UNITED KINGDOM QUALITY ASH ASSOCIATION

6.4.1

Technical Datasheet

Fly Ash in Highway Pavement Construction Specification for FABM 1

Contents

Foreword

FABM 1 is one of 5 fly ash bound mixtures described in BS EN 14227-3. Specifically, it is a 0/31.5mm well-graded mixture of aggregate, fly ash, quick or hydrated lime, and water. It is basically the mixture previously known as GFA (Granular material treated by Fly Ash), which has been used since 1997 by Staffordshire and Kent County Councils.

The fly ash (previously known as pfa in the UK) for FABM 1 is typically run-of-power-station dry or wet (conditioned) ash in conformity with BS EN 14227-4:2004 that, in combination with lime, performs as a slow setting slow hardening binder. This combination means that FABM 1 behaves as an unbound material in the short-term but as a bound material in the long term. It is also immediately traffickable and thus ideal for congested sites and reconstruction schemes where laying flexibility is paramount, as well as large new-build jobs.

The aggregate for FABM 1 should be clean, hard and non-plastic and can be made from natural, artificial or recycled material including processed planings, demolition material, arisings and refuse incinerator bottom ashes.

Typical mixture proportions by dry weight for FABM 1 is; lime (2-3%), fly ash (8-13%) and aggregate (85-90%). Where faster setting is required, CEM 1 cement can be used in lieu of lime in FABM 1 but without the above construction flexibility since behaviour is akin to normal cement-bound mixtures.

FABM 1 is specified in the 800 series of the Specification for Highway Works (SHW) along with other hydraulically-bound mixtures (HBM) for use in base and sub-base. This data sheet effectively 'strips-out' the other FABM and HBM to produce a specification solely for FABM 1 that is appropriate for use with the pavement design data sheet 6.3 produced by the United Kingdom Quality Ash Association. The specification is considered equivalent to the SHW 800 series but requires no reference to it or to BS EN 14227-3 or BS EN 14227-4.

1. Scope

1.1. This specification defines the requirements for the composition, the laboratory mechanical performance and the production, placement, and testing of FABM 1.

2. Standards & references

2.1. BS EN 14227-3:2004. Hydraulically bound mixtures – Specifications – Part 3: Fly ash bound mixtures. BSi, London, UK.

2.2. BS EN 14227-4:2004. Hydraulically bound mixtures – Specifications – Part 4: Fly ash for hydraulically bound mixtures. BSi, London, UK.

2.3. Highway Agency. Manual of Contract Documents for Highway Works. Volume 1.

2.4. Specification for Highway Works. The Stationery Office, Norwich, UK.

2.5. BS EN 13286-4:2003. Unbound and hydraulically bound mixtures – Part 4: Test methods for laboratory reference density and water content – vibrating hammer.

2.6. BS EN 459-1. Building limes. Part 1: Definitions, specifications and conformity criteria.

2.7. BS EN 459-2. Building limes. Part 2: Test methods.

2.8. BS EN 13242. Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction. BSi, London, UK.

2.9. BS 1377-2. Methods of test for soils for civil engineering purposes. Part 2. Classification tests.

2.10. BS EN 197-1, Cement – Part 1: Composition, specifications and conformity criteria for common cement.

2.11. United Kingdom Quality Ash Association. www.ukqaa.org.uk

2.12. BS EN 933-1: Tests for geometrical properties of aggregates - Part 1. Determination of particle size distribution – sieving method.

2.13. BS EN 13286-51:2004. Unbound and hydraulically bound mixtures – Part 51: Method for the manufacture of test specimens of hydraulically bound mixtures using vibrating hammer compaction.

2.14. BS EN 13286-41:2004. Unbound and hydraulically bound mixtures – Part 41: Test method for determination of the compressive strength of hydraulically bound mixtures.

2.15. BS EN 13286-42:2004. Unbound and hydraulically bound mixtures – Part 42: Test method for the determination of the indirect tensile strength of hydraulically bound mixtures.

2.16. BS EN 13286-43:2004. Unbound and hydraulically bound mixtures – Part 43: Test method for the determination of the modulus of elasticity of hydraulically bound mixtures.

2.17. BS 1924: Part 2: 1990. Stabilised materials for civil engineering purposes. Part 2. Methods of test for cement-stabilised and lime-stabilised materials.

3. Definitions

3.1. **FABM 1:** a 0/31.5 mm mixture of granular material, fly ash and lime (or cement), with a water content compatible with compaction by rolling.

3.2. **Immediate bearing index**: immediate CBR value determined without surcharge determined on specimens compacted using 4.5 kg compaction at optimum moisture content (Annex C).

NOTE: The IBI is a measure of immediate traffickability.

4. Symbols & abbreviations

4.1. **OMC:** Optimum moisture content determined using vibrating hammer compaction in accordance with BS EN 13286-4.

4.2. **UKQAA United Kingdom Quality Ash Association**

5. Binder constituents

5.1. Fly ash: Fly ash, dry or conditioned with water, shall comply with the specification given in Annex A.

5.2. Lime: Lime shall be CL 90 [NforG] quick lime to BS EN 459-1 or hydrated lime to an equivalent specification from BS EN 459-1. In addition, quick lime;

5.2.1. when tested using the reactivity test in BS EN 459-2, shall attain a temperature of 60 degrees C within 5 minutes,

5.2.2. shall have a particle size with not less than 95% passing 2mm, 70% passing 0.2mm and 50% passing 0.08mm. [NforG]

6. Water

6.1. Water shall not contain components that interfere with the setting, hardening and performance of FABM1.

7. Granular material

7.1. Granular material shall comply with this sub-clause and Table 1, and shall be natural, artificial or recycled material including, planings, demolition material, arisings and incinerator ashes, conforming to BS EN 13242. The material shall produce, in combination with the fly ash and lime, a mixture, which meets the grading requirements specified in Table 3 [NforG].

Attribute	*Requirement*
Crushed or broken particles or totally rounded particles	C90/3 or C30/50 NforG for FABM 2
Plasticity as defined by and tested to BS 1377-2	The fraction passing the 0.425 mm sieve shall be non-plastic
Los Angeles Coefficient	LA_{50} or LA_{60} NforG
Glass content	40% maximum by mass
Acid soluble sulfate and total sulfur categories	$AS_{0.2}$ & S_1 respectively **
Impurities – wood	1% maximum by mass

Table 1: Aggregate requirements (to BS EN 13242 unless specified otherwise)

*Current knowledge indicates that satisfying the immersion test requirement in 23 below obviates the need for sulfate testing and thus compliance with the stated sulfate limit but not the need for the sulfur limit and testing.

8. Other constituents

8.1. CEM 1 cement to BS EN 197-1.

9. Composition

9.1. Unless agreed otherwise;

9.1.1. FABM 1 shall be designed in accordance with the mixture design procedure in 23

9.1.2. using constituents specified in 5, 6, 7 & 8

9.1.3. using the minimum constituent proportions specified in Table 2 [NforG]

9.1.4. using a water content range selected for compaction on site by rolling

9.1.5. to comply with the selected grading requirements of Table 3 [NforG]

9.1.6. to satisfy the selected class of laboratory mechanical performance from 10, 11 & 12 [NforG]

9.1.7. to satisfy the 'strength after immersion' class $I_{0.8}$ when tested to sub-clause 23.

Constituent	*Application*	*Minimum addition for production employing batching by mass*	*Minimum addition for production employing batching by volume*
Lime (quick or hydrated	When used with dry or wet fly ash	1.5%	2%
CEM 1 cement	Ditto	2%	3%
Dry fly ash	When used with CEM 1	4%	5%
Dry fly ash	When used with lime	6%	8%
Wet (conditioned) fly ash	When used with CEM 1 or lime	8%	11%

Table 2: Minimum constituent additions by dry mass of mixture as a function of batching

Sieve size (mm)	*Percentage passing by mass for FABM 1*
45	100
31.5	85-100
25	75-100
20	66-95
10	48-82
6.3	-
4	34-68
2	26-58
0.5	16-38
0.25	13-30
0.063	7-18
The particle size shall be determined by washing and sieving to BS EN 933-1.	The target grading shall be declared and shall produce a smooth particle size curve within the envelope unless otherwise agreed [NforG].

Table 3: Grading envelope for FABM 1 (using conditioned fly ash*)

* where dry fly ash or a factory blend of lime (or cement) and fly ash are used, the grading envelopes in BS EN 14227-3 for FABM 1 made with calcareous fly ash may be more appropriate.

10. General

10.1. The laboratory mechanical performance class shall be selected using one of the following methods of characterisation:

10.1.1. compressive strength (R_c) or

10.1.2. the combination (R_tE) of tensile strength (R_t) and static modulus of elasticity (E).

NOTE: No correlation or equivalence is intended nor shall be assumed between the 2 methods of characterisation. The choice of method depends on design philosophy, utilisation and experience. NforG

11. Classification by Rc

11.1. Performance shall be classified by the 28 day compressive strength (R_c) determined in accordance with Annex B.

11.2. According to the pavement requirements, the class shall be selected from the following classes:

11.2.1. C3/4, C6/8, C9/12, C12/16, C15/20, C18/24, C21/28, C24/32, where C designates compressive strength and the numbers after C, the minimum standard strength in MPa of the class; the first number referring to the strength of cylinders with a height:diameter ratio of 2 and the second number, to cylinders with a height:diameter ratio of 1 or cubes.

12. Classification by R_tE

12.1. Performance shall be classified by the combination, designated (R_tE), of the tensile strength (R_t) and static modulus of elasticity (E) at 28 days established in accordance with Annex B.

12.2. According to the pavement requirements, the class shall be selected from one of the following classes of R_tE detailed in Figure 1.

12.3. T1, T2, T3, T4 & T5.

NOTE: The mixture characteristics and proportions necessary to meet the required R_tE class are determined at the mixture design stage (clause 23). This may also include compressive strength testing which can be used for compliance purposes (sub-clause 22).

13. Production, placing and testing

13.1. General requirements

13.1.1. Prior to the commencement of the works, the contractor shall provide;

13.1.1.1. The mixture design results, including the 'strength-after-immersion' results

13.1.1.2. The target proportions of constituents

13.1.1.3. A method statement for production, transport and laying in accordance with 20

13.1.1.4. And a demonstration area in accordance with 21.

13.2. Unless otherwise agreed, mixtures used in base layers shall be paver-laid.

13.3. Compaction, including any reworking and reuse, shall be completed within the construction period stated in Table 4. For multi-lift work, the construction period shall be measured from the addition of the lime/cement for the first lift and the completion of compaction of the overlying lift.

Binder	*Construction period in °C hours*
Cement with fly ash	35* from addition of cement (~ 2 hours at 20°C)
Lime with fly ash	800* from addition of lime (~ 48 hours at 20°C)

Table 4: TABLE 4: Construction period for FABM 1 & 2

* actual time in hours is the 'construction period °C hours' divided by 'the numerical difference between the actual temperature and 3°C'.

13.4. During cold weather:

13.4.1. the temperature of the mixture shall not be less than 5°C at the time of laying

13.4.2. mixture shall not be laid on a surface with a temperature below 3°C

13.4.3. laying shall cease when the air-temperature falls below 3°C and shall resume only until the rising air temperature reaches 3°C.

13.5. The laying of mixtures containing less than 3% CEM 1 cement by dry mass of mixture shall be restricted in use to the period 1st May to 30th September unless otherwise agreed.

13.6. In the case of heavy or persistent rain, production shall cease and laid mixture compacted immediately.

14. Storage of constituents

14.1. Aggregates and wet (conditioned) fly ash shall be stored on a firm and clean substrate avoiding contamination with other constituents

14.2. Before production, conditioned fly ash shall be stored for at least 3 days at a minimum moisture content of 10% and screened to remove agglomerations greater than 10mm.

14.3. Dry powder components such as lime and, when employed, dry fly ash, shall be stored in silo(s).

15. Manufacture

15.1. The mixture shall be produced in a central mixing plant that batches by weight and mixes in a forced-action mixer. The plant shall have hoppers for the aggregate and conditioned fly ash. For uniformity NforG, the aggregate shall be added as a minimum of 2 separate fractions – generally a sand fraction and at least one coarse fraction. For ease of discharge of the conditioned fly ash, the hopper(s) concerned shall have steep sides or be lined with sheet plastic or be fitted with vibrators or a combination of these features.

15.2. Either through direct measurement or process control records, the supplier/producer/contractor shall provide evidence that constituents are batched to within 0.5% of the required quantity.

16. Transport

16.1. Transport of mixture shall be by rear-tipping lorries or dump trucks, fitted with covers to protect the mixture from drying or wetting during haulage or delays.

17. Laying

17.1. The total course thickness of mixture up to 230mm thickness shall be placed in one lift, by dozer, blade or paver avoiding segregation and drying out. Total course layer thickness greater than 230mm may be undertaken:

17.1.1. in one lift provided the compaction requirements of sub-clause 18 are met,

17.1.2. or in 2 lifts subject to a minimum compacted lift thickness of 150mm. Subject to the other requirements of this clause, the first lift shall always be as thick as possible.

17.2. In no case shall mixture be added to freshly compacted mixture to make up level without vigorous scarifying of the surface of the compacted mixture to a depth of at least 50mm.

17.3. Surface trimmed material and mixture arising from ramps at the end of a day's work or elsewhere can be used in the permanent works day provided the mixture remains within the construction period, has not dried excessively and is uncontaminated.

17.4. The face of previously compacted mixture or other material shall be vertical before placement and compaction of fresh mixture.

17.5. In the case of rain, production shall cease and laid material shall be immediately compacted.

18. Compaction

18.1. Compaction shall be carried out by a combination of vibrating roller (VR) and pneumatic-tyred roller (PTR) and shall:

18.1.1. be completed before drying out and/or setting of the mixture

18.1.2. achieve an insitu wet density in the layer not less than 95% of the maximum laboratory wet density as specified in sub-clause 22.2

18.1.3. produce a layer with a well-closed surface, free from ridges, cracks, loose material, pot-holes, ruts, shear planes and cracks.

18.2. PTR compaction shall follow VR compaction and shall consist of at least 8 passes of a PTR with a wheel load of not less than 3 tonnes operating at a tyre pressure progressively increasing to circa 700 kPa.

18.3. At no time during compaction shall the surface of the mixture be allowed to dry out. To avoid this the contractor shall provide plant capable of applying a light spray of water to the surface.

18.4. Any defective areas shall be rectified during the construction period. If rectification is not completed within this period, the defective area shall be removed to the full thickness of the layer, and new mixture laid and compacted.

19. Curing, protection & trafficking

19.1. The layer shall be protected at all times from the detrimental effects of weather and use during construction and prior to overlaying with the next pavement course.

19.2. At no time after compaction, and prior to the placing of the next lift or layer, shall the surface be allowed to dry out. To avoid this the contractor shall provide plant capable of applying a mist/fog/light spray of water to the surface, daily or more frequently as necessary.

19.3. Excluding mixtures containing cement that have a 7-day non-trafficking period, careful and controlled trafficking of the layer is permitted. Surface contamination of the layer shall be avoided and removed prior to overlaying. Reworking and re-compaction of the layer, watering if necessary, shall be permitted within the construction period.

19.4. As an alternative to light spraying with water, and before drying out of the surface, the surface shall be sprayed with 40% bitumen emulsion at the rate of at least 0.5 l/m2 to achieve full and even coverage. Provided the surface is gritted at the rate of at least 1.5 kg/m2 to prevent the emulsion from being removed by vehicle tyres, controlled trafficking of the layer is permitted.

19.5. Whatever the curing method, care should be taken with turning and other operations. Lorries, such as those discharging material for the next layer, or plant involved with kerbing and gully operations, can use the layer immediately but extensive use by site traffic shall be avoided until the next course or a surface dressing is applied.

19.6. Trafficking shall be avoided in wet conditions.

19.7. Before overlaying, loose material shall be removed or rectified as above.

20. Method statement

20.1. At least 10 days prior to construction the demonstration area described in 8.9, the contractor shall provide a full method statement indicating the intended procedures including;

20.1.1. the intended mixture proportions and supporting data to justify the proportions

20.1.2. storage of constituents,

20.1.3. batching and mixing facilities including production control checks

20.1.4. transport and weather protection to point of use

20.1.5. laying, compaction, curing, protection, trafficking including control checks

20.1.6. a sample record sheet for completion each working day, detailing construction times, sample and check locations, and check results (e.g. insitu density) available that day and to be made available by the start of the next working day.

21. Demonstration area

21.1. Prior to the commencement of the main works, the contractor shall construct a demonstration area of at least 800 m2 conforming to the submitted method statement. The demonstration shall consist of at least 2 full-width bays so as to include a transverse end-of-bay joint.

21.2. Subject to satisfactory demonstration, the area may be constructed and accepted in the permanent works.

21.3. Once accepted, the constituents, proportions, production and construction procedures shall not be changed without a further demonstration area and or agreement.

22. Tests, controls and checks

22.1. Tests, controls and checks shall be carried out at agreed locations in accordance with Table 5 and sub-clauses below. With agreement, the frequency of the sampling shall be increased or relaxed as necessary.

Test/control/check	*Frequency*	*Reference*
Aggregate properties	Weekly certification	Sub-clause 5.4
Fly ash properties	Weekly certification	Annex A
Lime, cement	Weekly certification	-
Batching records	Continuously	-
Water content of mixture	3/1000 m2 but not less than 4 per day	BS 1924-2, clause 1.3
Grading of mixture	1/1000 m3 or daily if less	BS EN 933-1
Insitu wet density	Sub-clause 22.2	Sub-clause 22.2
Mixture strength	Sub-clause 22.3	Sub-clause 22.3
Volume stability	At mixture design stage	Clause 23
IBI if necessary	At mixture design stage	Clause 23

Table 5: Requirements for tests, controls and checks

22.2. The insitu wet density of the layer shall be not less than 95% of the maximum laboratory wet density as determined by the vibrating hammer test of BS EN 13286-4 and shall be the average of 5 results for every 1000m^2 or part thereof laid each day, determined using a nuclear density gauge in direct transmission in accordance with section 3.7 of BS1924-2. The source rod shall be lowered to within 25mm of the bottom surface of the layer and readings taken within 2 hours of completing compaction. The result for each determination shall be the average of the higher 2 of 3 readings taken at 120 degrees to each other. The gauge shall be calibrated on a block of the mixture and recalibrated monthly thereafter or when constituents or proportions are changed.

22.3. For every 1000m^3 of mixture placed or part thereof laid each day, five full-depth samples shall be taken from the layer and from each sample and without further mixing, a cylindrical specimen manufactured for compressive or tensile strength testing at 28 days. The specimens shall be compacted to refusal by vibrating hammer and sealed to prevent loss of moisture and stored for 28 days at 40^{o}C before testing in accordance with Annex C. The average measured strength of each set of 5 specimens shall satisfy the requirements of the selected class as follows.

22.3.1. In the case of pavement design based on R_c, compliance shall be satisfied if the average compressive strength of any group of 5 specimens is equal to or greater than the minimum compressive strength for the specified class with no individual test result less than 67% of the minimum.

22.3.2. In the case of pavement design based on R_tE, compliance shall be satisfied if the average tensile strength of any group of 5 specimens is equal to or greater than the minimum tensile strength, R_t, of the selected T class appropriate to the E value determined from the mixture design process, with no individual result less than 67% of the minimum. Compressive strength R_c may be used for compliance purposes provided the mixture design work establishes the correlation between R_c and R_t.

23. Mixture design procedure

23.1. The composition of the mixture shall be based on a mixture design test schedule using a minimum of 3 binder contents and a minimum of 2 water contents for each binder content, that satisfies the selected laboratory mechanical performance and the volume stability requirement.

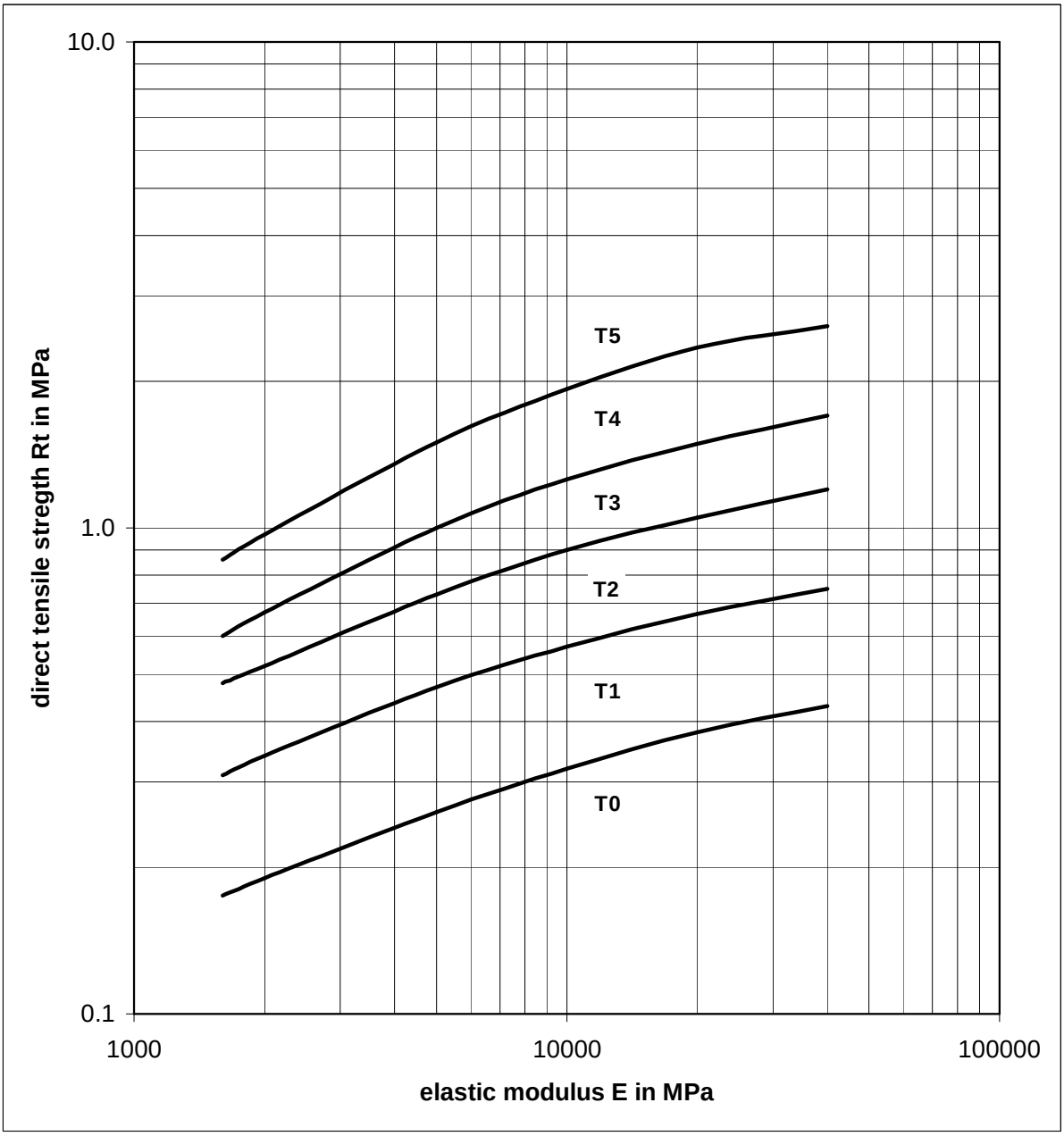
23.2. The mixture design test schedule shall reflect the selected method of mechanical performance characterisation, R_c or R_tE, and the adopted method of mechanical performance compliance. [NforG]

23.3. The selected age of testing shall be 28 days and other ages reflecting the time available for testing, the desired age of compliance testing and the design requirements.

23.4. The requirement for volume stability shall be assessed, by comparing the average 28-day strength of 3 specimens immersed in aerated water, with that of 3 sealed specimens. The immersed specimens shall be unconfined and have water contact to all surfaces. For mixtures containing less than 3% CEM 1 cement by dry mass of the mixture, the immersion period shall be 14 days following 14 days sealed curing, both

using 40C. In the case of mixtures containing 3% or more cement, the procedure is identical but employs 20C rather than 40C.

Figure 1



NOTE The table beside gives the values of Rt and E used to draw the curves limiting the categories T5, T4, T3, T2 and T1.

E (MPa)	2000	5000	10000	20000	40000
Low limit of category	Rt (MPa)				
T5	0,97	1,50	1,93	2,35	2,60
T4	0,67	1,00	1,26	1,49	1.70
T3	0,52	0,73	0,90	1,05	1,20
T2	0,34	0,47	0,57	0,67	0,75
T1	0.19	0,26	0,32	0,38	0,43

ANNEX A: Specification for fly ash

A1 Scope

This specification applies to fly ash for use in FABM and other HBM.

A2 References

BSEN451-1 Method of testing fly ash - Part 1: Determination of free calcium oxide content.

BSEN451-2 Method of testing fly ash - Part 2: Determination of fineness by wet sieving.

BSEN196-2 Method of testing cement. Part 2: Chemical analysis of cement.

BSEN196-3 Methods of testing cement. Part 3: Determination of setting time and soundness.

A3 Definitions

Fly ash Fine powder produced by the combustion of pulverized coal in energy generating plants and captured by mechanical or electrostatic precipitators. The essential chemical components are silicates, aluminates and iron oxides. Fly ash is a pozzolanic material. It can be stored, supplied and used either in a conditioned (typically 10 – 20% added water) or dry (less than 1% water) condition.

A4 Particle size

Particle size, carried out in accordance with BSEN451-2, shall conform to the following.

Sieve	*% by mass passing*
90 micron	$\geq$ 70
45 micron	$\geq$40

A5 Chemical composition

Chemical composition shall comply with the following expressed as a percentage by mass of the dry product. The composition shall be determined on a laboratory sample, obtained by drying to constant weight in a well ventilated oven at 105 $\pm$ 5 degrees C, and then cooled in a dry atmosphere.

A5.1. Loss on ignition (LOI)

The LOI, measured in accordance with BSEN196-2, but using an ignition time of 1 hour, or other equivalent method, shall not exceed 15% (Note: Previously 10%).

NOTE: The purpose of this requirement is to limit the residue of unburnt carbon in fly ash. It is sufficient therefore, to show through direct measurement of unburnt carbon residue, that it is less than the value specified above.

A5.2. Sulfate content

The sulphate content, expressed as total SO_3, shall not exceed 4% by mass when measured in accordance with BSEN196-2.

A5.3. Free calcium oxide content

The free calcium oxide content, measured in accordance with BSEN451-1, shall not exceed 1% by mass. If this requirement is not met, soundness shall be measured in accordance with BSEN196-3, and the expansion shall not exceed 10mm with a 50:50 blend of fly ash and cement.

ANNEX B: Determination of compressive strength, tensile strength and elastic stiffness

B1: For characterisation or mixture design testing in the laboratory, the representative values of R or E shall be taken as the average result from at least 3 specimens. If one results varies by more than 20% of the average, it shall be discarded and R or E taken as the average of the other values.

B2: For compliance testing, acceptance shall be in accordance with 8.10.2.

B3: Specimens for R and/or E shall be cylindrical specimens with a height diameter ratio of 1 (2 for E) made to refusal using vibrating hammer compaction in accordance with BS EN 13286-51.

NOTE: Either metal, split or otherwise, or rigid plastic moulds can be employed. 150mm diameter HDPE (10mm wall thickness) pipe precision cut to 150mm (300mm for E) lengths has been found particularly convenient for FABM 1 since the specimen can be left in the mould until time of test and the mould is sufficiently robust to allow reuse.

B4: Specimens shall be stored:

- Vertically
- In a manner that prevents loss of moisture
- At a temperature within $\pm$ 2 C of the specified or selected curing temperature
- Such that weight loss during storage is not in excess of 2%.

Non-compliance with the above shall lead to rejection of the specimen.

B5: Specimens shall be tested for compressive and/or tensile strength in accordance with BS EN 13286-41 and BS EN 13286–42 respectively. The latter describes the test to determine the indirect tensile strength also known as the tensile splitting or Brazilian test. Indirect tensile strength, R_{it} , is related to direct tensile strength, R_t , as follows:

- $R_t = 0.8\ R_{it}$

B6: Direct measurement of E shall be determined in accordance with BS EN 13286-43. However E is determined, it can be assumed that:

- $E = E_t = E_c = E_{it}$

ANNEX C: Determination of immediate bearing index (normative)

NOTE: The California Bearing ratio (or CBR) is an index that characterises the bearing capacity of a material. It can be determined immediately or after a period of curing. The immediate bearing index (or IBI) is a similar index that evaluates the ability of a mixture to directly support construction plant or in-service traffic. Essentially it is an immediate CBR test except that it is determined on a specimen without surcharge rings.

The IBI shall be determined, without the use of surcharge rings, on CBR specimens compacted using the 4.5kg rammer to standard compactive effort (i.e. 62 blows per layer). The IBI shall be determined at the OMC or other moisture content as agreed. and at the OMC – 2% or other such moisture content dictated by mixture design & site practice.

Notes for Guidance

NG 5.2: Lime

The BS EN for FABM, BS EN 14227-3, and the SHW, allow the use of either CL90 or CL 80 quick lime for FABM 1. Since the performance of FABM depends on the efficient and full mobilisation of the pozzolanic potential of fly ash and since this is a function of the purity or available CaO in quick lime, the use of CL90 quick lime or equivalent hydrated lime is preferred here.

Similarly, the finer the particle size of the quick lime, the more effective is the reaction between fly ash and lime. Thus the finer of the two quick lime categories allowed in BS EN 14227-3 is also specified here despite allowance for the use of either in the standard and the SHW.

NG 7: Granular material

The setting and strength development of the lime / fly ash reaction is purposely slow and thus the performance of FABM in the short term depends on the grading and quality of the granular material.

With regard to grading, it is desirable for immediate trafficking purposes, that the combined grading of the aggregate, fly ash and lime follows a smooth curve within the specified grading envelope. This is discussed in more detail in NG 6.

In addition, immediate trafficking without distress is also a function of the shape and strength of the aggregate particles. With regard to shape, it is important to specify as a minimum the C50/30 (not less than 50% crushed or broken particles) category from BS EN 13242, but it is recommended that the C90/3 category is specified for base application and for sub-base where sub-base is not overlaid immediately with the base material.

Regarding particle strength, the LA60 category from BS EN 13242 is the minimum that should be used, but it is recommended that the higher LA50 category is specified for base application and for sub-base where the sub-base is not overlain immediately with the base material.

NG 9: Composition

Tables 2 (permitted constituent proportions) and 3 (permitted grading envelopes) need to be considered together. Good performance, both short term under direct trafficking, and long term, is best achieved with a mixture that follows a smooth curve within the grading envelope. With conditioned fly ash, between 10 and 15% combined addition of fly ash and lime is necessary for the achieval of the laboratory mechanical performance requirements. This is a significant amount of fines. Thus in order to produce a smooth particle size curve, the desirable aggregate for treatment is one with few 'fine' fines in order that the target grading is achieved. Planings are ideal in this regard since the conditioned fly ash/lime addition becomes the fine element and will produce a well-graded mixture with good bearing capacity and maximum mechanical performance.

On the other hand, the addition of say 12% combined fly ash/lime to an aggregate with an excess of fines, will produce a mixture with a fines content close or in excess to the upper 'bottom-end' limits of the envelope, and, depending on the rest of the overall grading, possibly poor bearing capacity for immediate trafficking purposes and also low mechanical performance.

As a rule of thumb, for those cases where the aggregate has significant fines, 3/4% cement should be used instead of the more normal 2/3% lime together with a 7 day non-trafficking period, or a pre-blended dry fly ash and lime combination. Where doubt or uncertainty exists concerning the amount of fines in the mixture and trafficking, then the IBI test detailed in Annex C should be carried out. This should be examined at the mixture design stage looking for a value > 50.

NG 10: Laboratory mechanical performance

It is now common in Highway Engineering to use ultimate strength and stiffness properties for pavement design purposes. The ultimate strength (R) or static elastic stiffness (E) of FABM 1 is taken as the value measured at 360 days on specimens sealed to prevent water ingress or egress and stored at 20 degrees C. Compliance results on the other hand are required considerably earlier, usually at 28 days or even earlier provided correlations exist.

The 360-day or ultimate values are normally established from 28-day results as follows:

Ultimate R or E > R or E (at 28 days employing sealed storage at 40^{o}C)

NOTE: This relationship is conservative and safe since extensive testing indicates that the ultimate R or E is typically 1.15 x the 28-day value after 40^{o}C sealed curing.

For illustration purposes, Table C1 gives a tentative relationship between the R_c and R_tE classifications. For comparison, the old UK cement-bound material (CBM) classes are also included. The illustration is conservative with regard to the R_tE classes showing them in a poor light compared to compressive strength classification. Pavement design based on R_tE is more appropriate and robust than that based on R_c and is used in data sheet 6.3.

R_tE classes	Equivalent R_c classes	Nearest equivalent 'old' UK CBM classes
T1	C 3 / 4	CBM 1
T2	C 6/8	CBM 2
T3	C 9/12	CBM 3
T4	C 12/16	CBM 4
T5	C 15/20	CBM 5

Table C1: Tentative relationship between the R_c and R_tE classifications

NG 13: Production, placing and testing

The manufacture of FABM 1 should always be carried out in a central plant employing weigh batching. To minimise segregation and optimise homogeneity and thus immediate traffickability, the aggregate should be batched and added using a minimum of 2 fractions. Thus all-in planings should be screened into a coarse and a finer fraction beforehand. Where hopper availability is limited, pre-blending beforehand of the fine fraction and fly ash, using the same plant as will be used for mixture manufacture, is recommended.

FABM 1 should not be attempted with weak aggregate (LA60) accept in summer and should be overlain as soon as possible or otherwise consideration should be given to the use of OPC in lieu of lime, at least for the sub-base layer where kerbs and or other edge details are to be laid. Ideally however, kerbs and other edge details should be laid on capping

Ideally FABM 1 should not be laid in the period November to March inclusive with the ideal laying season running from 1st May to the 30th September.

Whatever the time of year, it is advisable that FABM 1 be overlain as soon as possible to limit exposure to weather and traffic

NG 23: Mixture design procedure

For the situations where pavement design is based on R_tE, compliance may be more conveniently carried out monitoring R_c. In this case, the mixture design procedure should include R_c testing.

When from NG9, it is recommended that IBI be determined, it is suggested that the IBI be determined at the OMC, at say OMC + 2%, and also after say 3 days in order to assess bearing capacity for trafficking under a possible worse case site scenario – excess water in the mixture - or after a limited period of time. The results of this exercise will enable selection of a workable range of water content and whether it will be necessary to delay trafficking for say 3 days.

In general usage the term 'fly ash' is used for pulverized coal ash but it can also cover ash from burning other materials. Such 'fly ash' may have significantly differing properties and might not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to PFA / fly ash produced from the burning of predominantly coal in power stations.