

Additions

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The new standards for concrete, BS EN 206–1 and BS 8500 will co-exist and have equal status to the existing BS 5328 until its withdrawal in December 2003. However, BSI recommends that BS 5328 is used for specifications until the end of 2003 and BS EN 206–1/BS 8500 is used from 2004.

One of a series of publications produced in conjunction with the following organizations, and part-funded by DTI (formerly DETR):

Association of Concrete Industrial Flooring Contractors

Association of Lightweight Aggregate Manufacturers

British Cement Association

British Standards Institution

Building Research Establishment

Cement Admixtures Association

Cementitious Slag Makers Association

Concrete Industry Alliance

Concrete Society

Glanville Consultants

Institute of Concrete Technology

Ove Arup & Partners

Quarry Products Association

Ready-mixed Concrete Bureau

RMC Readymix

L M Scofield Ltd.

United Kingdom Quality Ash Association

A full list of the publications in this series is given on the back page.

INTRODUCTION

BS EN 206–1 defines an addition as follows:

“3.1.23 - addition

finely divided inorganic material used in concrete in order to improve certain properties or to achieve special properties. There are two types of addition:

- nearly inert additions (Type I);
- pozzolanic or latent hydraulic additions (Type II).”

This publication provides information about using additions in concrete that conforms to:

- BS EN 206–1: *Concrete – Part 1: Specification, performance, production and conformity*, and
- BS 8500: *Concrete – Complementary British Standard to BS EN 206–1*.

The following additions are covered:

- fly ash/pulverized-fuel ash (pfa);
- ground granulated blastfurnace slag (ggbs);
- metakaolin (Type II);
- silica fume (Type II);
- limestone fines;
- mineral filler aggregates;
- pigments.

TYPE II ADDITIONS

Fly ash/pulverized fuel ash (BS EN 450, BS 3892–1 and BS 3892–2)

Fly ash/pulverized fuel ash is a fine powder extracted by electrostatic and mechanical means from the flue gases of furnaces burning pulverized bituminous, anthracite or other hard coal. It may conform to one or several of the following:

- BS EN 450, *Fly ash for concrete – Definitions, requirements and quality control*;
- BS 3892–1, *Pulverized-fuel ash - Part 1: Specification for pulverized-fuel ash for use with Portland cement*; or
- BS 3892–2, *Pulverized-fuel ash – Part 2: Specification for pulverized-fuel ash to be used as a Type 1 addition*.

The terms 'pulverized-fuel ash (pfa)' and 'fly ash' are used to refer to essentially the same material, depending on whether the ash conforms to a British (pfa) or to a European (fly ash) standard. Whilst other types of fly ash exist, e.g. incinerator ash, they are not covered by the European Standard BS EN 450 whose scope is limited to what is known in the UK as pfa.

BS EN 450 sets a relatively high maximum limit for 45 µm sieve residue, which permits a wide range of fineness for the fly ash. However, the fineness of any individual ash has to be within ±10% of the supplier's declared value. BS EN 450 is currently undergoing a review and conversion to a harmonised European standard. Proposed changes include the introduction of three categories for loss on ignition and an extension of the scope to include fly ashes produced by the co-combustion of coal with other materials.

Pfa conforming to BS 3892-1 conforms to more restrictive limits than BS EN 450, including a lower limit on the maximum fineness value and a requirement for the ash to have water-reducing properties. Pfa that conforms to BS 3892-1 will normally also be capable of conforming to BS EN 450.

BS 3892-2 is less restrictive on the permitted fineness than BS 3892-1 or BS EN 450. The title is: *Specification for pulverized-fuel ash to be used as a Type I addition* and consequently, for pfa conforming to BS 3892-2, BS 8500 acknowledges its suitability as a Type I addition only.

Ground granulated blastfurnace slag (BS 6699)

Ground granulated blastfurnace slag to BS 6699, *Specification for ground granulated blastfurnace slag for use with Portland cement* is a by-product of the manufacture of iron. Molten iron slag is quenched in water or steam to produce a glassy granular product, which is then dried and ground to a fine powder. It is a latent hydraulic material in its own right but is normally blended with Portland cement, which works as an activator.

Silica fume (prEN 13263: 1998)

BS EN 206-1 refers to a draft European Standard: prEN 13263: 1998, *Silica fume for concrete – Definitions, requirements and conformity control*. It is anticipated that

BS EN 13263 will be finalised and published during 2003. Silica fume is also known as condensed silica fume or microsilica. It is an ultra-fine powder (average particle size less than 10^{-6} m) consisting of mainly spherical particles of amorphous silicon dioxide. Silica fume is a by-product of the smelting process used to produce silicon metal and ferro-silicon alloys. For ease of handling it is normally supplied either densified (agglomerated), micro-pelletized or as a slurry.

Metakaolin

Metakaolin is a highly pozzolanic material produced by calcining china clay at temperatures of 700 – 900°C. There is no British Standard for metakaolin but its use is permitted by BS 8500 with an appropriate Agrément Certificate.

BORDERLINE TYPE OF ADDITION

Limestone fines (BS 7979)

Limestone fines to BS 7979, *Specification for limestone fines for use with Portland cement* is a fine powder obtained from the processing of limestone. There is uncertainty over whether limestone fines should be classified as a Type II or Type I addition. It is less reactive than the other Type II additions, but research shows that it can have slight reactivity as well as any physical effects conferred by virtue of its fine particle size. BS 8500 permits the use of limestone fines in a way that makes it unnecessary to resolve whether it is a Type I or II addition

TYPE I ADDITIONS

Filler aggregate

BS EN 12620, *Aggregates for concrete including those for use in roads and pavements* is currently in the course of preparation. This standard is expected to include 'filler aggregate', that is sufficiently fine for at least 75% to pass a 0.063 mm sieve.

Pigments (BS EN 12878)

A pigment to BS EN 12878, *Pigments for the colouration of building materials based on cement and lime – Specifications and methods of test* is a substance, generally in the form of fine particles, whose sole purpose is to colour cement- and lime-based building materials. It may be either organic or inorganic.

USE OF ADDITIONS IN CONCRETE

Table 1 summarizes the ways in which additions may be used according to BS EN 206–1 and BS 8500.

BS EN 206–1 places little restriction on the use of additions, simply stating that additions of Type I and Type II may be used in concrete in quantities as used in the ‘initial tests’. Initial tests are defined in BS EN 206–1 Annex A, as those required to demonstrate that all the specified requirements for the fresh and hardened concrete are satisfied. These initial tests may consist of laboratory work or long-term experience.

The situation becomes more complex when additions are to be taken into account as part of the cement content and for calculating the water/cement ratio. BS EN 206–1 contains specific ‘rules’ for fly ash to BS EN 450 and silica fume to prEN 13263: 1998, by which they can be taken into account in this respect. It also permits the use of other procedures, if their suitability is established. One way of establishing suitability is via a national standard valid in the place of use of the concrete. BS 8500 provides UK procedures for calculating cement content and water/cement ratio, which can be used in conjunction with EN 206–1, for concrete that is to be used in the UK. However the BS 8500 procedures may not necessarily extend to concrete to be used in other EU Member States.

k-value concept

BS EN 206–1, 5.2.5.2 sets out the ‘k-value’ concept for Type II additions. Note that the addition is not considered to be ‘cement’:

- The term water/cement ratio is replaced by water/(cement + (k x addition)) ratio.
- The addition may be taken into account towards the minimum cement content

Specific k-values are given for only two additions.

- Fly ash to BS EN 450 has a k-value of 0.2 or 0.4, depending on the strength class of the Portland cement with which it is used. The k-value does not vary with the quantity of ash being used (see BS EN 206–1, 5.2.5.2.2). Up to 0.33 ratio of fly ash/cement by mass (25% fly ash by total mass of cement + fly ash) is allowed to be counted as cementitious. Any additional fly ash within the concrete is regarded as a Type I addition, and is

assumed to act as an inert filler. Two further restrictions apply: the minimum cement content (MCC) may not be reduced by more than the amount given by the formula $k \times (MCC - 200) \text{ kg/m}^3$, and the amount of cement plus fly ash must equal or exceed the MCC value.

- Silica fume to prEN 13263:1998 has a k-value of 1.0 or 2.0 depending on the exposure class (see BS EN 206–1, 5.2.5.2.3). Because certain exposures that permit a k-value of 2.0 cannot exist without other exposure classes where the k-value is 1.0, there can be a conflict in the choice of the correct k-value to use. A maximum of 0.11 silica fume/cement (10% silica fume by total mass of cement + silica fume) can be regarded as a Type II addition. Any additional silica fume within the concrete is regarded as a Type I addition, and is assumed to act as an inert filler. The amount of (cement + k x silica fume) must equal or exceed the minimum cement content (MCC) value and the MCC must not be reduced by more than $30k \text{ g/m}^3$ when the MCC is $\leq 300 \text{ kg/m}^3$.

BS EN 206–1 permits the use of other values of ‘k’ or other k-value concepts provided their suitability is established.

Equivalent concrete performance concept

BS EN 206–1, 5.2.5.3 sets out an ‘Equivalent concrete performance concept’, which may be applied to a combination of any specified cement with any specified addition provided that the suitability has been established. Guidance on applying it is provided in BS EN 206–1, Annex E. Unfortunately the test methods needed for its implementation are not standardized and BS 8500–1, 4.4 requires that the equivalent performance concept shall only be used where the producer’s proposals for demonstrating equivalence and ensuring conformity have been approved by the specifier.

COMBINATIONS

BS 8500–1 defines a combination as follows:

“3.1.2 - combination

restricted range of Portland cements and additions which, having been combined in the concrete mixer, count fully towards the cement content and water/cement ratio in concrete”

The only combinations that are allowed to count fully towards the cement content and water/cement

ratio in concrete, are those comprising a BS EN 197-1, CEM I cement of standard strength class 42,5 or greater, together with one of the following additions:

- fly ash conforming to BS EN 450 with a loss-on-ignition not more than 7%;
- ggbs conforming to BS 6699;
- limestone fines conforming to BS 7979;
- pfa conforming to BS 3892–1.

The combination of CEM I cement and addition has to fulfil early age and 28 day strength requirements, which are set out in BS 8500–2 Annex A, and which take into account within-source variability. The Annex establishes the range of combination proportions that can fully count towards the cement content and w/c ratio.

WHEN TO SPECIFY OR USE ADDITIONS

Additions can influence many concrete properties, including:

- sulfate resistance;
- chloride resistance;
- protection against reinforcement corrosion;
- freeze/thaw resistance;
- chemical resistance;
- strength;
- permeability;
- abrasion resistance;
- heat generation;
- aesthetic properties such as colour.

In some circumstances, specific additions at specific proportions may be specified to enhance selected properties of the concrete. Additions may also be used for economic reasons. BS 8500 includes restrictions on the types and proportions of additions in its guidance for the use of designed, designated and standardized prescribed concretes.

Table 1: A summary of the ways specific additions may be used in concrete conforming to BS EN 206–1 and BS 8500

Addition	Standard for addition	Type	Use in concrete permitted by:	Route to count towards cement content and water/cement ratio ¹⁾
Fly ash/pulverized-fuel ash	BS EN 450	II	BS EN 206–1, 5.1.6	BS EN 206–1, 5.2.5.2.2 or BS 8500–2, 4.4.
	BS 3892–1	II	BS 8500–2, 4.4	BS 8500–2, 4.4.
	BS 3892–2	I	BS 8500–2, 4.4	No route
Ground granulated blastfurnace slag	BS 6699	II	BS 8500–2, 4.4	BS 8500–2, 4.4.
Silica fume	prEN 13263:1998	II	BS EN 206–1, 5.1.6	BS EN 206–1, 5.2.5.2.3
Metakaolin	Agrément Certificate	II	BS 8500–2, 4.4	No route
Limestone fines	BS 7979	1 or 11	BS 8500–2, 4.4	BS 8500–2, 4.4.
Filler aggregate	prEN 12620	I	BS EN 206–1, 5.1.6	No route
Pigments	BS EN 12878	I	BS EN 206–1, 5.1.6	No route

NOTE

1) The "equivalent concrete performance concept" in **5.2.5.3** of BS EN 206–1 provides an additional route for any Type II addition to effectively count fully towards the cement content and water/cement ratio (by permitting amendments to the recommended values). To take advantage of this route, the manufacturing source and characteristics of both the addition and the cement with which it is used have to be clearly defined and documented. BS 8500–1 clause 4.4 requires that the equivalent performance concept shall be used only where the producer's proposals for demonstrating equivalence and ensuring conformity have been approved by the specifier.

FURTHER READING

The other publications from this series will be helpful. Visit www.cementindustry.co.uk and click 'information'/'library'/'BCA publications' to check availability and for free download.

Standards for fresh concrete – a composite of BS EN 206-1 and BS 8500

Specifying concrete to BS EN 206-1/BS 8500:

Concrete for normal uses

Concrete resistant to chemical attack

Guide to the selection of concrete quality and cover for reinforcement for normal concrete structures

Examples of the specification of designated concrete

Examples of the specification of designed concrete

Guidance on additional requirements for designed concrete

Lightweight concrete

Visual concrete

Coloured concrete

Concrete for industrial floors

Specifying constituent materials for concrete to BS EN 206-1/BS 8500:

Cements

Additions

Admixtures

European replacements for British Standards:

Concrete and its constituent materials

Further information on additions can be found at: www.ukqaa.org.uk and www.ukcsma.co.uk

Specifying constituent materials for concrete to BS EN 206-1 /BS 8500: Additions

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British Cement Association
Riverside House, 4 The Meadows Business Park
Station Approach, Blackwater
Camberley, Surrey GU17 9AB
Telephone 01276 608700
Facsimile 01276 608701
www.cementindustry.co.uk

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