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Notes for Guidance on the Specification of Works – Road Pavements – Unbound and Hydraulically Bound Mixtures

CC-GSW-00800

November 2024

CC Construction & Commissioning

Standards

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Contents

Updates to TII Publications resulting in changes to

Notes for Guidance on the Specification of Works – Road Pavements – Unbound and Hydraulically Bound Mixtures CC-GSW-00800

Date:	14 November 2024
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Amendment Details:

This publication required a complete revision of the document. Updates include:

(i) Updates section numbering in alignment with CC-SPW-00800

(ii) Detailed background to water soluble sulphate and oxidisable sulphides assessment

(iii) Updated referencing to new material categorisation i.e.. UGM and HBM

(iv) Clarification on Environmental requirements and regulations

(v) Further guidance on CE marking and application of non-harmonised standards

(vi) Guidance on performance-based specification

(vii) Updates to pre-existing guidance based on latest experience and knowledge

Contents

1. General Requirements and Definitions

1.1 General

The requirements for the production and construction of Unbound and Hydraulically Bound Granular Materials is specified in CC-SPW-00800 Specification for Works Unbound and Hydraulically Bound Granular Mixtures.

The section numbering of this document aligns with the section numbering of CC-SPW-00800 to allow ease of document cross referencing to identify guidance relevant to a particular section of the specification document.

2. Unbound Granular Mixtures

IS EN 13285 Unbound mixtures – Specifications, specifies the requirements for unbound mixtures used for the construction and maintenance of roads and other trafficked areas. The requirements for the properties of aggregates used in unbound mixtures are defined by appropriate cross-reference to IS EN 13242 Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction. Unbound mixtures and the requirements for their constituents specified in CC-SPW-00800 are specified in line with IS EN 13285 and IS EN 13242.

IS EN 13285 is not a harmonised European Standard. Therefore, UGM mixtures are not required to be CE Marked. However, UGM mixtures are required to have a Declaration of Performance (DoP) and to be manufactured under the Assessment and Verification of Constancy of Performance ((AVCP) system as defined in IS EN 13285.

IS EN 13242 is a harmonised European Standard. Therefore, the aggregates, when placed on the market and to be incorporated into UGM mixtures, are required to be CE Marked and therefore are required to have a DoP in place. UGMs which are manufactured with aggregate products procured from the market are required to include the aggregate manufacturers CE Mark and DoP with the UGM DoP. The responsibility for the compliance of the UGM and constituent aggregate with a DoP remains with the UGM manufacturer. UGM constituent aggregate not placed on the market as a product and manufactured by the UGM manufacturer are not required to have a CE marking, this includes aggregate produced on site as part of the Works.

The scope of IS 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 maximum dry density and optimum water content for each unbound mixture.

2.1 Mixture Types

Two basic unbound granular mixture types are defined namely UGM A and UGM B, with additional requirements where the material is placed adjacent to cementitious or metallic materials.

The new material categories should not be compared against historic material categories e.g. Clause 804.

2.2 Constituent Materials

2.2.1 Aggregates

IS EN 13285 requires the aggregates used in unbound mixtures to comply with IS EN 13242. Further guidance on the use of IS EN 13242 is given in Standard Recommendation (SR) 21 Guidance on the use of I.S. EN 13242:2002 - Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction" published by National Standards Authority of Ireland (NSAI).

The supplier of the mixture is required to monitor water absorption values as part of the system of factory production control required by IS EN 13242. The value for the aggregate used should be stated. 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.

2.2.1.1 Fines Quality

The fines quality is critical to the performance of UGM materials. The fines quality of a virgin UGM material shall be assessed through the determination of the Liquid Limit. However, the Liquid Limit test requirement on its own is unsuitable for Reclaimed Aggregates and therefore does not apply to the Reclaimed Aggregate portion contained within a UGM mixture. Therefore, the Methylene Blue test is also require to be carried out and the test results reported with Liquid Limit test results. The Methylene Blue test is required to be carried out to facilitate the collection of sufficient test data to determine the suitability of the Methylene Blue test and test result limits for typical Irish UGMs.

2.2.1.2 Water-Soluble Sulfate (WS) and Oxidisable Sulfides (OS)

Background

A significant number of projects and cases studies have shown the deleterious effect of sulfur compounds, present in some aggregates on civil engineering infrastructure and the surrounding environment. The deleterious effects experienced include the corrosion of adjacent metallic and cementitious materials, leachate of harmful chemicals to surface and groundwater and material expansion or heave.

Sulfur compounds occur in several forms both naturally and artificially. Sulfur refers to the chemical element with atomic number 16 and symbol S. Sulfides are a type of chemical compound containing one or more S^{2-} ions and occur most commonly in a reduced form such as pyrite, in rocks and soils and less commonly as mineral ores of lead, zinc and other metals. These minerals in and of themselves are not deleterious.

The weathering and oxidation of sulfides, leads to the production of soluble sulfate minerals which may be deleterious to construction materials. Weathering may also increase acidity, which increases the solubility of sulfates, which further exacerbates damage to the construction material.

Therefore, sulfates are chemical compounds produced from the oxidation of sulfur or sulfide minerals which can have a deleterious effect on Civil Engineering Infrastructure.

A road pavement structure is a favourable environment for the oxidation and weathering of sulfides to produce sulfates and therefore the need to determine WS and OS contents for aggregates is due to the deleterious effect of sulfur compounds, present in some aggregates, when placed within 500 mm of concrete or metallic elements.

Specification limits

The WS and OS limits specified are based on research and recommendations made in *Building Research Establishment (BRE) Special Digest 1 Concrete in aggressive ground* and *TRL447 Sulfate specification for structural backfills.* TRL447 outlines a number of projects and case studies where the occurrence of sulfates has had deleterious effects on adjacent infrastructure and the environment.

WS and OS limits specified in CC-SPW-00800, Table 2.1 are in the sulfate form of SO_4. WS is determined directly according to the procedures detailed in IS EN1744-1 Tests for chemical properties of aggregates - Part 1: Chemical analysis. OS is calculated from the determination of Total Sulfur content (TS) and Acid-soluble Sulfates (AS) as detailed in IS EN1744-1. IS EN1744-1 allows for the reporting of WS and OS test results in the sulfate form of SO_4.

WS limits are specified in CC-SPW-00800, Table 2.1 as mg/l. The determination of WS according to IS EN1744-1 is expressed as a percentage.

The results for WS may be expressed in either mg/l or %. As the water to soil ratio for the test is fixed at 2:1, the results can be converted from percentage to mg/l by multiplying by 5000.

The form in which WS and OS is determined should be clearly stated in the analytical report, to avoid confusion and possible misclassification.

Sampling

Because of the variability of sulfur compounds in natural and artificial materials, it is important that enough samples are tested and that the values selected for comparison with the limiting values are based on the highest values. The requirements set out in CC-SPW-00800, Table 2.1 and CC-SPW-00800, Section 2.2.1.2 follow the principles set out in BRE Special Digest 1.

TRL 447, which is available from the Transport Research Laboratory (www.trl.co.uk), provides further background to the specification requirements should a particular aggregate source require close consideration in this regard.

2.2.1.3 Requirements Related to the use of Reclaimed Aggregates

CC-SPW-00800, Table 2.2 specifies the allowable reclaimed aggregate content of a UGM. CC-SPW-00800, Table 2.3 details the allowable constituents and contents of the reclaimed aggregate portion of the UGM.

The use of Reclaimed Asphalt (RA) within a UGM should take consideration of circular economy principles to re-use RA at its highest value. The re-use of RA at its highest value would equate to its re-use within another bituminous mixture. The use of RA within a UGM should only be considered where the use of the RA within a bituminous mixture has been identified as not being optimal in terms of environmental and economic considerations. An example where RA might be considered suitable for re-use within a UGM is where the RA is of poor quality and unsuitable for use within a bituminous mixture as determined in CC-SPW-00900 Road Pavements – Bituminous Materials.

When dry, RA exhibits 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. Unbound mixtures with high RA content should, therefore, be compacted at moisture contents close to the stated optimum water content of the mixture.

2.3 Mixture Composition

Grading

CC-SPW-00800, Table 2.5 and Table 2.6 detail the grading requirements for UGMs. As part of the application of these requirements, the supplier shall declare a grading curve which is representative of the UGM product and which lies within the Supplier Declared Value Grading Range in CC-SPW-00800, Table 2.5 and Table 2.6 as appropriate for UGM A and UGM B respectively. Individual batches of UGM material are then assessed using the tolerances in CC-SPW-00800, Table 2.5 and Table 2.6, applied to the supplier declared values. As explained in IS EN 13285, Annex A, the use of tolerances does not change the overall grading range.

CC-SPW-00800, Table 2.5 and Table 2.6 also include requirements for the calculated difference between the percentage by mass passing values of selected adjacent sieves, for example, for UGM A as per CC-SPW-00800, Table 2.5, the percentage by mass passing the 16mm sieve and retained on the 8mm sieves shall be between 10% and 25%. These requirements are taken from IS EN 13285 and ensure a ‘well graded’ mixture by controlling the continuity of the grading curve.

CE marking and factory production controls

Because the requirements for aggregates used in the unbound mixtures refer to the requirements of IS EN 13242, confirmation of conformity of the aggregates with the specification can be obtained from the DoP and CE Mark Certificate for the aggregates used in the mixture.

In the scenario where a UGM is produced on site as part of the Works using site won materials or where a UGM producer is also the producer of the constituent aggregates which have not been placed on the market and therefore a CE Mark Certificate is not required. However the manufacturer is required to confirm the suitability of the source of the constituent aggregates by providing test certificates from a testing laboratory accredited in accordance with CC-SPW-00100 for the test, showing compliance with the specification and dated not more than 6 months prior to use of the material within the Works.

A CE Mark is not required for the constituent aggregate of a UGM where the aggregates have not been placed on the market.

IS EN 13242, Annex C and IS EN 13285, Section 5.3 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.

Although parameters related to the control of the construction of the pavement layer are outside the scope of IS EN 13285, it is appropriate to make information available to assist the purchaser's choice of unbound mixture. IS 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.

2.3.1 Frost Heave

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 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.

2.3.2 Environmental Considerations

Where reclaimed aggregates are incorporated within a UGM, the use case of the UGM, for example as a subbase layer beneath an impermeable bituminous layer, should be considered in order to meet the requirements related to the reuse or recycling of materials respectively defined by Regulation 27 (by product) and Regulation 28 (end of waste) as defined in European Union (Waste Directive) Regulations, 2011 - 2020 (transposing EU law).

National Decision criteria under Regulation 27 (by product) have been developed by the Environmental Protection Agency (EPA) for site-won asphalt (road planings). These National Decision criteria negate the need to make single case notifications to the EPA for determination by manufacturers of these products or products containing these materials. Instead, the producer of these materials to comply with the national criteria is required to be registered.

Registration details are displayed on the publicly available register published by the EPA. Where the National Decision criteria are not met a single case Regulation 27 (by product) notification to the EPA is required.

National Decision criteria under Regulation 28 (end-of-waste) have also been developed by the EPA for recycled aggregates. End-of-waste criteria represent the specific requirements that need to be fulfilled by a Producer of recycled aggregates or products containing these materials to cease to be regulated as waste. These criteria are specific for the defined use(s) of the material. Producers (waste operators) of recycled aggregate or of products containing these materials must be registered with the EPA. A list of producers can be found on the EPA's End-of-Waste Register along with details of how to register. Where the National Decision criteria are not met a single case Regulation 28 (end-of-waste) notification to the EPA is required.

2.4 The Works

2.4.1.4 Use of Surfaces by Construction Plant and Other Traffic

UGM subbase layers shall not be used as a construction haul road. UGM subbase layers shall only carry construction traffic related to the construction and paving of overlying pavement layers.

2.4.2 Works

The use of Design Level (DL) 2 materials is most suitable for schemes where the opportunity exists for the designer, contractor and material producer to interact at an early stage and provide inputs to the pavement design, specification and material performance characterisation.

Where a Design Level (DL) 2 material has been designed and specified for use with a pavement structure, a detailed understanding and validation of the characteristics and performance of the UGM in the laboratory and in the Works is required.

2.4.2.2 Design Performance

2.4.2.2.1 FWD Testing

Falling Weight Deflectometer (FWD) testing in accordance with CC-SPW-00800 is the default method to assess UGM works performance. The use of a Light Falling Weight Deflectometer (LFWD) is currently not permitted due to the variability in deflections measured across LFWD devices from various manufacturers.

3. Hydraulically Bound Mixtures

The IS EN 14227 series of European Standards for Hydraulically bound mixtures, specify the requirements for hydraulically bound mixtures and covers a range of potential binder types. The requirements for the properties of aggregates used in hydraulically bound mixtures are defined by appropriate cross-reference to IS EN 13242. However, CC-SPW-00800 only considers Hydraulically bound mixtures bound with cement. Therefore, IS EN 14227-1 is relevant to this specification.

IS EN 14227-1 is not a harmonised European Standard therefore HBM products are not required to be CE Marked. However, HBMs and their constituent aggregates shall have a Declaration of Performance (DoP) and be manufactured following the production control procedures detailed in IS EN 14227-1.

IS EN 13242 is a harmonised European Standard therefore aggregate products placed on the market are required to be CE Marked and have a DoP in place. HBMs which are manufactured with aggregate products procured from the market are required to have the aggregate manufacturers CE Mark and DoP with the HBM mixtures DoP. The responsibility for the compliance of the HBM and constituent aggregate with a DoP remains with the HBM product manufacturer. HBM constituent aggregate not placed on the market as a product and manufactured by the HBM manufacturer are not required to have a CE Mark, this includes aggregate produced as part of the Works. Requirements for HBMs should be identified by the compiler in accordance with CC-SPW-00800 and detailed in the contract specific Appendix 7/1, including:

1. the HBM mixture designation
2. laboratory mechanical performance category
3. aggregate requirements.

3.2 Constituent Materials

3.2.1 Aggregate

CC-SPW-00800, Table 3.1 details the geometric, physical and chemical properties required for HBM aggregates using the categories from IS EN 13242.

Crushed or broken particles perform better than rounded particles in a HBM mixture with the same grading curve in supporting both construction and in-service traffic. Therefore, the proportion of crushed/broken versus rounded particles is a key parameter of the crushed rock constituents of a HBM mixture.

In addition, the Los Angeles coefficient (LA) is a measure of the aggregate's resistance to fragmentation and an indicator of mechanical strength. A lower value indicates greater resistance.

3.2.1.1 Requirements Related to the use of Reclaimed Aggregates

CC-SPW-00800, Table 3.2 specifies the allowable reclaimed aggregate content of a HBM. CC-SPW-00800, Table 3.3 details the allowable constituents and contents of the reclaimed aggregate portion of the HBM.

Further guidance on the use of Reclaimed Aggregates within UGMs is provided in Section 2.2.1.3 of this document. This guidance is also applicable to the use of Reclaimed Aggregates within HBMs.

3.3 Mixture Composition

3.3.3 Binder Content

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.

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 CC-SPW-00800, Table 3.6. Success at such low cement contents depends on:

1. grading and cleanliness of the material to be stabilised
2. close control of the binder addition rates
3. efficiency of the binder dispenser or spreader
4. mixing efficiency.

The optimal binder content for the HBM to achieve the required laboratory performance may not drop below the minimum binder content specified in CC-SPW-00800.

3.3.4 Environmental Considerations

Where reclaimed aggregates are incorporated within a HBM, the use case of the HBM, for example as a bound basecourse layer beneath an impermeable bituminous layer, should be considered in order to meet the requirements related to the reuse or recycling of materials respectively defined by Regulation 27 (by product) and Regulation 28 (end of waste) as defined in European Union (Waste Directive) Regulations, 2011 - 2020 (transposing EU law).

National Decision criteria under Regulation 27 (by product) have been developed by the Environmental Protection Agency (EPA) for site-won asphalt (road planings). These National Decision criteria negate the need to make single case notifications to the EPA for determination by manufacturers of these products or products containing these materials. Instead, the producer of these materials to comply with the national criteria is required to be registered. Registration details are displayed on the publicly available register published by the EPA. Where the National Decision criteria are not met a single case Regulation 27 (by product) notification to the EPA is required.

National Decision criteria under Regulation 28 (end-of-waste) have also been developed by the EPA for recycled aggregates. End-of-waste criteria represent the specific requirements that need to be fulfilled by a Producer of recycled aggregates or products containing these materials to cease to be regulated as waste. These criteria are specific for the defined use(s) of the material. Producers (waste operators) of recycled aggregate or of products containing these materials must be registered with the EPA. A list of producers can be found on the EPA's End-of-Waste Register along with details of how to register. Where the National Decision criteria are not met a single case Regulation 28 (end-of-waste) notification to the EPA is required.

3.3.5 Design Performance

3.3.5.1 Mixture Design

Grading

When assessing the acceptability of the aggregate grading, allowance should be made for the grading of the added binder. This is usually 100% by mass passing the 0.063 mm test sieve.

Performance Classification

Two methods of material performance classification are included in CC-SPW-00800 for HBMs. Classification by compressive strength using unconfined cylindrical or cubic specimens and measured in accordance with IS EN 13286-41 is specified for pavements and materials designed to Design Level (DL)1.

Classification by tensile strength in combination with elastic modulus provides a modelling regime closer to the performance of bound pavement layers and is specified for pavements and materials designed to DL2.

The DL2 classification requires that materials be characterised in terms of tensile strength and elastic stiffness. Tensile strength shall be measured by indirect (cylinder-splitting) testing in accordance with IS EN 13286-42. Elastic modulus is measured in accordance with IS EN 13286-43 in direct compression.

The performance class required to be achieved shall be determined through the pavement design process. Further guidance is given in DN-PAV-03021. Appendix 7/1 shall show the required performance class and the associated layer thickness. For employer designed contracts, there will not be an alternative to the pavement types and materials specified in the Appendix 7/1. For Design and Build type projects the pavement design and material selection shall be determined by the contractor/designer.

IS EN 14227-1 defines a performance characteristic based on the average values from at least three test specimens. The characteristic strength of HBM mixtures should be determined from the mean value of any consecutive five test results to improve the level of confidence in the material performance characterisation.

Works performance requirements

For site control and work performance verification 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 requested earlier age and results at 28 days using representative samples of the aggregates and binder used in the Works. This correlation should be determined at mixture design stage and monitored during the Works.

In order to develop the required correlation a schedule of testing similar to that shown in Table NG 1 should be used for each combination of binder and water content. 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.

Table NG1 – Suggested Schedule of Testing for Laboratory Mechanical Performance of One Combination of Binder and Water Content

Curing Temperature	**Age of Sealed Specimens at Time of Test (at least 3 Specimens for Each Test Age)**		
	7 days	**14 days**	**28 days**
20°C	✓	✓	✓

3.4 The Works

3.4.1 Construction

HBM Production

Three methods of blending and mixing are recognised in 3.4.1; 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.

Laying

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.

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.

Basecourse layer mixtures are required to be laid using a paver, to assure consistent compaction and compliance with surface level tolerance. The Employer may permit the use of other laying methods, if the Contractor can confirm satisfactory performance using a validation trial section and works proposal as described in CC-SPW-00800, Section 3.4.2.4 and 3.4.2.5.

Segregation can be seen as zones of coarse aggregate without enough fine aggregate to fill the gaps between the larger particles. Segregation should be avoided as 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.

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.

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 reclaimed aggregate can also be reduced by the use of pneumatic tyred rollers.

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.

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, CC-SPW-00800, Section 3.4.2.5 requires the Contractor's works proposal 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.

Construction Period

CC-SPW-00800 details the calculation of the construction period for HBMs. An example calculation of the construction period, in degree hours, is provided in Table NG2 below.

Table NG2 – Example Calculation of Construction Period

Period (24hr)		Period, t (hr)	Average Air Temperature, T (°C)	T.t (°C.hr)
Start	End			
09h00	10h00	1	6	6
11h00	12h00	1	10	10
12h00	13h00	1	14	14
			Σ(T.t)	**30**

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.

The Contractor should use a risk assessment approach to evaluate and define appropriate weather and construction time criteria for the HBM layers. Suitable criteria may include the following:

1. the depth of cover provided by the overlying layers
2. the type and durability of the aggregates used in the mixture
3. the likely strength gain of the mixture prior to overlay
4. the site location
5. the likely construction date.

3.4.1.1 Cold and Wet Weather Working

The values of construction period 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 to occur at temperatures below 3ºC.

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 3.4.2.5 requires the Contractor's works proposal 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.

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.

3.4.1.2 Induced Cracking of HBM

3.4.1.3 Curing, Protection and Trafficking

Early trafficking of the pavement, outside of the trafficking requirements set out in 3.4.1.3, is not permitted.

The application of a bitumen emulsion to facilitate the optimal curing of the HBM layer through limiting moisture loss from the HBM is preferred. This method of ensuring the retention of the optimal mix moisture, as determined by the mixture design process, will assist in ensuring the expected curing of the HBM, meeting the design and specification performance requirements. The application of water through a mist / fog is a less controlled method of ensuring sufficient moisture in the HBM mix and may result in inadequate moisture application and inhibited curing of the HBM.

3.4.1.4 Mix-in-Plant Method of Construction Using Batching by Mass

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:

1. a batch mix system using a vertical axis rotating pan mixer with fixed location vertical blades to force the flow to the centre of the pan and prevent the agglomeration of fine material at the pan wall
2. 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.

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.

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).

3.4.1.5 Mix-in-Plant Method of Construction Using Volume Batching

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 3.4.1 does not permit volume batching for mixtures used in basecourse layers.

3.4.1.6 Mix-in-Place Method of Construction

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. 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 moisture content must be rigorously maintained if full integration and activation of binder(s) is to be effective. 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.

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.

Uniformity of binder distribution and depth of pulverisation and mixing are important factors in achieving the expected pavement stiffness and durability. 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 material.

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).

3.4.2 Works Requirements

3.4.2.1 Compaction

3.4.2.1.1 Test Locations and Sampling

The sampling and testing schedule provided in Appendix 1/5 shall be prepared with consideration of the Design Level specific sampling and testing requirements.

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