course
Binder course	previously known as basecourse
Surfacing	surface course or combination of surface and binder courses
Base	previously known as roadbase
Subbase	previously hyphenated i.e. sub-base
HBM	hydraulically bound mixture; a mixture that hardens through the hydraulic reaction between the constituents and water
CBM	cement bound mixture (previously cement bound material); an HBM that hardens through hydration of cement
CBGM	cement bound granular mixture; a type of CBM
FABM	fly ash bound mixture; an HBM that relies on the pozzolanic/hydraulic combination of coal fly ash (also known in the UK as pfa, the acronym for pulverized fuel ash) with quick or hydrated lime, or cement
SBM	slag bound mixture; an HBM that relies on the hydraulic/sulfatic combination of granulated blast furnace slag (GBS) with other slags and or with quick or hydrated lime
HRB	hydraulic road binder – a factory blended hydraulic binder, typically made from GBS and or fly ash, lime and gypsum, specifically formulated to be slow setting for road and stabilisation use
HRBBM	HRB-bound mixture; an HBM that uses HRB as the binder
CBGM A	graded aggregate mixture which includes sandy mixtures (ref. SHW 821)
CBGM B	well graded aggregate mixture (ref. SHW 822)
FABM 1, SBM B1-2 & HRBBM 1	0/31.5 mm graded mixtures (ref. SHW 830)
FABM 3, SBM B3 & HRBBM 3	0/6.3 mm mixtures (ref. SHW 831)
msa	millions of standard axles
sa	standard axles
SC	soil (treated by) cement (ref. SHW 840)
SFA	soil (treated by) fly ash (ref. SHW 840)
SS	soil (treated by) slag (usually ggbs, which is ground GBS) (ref. SHW 840)
SHRB	soil (treated by) HRB (ref. SHW 840)
SHW	*Specification for Highway Works*

1 Introduction

These guidelines provide thickness design, specification and construction advice for the use of hydraulically bound mixtures (HBM) including cement bound mixtures (CBM) for residential and commercial road pavements subject to trafficking by vehicles permitted for use on public roads.

The guidelines are applicable to:

- The use of hydraulically bound mixtures (HBM) for the main structural layer in the pavement i.e. as the base (see Figure 1 for terminology).
- HBM produced, but not exclusively, in a central plant where the aggregate may comprise natural, artificial or recycled aggregate.
- Binders or hydraulic combinations based on Portland cement, quicklime (CaO) or hydrated lime [$Ca(OH)_2$], ground granulated blast-furnace slag (ggbs) and coal fly ash (also known as pulverized fuel ash or pfa).
- Asphalt, concrete block or brick paver surfacing.
- The normal construction sequence for residential and commercial roads, namely:
    1. Subbase construction.
    2. Kerb laying (and drainage work).
    3. Base construction.
    4 Surfacing, the final course of which may be delayed until completion of the associated residential or commercial development.

Figure 1: Terminology

Pavement	Surface course	Known as the surfacing
	Binder course	
	Base	Main structural layer
	Subbase	Known as the foundation
Subgrade	Subgrade	

The thickness design and surfacing advice is based on data from well-established and proven documentation [1–4] but is conservative since it is recognised that the construction of residential and commercial roads will not usually be carried out by specialist paving contractors. HBM compressive strength classes are in accordance with the European standards for HBM introduced as British Standards in the UK in 2004 and 2006 [5, 6]. HBM specification is based on the Highways Agency's *Specification for Highway Works* (SHW) [7].

2 Design parameters

2.1 General

Unlike major roads, residential and commercial roads form part of a development, where the sequence of construction of the buildings and roads may vary. Therefore the following scenarios need to be considered:

1 Construction of the roads in advance of the development construction.

2 Construction of the roads during construction of the development. This means addressing the issue of which pavement layer will bear the brunt of the construction traffic and construction material deliveries connected with the development.

3 Construction of the roads after construction of the development.

Considering the first scenario, construction of the surfacing may be delayed until the bulk of the development works is carried out. Therefore the combination of subbase and base layers will need to be strong enough to carry the development construction traffic, which may be significant compared with the in-service traffic. The combined subbase and base thickness recommended in these guidelines are considered adequate to cover this situation. It is important to remember, however, that the HBM will normally need protection from traffic and weather during construction. Where two-course asphalt surfacing is used, this protection is best achieved by prompt laying of the first or binder course. With one-course surfacing, there is no alternative but to lay this promptly after HBM construction. The subbase will need to be thick enough to carry only the traffic associated with the kerb, drainage and HBM laying operations. In essence, this represents little difference from what happens with major road construction.

With regard to the second scenario (development and road construction proceeding in parallel), the subbase may be required to carry construction traffic in excess of that associated with kerb, drainage and base laying. As a result, it will need to be thickened and/or strengthened. This scenario is covered in this guidance document.

The third scenario is very unlikely, as access is typically needed for construction of the development. However, if this construction sequence is planned, the first scenario will apply for design purposes.

2.2 Subbase (or foundation) design

Foundation design is governed by the traffic to be carried by the foundation and the type and condition (strength) of the subgrade. The latter is normally characterized by a California bearing ratio (CBR) value.

If the subbase / foundation is expected to carry materials and construction traffic for the associated development, then the thickness must be related to this traffic and to the CBR that will apply during this period. Provided design is carried out in this way, the structure will be adequate for the in-service situation when the foundation will have the benefit of protection from the overlying layers and when the in-service CBR is likely to be higher than that during construction.

If the subbase / foundation is required to carry only traffic associated with the construction of the road itself, then clearly the applied loading will be less. CBR values during construction will still be relevant, however, as they may be lower than the long-term values.

The foundation thickness recommendations presented in Tables 1a and b cover both these cases and are based on construction traffic categories given in BS 7533 [4]. To use these tables, an understanding of CBR assessment is assumed. However, guidance for a variety of ground conditions is given in Appendix C of TRL publication LR1132 [8], which provides advice for both short- and long-term subgrade strength and stiffness for high and low water tables under differing construction conditions.

The recommendations in Table 1a assume an unbound subbase made from well-graded, non-plastic, hard material that produces a mechanically stable non-frost susceptible layer capable of being trafficked by site construction traffic and delivery vehicles.

Should a sandy or sandy gravel subgrade be present, in-situ stabilisation may be employed in lieu of imported unbound subbase. Strength category C3/4 should be specified (see Section 2.3 for an explanation of this terminology). Thickness recommendations are shown in Table 1b.

Key elements of mix-in-place stabilisation

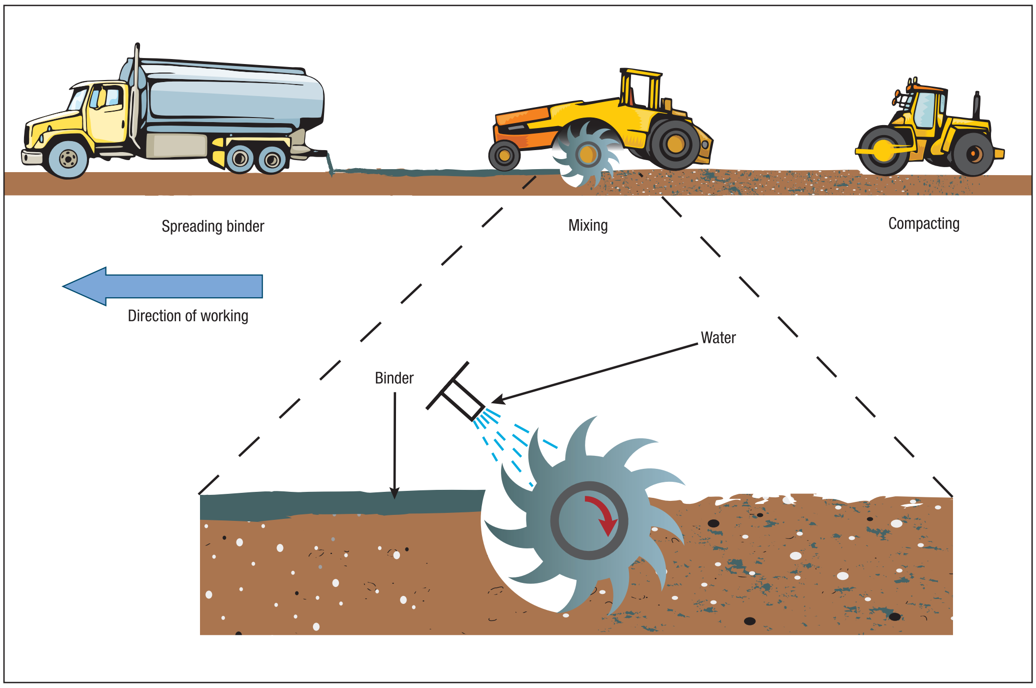


Table 1a: Unbound foundation thickness recommendations assuming the subbase carries the development construction traffic and material deliveries. (Where the base layer performs this function, then the '< 50 sa' column applies irrespective of development size)

Construction traffic in sa	< 50	50 – 200	201– 500	501– 2000	> 2000
Illustrative size of development (taken from reference 1)	Up to 4 dwellings	Up to 20 dwellings or 2000 m^2 commercial property	Up to 50 dwellings or 5000 m^2 commercial property	–	Large development
Subgrade CBR < 2	Ground improvement will be necessary				
Unbound thickness for subgrade CBR 2 to 3 (typically high plasticity heavy clay subgrade)	300 mm	350 mm	400 mm	450 mm	500 mm
Subgrade CBR > 3 to 5 (typically medium plasticity clay subgrade)	250 mm	275 mm	325 mm	375 mm	425 mm
Subgrade CBR > 5 to 7 (typically low plasticity sandy clay subgrade with average/good construction conditions and low water table assumed – otherwise use row above)	225 mm	225 mm	250 mm	300 mm	350 mm
Subgrade CBR > 7 to 14 (typically sandy subgrade)	225 mm	225 mm	225 mm	225 mm	275 mm
Subgrade CBR > 15 (typically sandy gravel subgrade)	200 mm	200 mm	200 mm	200 mm	225 mm

Table 1b: Stabilised foundation thickness recommendations assuming that the subbase carries the development construction traffic and material deliveries. (Where the base layer performs this function, then the '< 500 sa' column applies irrespective of development size)

Construction traffic	< 500 sa	> 500 sa
Illustrative size of development (taken from reference 1)	Up to 50 dwellings or 5000 m^2 commercial property	–
HBM C3/4 stabilised thickness for sandy or sandy gravel subgrade (CBR > 7)	200 mm	250 mm

Note

For the subgrades illustrated in the table, meeting the C3/4 strength requirement or greater means that it may be possible to use the stabilisation operation to produce the base layer directly without the need for a subbase. In this case, reference should be made directly to Table 2, but bearing in mind that it will be necessary to increase the HBM thickness recommendation by 70 mm as indicated in Table 2 and also satisfy the selected strength class in Table 2.

2.3 HBM base and surfacing design

While information on in-service traffic loading over the design life is required, such data for residential and commercial roads is difficult to assess and quantify. Prior to the 1990s, little attempt had been made to carry out this exercise in the UK and there was a lack of published data. However, subsequent research carried out in the early 1990s [1, 4] categorized traffic for residential and commercial roads. This categorization is used within this document

As a result, these guidelines include the following traffic categories expressed in millions of standard axles (msa), which should cover the majority of residential and commercial situations: less than 0.5; 0.5 to 2.5; 2.5 to 5; and 5 to 10 msa.

Surfacing (asphalt, concrete block or clay paver) and HBM thickness design recommendations for these in-service traffic categories are given in Table 2, which should be used in conjunction with the foundation guidance given in Section 2.2. Provided these foundation recommendations are followed, the HBM base will carry all the development construction traffic, without distress.

Clearly in-situ concrete is a pavement solution offering inherent structural benefits as well as durable, rutting- and abrasion-resistant running surfaces. However, as the focus of this document is the design of pavements where the main structural contribution is provided by HBMs, concrete options are not included in Table 2. Further guidance on these pavements types is available elsewhere [1, 9].

Table 2: Surfacing and HBM base thickness and strength recommendations

	1	2	3	4	5
A	Residential / commercial description	Access ways, mews courts, access collectors, roads serving up to 80 houses	Local distributors, roads serving up to 240 houses	District distributors	Major distributors. Access roads to lorry parks or roads within commercial and industrial estates
Traffic loadings					
B	Tentative commercial vehicles/day	Up to 15, say	Up to 75, say	Up to 150, say	Up to 300, say
C	Public service vehicles/day	None	Up to 25, say	Up to 50, say	Up to 100, say
D	msa band	< 0.5	0.5 – 2.5	2.5 – 5	5 – 10
Surfacing layer guidance (Note 1)					
E	Minimum asphalt surfacing	40 mm single course	80 mm two courses	100 mm two courses	
F	Concrete block or clay paver surfacing	60/65 mm block or brick on 30 mm bedding sand layer	80 mm block or brick on 30 mm bedding sand layer		
Base layer guidance					
G	Strength class (MPa) (Note 2)	HBM base thickness for mixture produced in a central plant. When produced by in-situ stabilisation, indicated thickness shall be increased by 50 mm. When the base, without a subbase, is produced by in-situ stabilisation, the thicknesses indicated below shall be increased by 70 mm.			
H	CBGM C8/10, other HBM C9/12	180 mm	180 mm	200 mm	220 mm
I	CBGM C5/6, other HBM C6/8	180 mm	200 mm	220 mm	–
J	CBGM C3/4, other HBM C3/4	200 mm	–	–	–

Notes

1. *The surfacing or first course of surfacing should be laid as soon as possible to provide a weather-proof seal. Grouted macadam concrete block paving should be given particular consideration where fuel and oil resistance is required. Refer to specification in Annex A.*
2. *The HBM and strength classes shown are compatible with the European standards for cement bound granular mixtures (BS EN 14227–1), other hydraulically bound mixtures (BS EN 14227–2, 3 & 5) and series 800 of the SHW. The first number of each class relates to the compressive strength of cylindrical specimens with a slenderness ratio of 2 and the second number to a slenderness ratio of 1 or cubes. Refer to specification in Annex A.*

3 Design basis

The design recommendations given in Table 2 are based on TRL 386 [2] and TRL 611 [3]. TRL 386 has been the main design and specification reference over the last few years for the strengthening of failed highway pavements using in-situ recycling. There have been no reported problems with pavements recycled in accordance with TRL 386. TRL 611 is effectively the latest version of TRL 386, but broadened in scope to include a wider range of HBM and the mix-in-plant method of production.

It should be noted, however, that the strength requirements in Table 2 reflect the new European compressive strength categories for HBM (e.g. C3/4, C5/6, C6/8, C8/10 and C9/12), which effectively encompass the old CBM strengths, e.g. CBM 1 (4.5 MPa at 7 days), CBM 2 (7 MPa at 7 days) and CBM3 (10 MPa at 7 days) categories used in TRL 386. This has resulted in HBM strength class recommendations that are close to (and in some cases lower than) the original CBM strength requirements. However, the changes are not considered significant as there is a degree of conservativeness in the thickness recommendations in Tables 1a, 1b and 2.

The recommendations given in TRL 386 also relate to HBM made exclusively using cement. TRL 611 broadened this scope and it should be noted that the recommendations in Tables 1 and 2 may also be used for HBM made from other hydraulic combinations including:

- Cement with either fly ash or ggbs.
- Lime with fly ash or ggbs.

Relative proportioning of the stabilisers should follow the minimum recommendations in Table 8/10 in the SHW [7] . Strength requirements should be in accordance with Annex A.

4 Durability to weather

The lowest HBM compressive strength class recommended in these guidelines is C3/4. At this strength level, the HBM, regardless of the material treated, can be considered resistant to frost heave and, provided it is surfaced promptly, will be durable to traffic and weather during the construction period.

With regard to the subgrade, the thinnest possible total pavement construction depth is 420 mm. This will be sufficient in most situations to insulate the subgrade from frost, although there may be instances (if in-situ treatment is employed to form the base in line with the note to Table 1b, where the total construction could be 310 mm. Frost resistance of the subgrade material beneath the stabilised layer will thus need consideration, and is discussed below.

Potential for frost heave in the subgrade depends on the nature of subgrade material, the severity of the weather and most importantly, the position of the water table. If the water table is deep relative to the subgrade, then there is unlikely to be a problem. If the overall cover thickness is at least 300 mm, there is also unlikely to be a problem, at least in the southern parts of the UK, since frost penetrations greater than 300 mm have not occurred in the southern half of the UK for some 20 years. Also, for granular subgrades, where in-situ treatment is used to form the base, the subgrade will consist of sandy or gravelly material and should therefore be non-frost susceptible anyway.

In the majority of cases therefore, frost should not be a problem. Nevertheless, where there is doubt, the frost index for the area should be established and a minimum overall construction thickness of at least 350 mm or 450 mm used where the frost index is less than or greater than 50 respectively.

5 Sulfates

The existence of sulfates, sulfides and other materials capable of causing volume instability in HBM layers, particularly stabilised clays (not especially relevant here) and some recycled/industrial aggregates (more relevant), should be examined at the mixture design stage using immersion and/or swell testing. For advice see references 7 and 10.

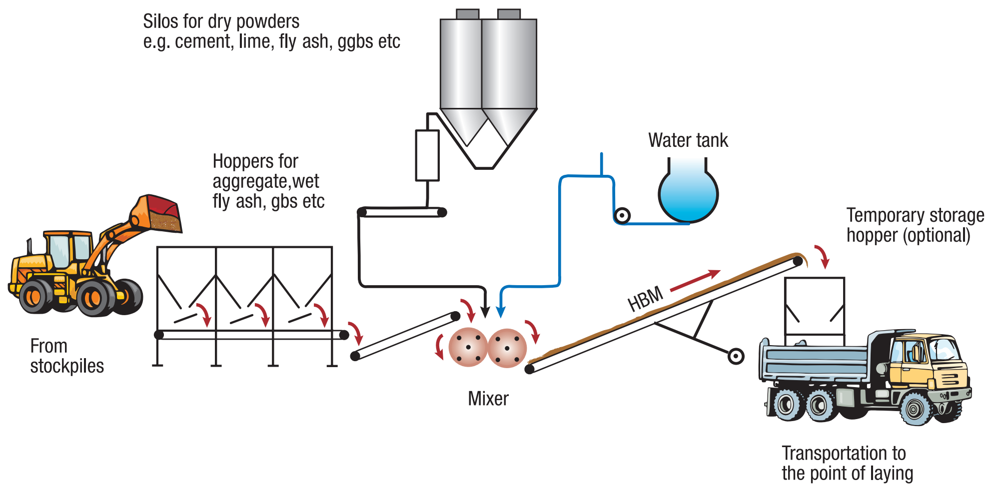
6 HBM specification

The HBM classes recommended in Tables 1 and 2 should conform to the notes to the tables, and to the specification framework in Annex A.

7 Mixture design, construction and control testing

These aspects are also covered by the SHW but further information can be found in references 11 and 12.

Key elements of mix-in-plant production



8 Drainage

The importance of the provision of adequate surface and subsoil drainage with adequate falls cannot be over-emphasised. When the water table is high the provision of subsoil drainage is paramount.

Annex A: Specification framework for HBM for residential and commercial road pavements

For ease of use, the design table in the main text is reproduced here but with the thickness recommendations removed and replaced with the specification recommendations, which are in accordance with the European standards for HBM and the 800 series of the SHW.

Table A1: Specification with SHW clause numbers (to be read in conjunction with all notes)

	1	2	3	4	5
A	Residential / commercial description	Access ways, mews courts, access collectors, roads serving up to 80 houses	Local distributors, roads serving up to 240 houses	District distributors	Major distributors. Access roads to lorry parks or roads within commercial and industrial estates
	Traffic loadings				
B	Tentative commercial vehicles/day	Up to 15, say	Up to 75, say	Up to 150, say	Up to 300, say
C	Public service vehicles/day	None	Up to 25, say	Up to 50, say	Up to 100, say
D	msa band	< 0.5	0.5 – 2.5	2.5 – 5	5 – 10
	Surfacing layer guidance (Note 6)				
E	Minimum asphalt surfacing	40 mm single course	80 mm 2-course	100 mm 2-course	100 mm 2-course
F	Concrete block or clay paver surfacing	60/65 mm block or brick on 30 mm bedding sand layer	80 mm block or brick on 30 mm bedding sand layer	80 mm block or brick on 30 mm bedding sand layer	80 mm block or brick on 30 mm bedding sand layer
	Base layer guidance				
G	Strength class (MPa) (Notes 1, 2)	HBM specification options (Note 2)			
H	CBGM C8/10, other HBM C9/12	HBM specification options: 1. CBGM A – to clause 821 of the SHW. 2. SBM B3, FABM 3 & HRBBM 3 – to clause 832 of the SHW. 3. SBM B4 to BS EN 14227–2, FABM 4 to BS EN 14227–3 or HRBBM 4 to BS EN 14227–5. Although not included in the SHW, these may also be used to clause 832 of the SHW. 4. In all cases refer to Notes 1 & 2 for strength advice.			
I	CBGM C5/6, other HBM C6/8				
J	CBGM C3/4, other HBM C3/4 (Note 5)				

Notes

1. *The strength classes shown are compatible with the European standards for cement bound granular mixtures (BS EN 14227–1), other hydraulically bound mixtures (BS EN 14227–2, 3 & 5) and the 800 series of the SHW. The first number of each class relates to cylindrical specimens with a slenderness ratio of 2:1 and the second number to a cylinder with a slenderness ratio of 1:1 or to cubes.*
2. *Strengths shall be assessed at 28 days using sealed curing at 20°C for CBGM and at 28 days using sealed curing at 40°C for the other HBM. In all cases, the specified strength shall mean the minimum based on the average of five specimens every 1000 m^2 with no individual result less than 70% of the minimum average requirement.*
3. *Thicknesses in Table 2 relate to HBM production in a central plant which shall be increased by 50 mm for HBM production by in-situ stabilisation. In the special case of HBM base without a subbase, that is formed using mix-in-place stabilisation, the thickness shown in Table 2 shall be increased by 70 mm.*
4. *Stabiliser proportions shall comply with Table 8/10 in the SHW.*
5. *Appropriate also for the subbase in Table 1b.*
6. *The surfacing or first course of surfacing should be laid as soon as possible to provide a weather-proof seal. 80 mm asphalt will normally be laid in two courses of, say, a 30 mm thin surface course on a 50 mm binder course. Where fuel and oil resistance is required, consideration should be given to using grouted macadam as the surface course or substituting the whole of the asphalt surfacing with 80 mm concrete blocks on a 30 mm sand laying course.*

Annex B: Example of the use of Tables 1 & 2 and the specification framework

Requirement

District distributor on a sandy gravel subgrade constructed in advance of the development construction.

Options

Surfacing

80 mm concrete blocks on bedding sand or 100 mm two-course asphalt (Table 2).

HBM base thickness and strength

200 mm HBM C8/10 (or C9/12) or 220 mm HBM C5/6 (or C6/8) (Table 2).

Foundation

200 mm well graded non-plastic hard material (Table 1a) or 200 mm HBM C3/4 produced by in-situ stabilisation of the sandy gravel subgrade (Table 1b).

HBM types

In the case of HBM C8/10 or C5/6 for the base:
– CBGM A to clause 821.
In the case of HBM C9/12 or C6/8 for the base:
– SBM B3, FABM 3 or HRBBM 3 to clause 832 or
– SBM B4, FABM 4 or HRBBM 4 to clause 832.
In the case of HBM C3/4 for the foundation:
– Any of the above types.

HBM construction

SHW clause 814 or 815 for the base and clause 816 for foundation.

HBM strength testing

Testing shall be carried out at 28 days after sealed curing at 20°C for CBGM and 40°C for other HBM. In all cases, the specified strength shall mean the minimum based on the average of five specimens every 1000 m^2 with no individual result less than 70% of the minimum average requirement.

Alternative base (without foundation) constructed by mix-in-place stabilisation

270 mm HBM C8/10 (or C9/12) or 290 mm HBM C5/6 (or C6/8) (Table 2).
Surfacing and HBM types as above.
Construction to clause 816.

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