

Fly Ash to BS EN450:2005 as an addition in concrete specified to BS EN206 - Part 1



EN450 - 1 & 2:2005 - An overview

There have been major changes to the specification of PFA/fly ash for use in concrete due to the revision of EN450. This document reviews those changes for producers of fly ash/PFA¹ and specifiers of concrete. The preferred term for 'fly ash' is Pulverised Fuel Ash (PFA) within the UK. However, the terminology used in EN450-1:2005 will be used in this document when referring to requirements of the standard, i.e. fly ash.

In May 2005 BS EN450 Parts 1 and 2:2005 were published

- BS EN450-1:2005, "Fly ash for concrete - Part 1, Definitions, specifications and conformity criteria"
- BS EN450-2:2005, "Fly ash for concrete - Part 2, Conformity Evaluation"

These standards replace BS EN450:1994 and eventually, BS3892 Part 1:1997 "Specification for PFA for use with Portland Cement" will be withdrawn.

There are some significant changes from the previous standards as follows:

1. BS EN450-1:2005 is a European harmonised standard - this means that all conflicting standards, such as BS3892 Part 1, will HAVE to be withdrawn in January 2007.
2. BS3892 Part 1 PFA has been incorporated into the new standard.
3. This standard gives specific rules for co-combustion fly ashes. No such rules existed in any other standard for fly ash. There are requirements for additional testing for such ashes, which are more demanding to ensure the quality of resulting concrete is maintained.
4. BS EN450-1:2005 has a level of attestation of 1+, the same as cement. In EU standards 'Attestation' defines the level of control required to produce a product, with 1+ being the highest level and 4 being the lowest. This means production and supply of fly ash for use in concrete has to be fully accredited by a third party accreditation body such as BSI.
5. CE marking is permitted for fly ash for concrete with the adoption of the new standard.

The major differences for the supplier...

BS EN450:1994 is a very short document in comparison with EN450-1&2:2005. However, while BS EN450-1 is a more comprehensive document, there are few technical changes that apply to coal only fly ashes. Co-combustion ashes do require considerably more testing, as detailed in the separate section below. This is to ensure the concrete producer, specifier and client still receive a quality product. The main compliance criteria are as follows:

Clauses specific to all fly ashes

Loss on ignition: There are now 3 categories of fly ash permitted;

- Category A: LOI $\leq 5.0\%$,
- Category B: LOI ≥ 2.0 to $\leq 7.0\%$ and
- Category C: LOI ≥ 4.0 to $\leq 9.0\%$.

However - Category C ash is not permitted in UK concrete as BS8500^a has a limit of 7.0%.

Chloride: No change - $\leq 0.10\%$.

Sulfuric anhydride: No change - $\leq 3.0\%$.

Free Calcium Oxide: The wording is slightly different, but the requirement is effectively the same, if $\leq 1.0\%$ then no further testing needed, otherwise a maximum of $\leq 2.5\%$ is allowed and soundness testing must be carried out.

Reactive Calcium Oxide: This is a new requirement. However, if the total CaO value is less than 10% then the reactive CaO is deemed to be complied with - this should be the case with all UKQAA members' ashes.

Fineness: There are two categories of fineness for fly ash;

- Category N - $\leq 40\%$ retained on the 45 μm sieve and a limit of $\pm 10\%$ on suppliers declared mean value permitted.
- Category S - $\leq 12\%$ retained on the 45 μm sieve.

Water Requirement: This is applicable to Category S fly ash only in order to demonstrate water reducing properties. The test method is described in Annex B and is similar to the method required in BS3892 Part 1 excepting a different flow table is now required.

Category S material is effectively the same material as BS3892 Part 1 PFA, i.e. it is a reduced fineness PFA with guaranteed water reduction.

Activity Index: There are no changes to the requirements - 75% at 28 days and 85% at 90 days.

NB: The Strength Factor as used in BS3892 Part 1 is not in the new standard - both Category S & N ashes must comply with Activity Index.

Soundness: No changes - a maximum of 10mm expansion is permitted.

Particle Density: The density shall now not deviate more than $\pm 200\text{kg/m}^3$ from the declared value.

Co-combustion fly ashes - additional requirements

Co-combustion fly ashes are produced when materials other than coal are fired with the coal in the power station. There are restrictions as to the quantity of co-combustion material that may be used with a maximum of 10% by weight of the resulting ash and 20% by weight of fuel. These strict limits are designed to ensure the resulting fly ash will not have any significantly differing properties to coal only ashes.

The standard requires the supplier to demonstrate that co-combustion ash behaves similarly to coal only fly ash using the following additional test methods:

Reactive Silica: >25% reactive silica. This has to be tested 1/month for routine testing.

Total Oxides: SiO_2 , Al_2O_3 and Fe_2O_3 have to be tested regularly, again 1/month for routine testing. Must be >70% total oxides.

Alkali Content: Must be $\leq 5.0\%$ and again 1/month for routine testing.

Magnesium Oxide: Must be $\leq 4.0\%$ and again 1/month for routine testing.

Soluble Phosphate: Must be $\leq 100\text{mg/kg}$ and again 1/month for routine testing; see Annex C for details of test method.

Initial Setting Time: This has a requirement for a maximum increase in initial setting time of 120 minutes and again 1/month for routine testing.

Labelling

The fly ash shall be labelled with the CE mark, as required with all 'harmonised standards'. There are specific pieces of information required on the mark, as shown in the figure 1.

The supplier is also obliged to supply certain information on request. These are:

- Characteristics of the test cement.
- Whether the fly ash is obtained from co-combustion.
- A typical chemical oxide composition of the fly ash.
- The total alkali content.
- The declared fineness value (category N only).
- The declared value of particle density.
- The water content for standard consistence of a co-combustion fly ash/test cement paste.
- The water requirement for category S fly ash.



Figure 1 CE marked fly ash

EN450 - Part 2: Conformity Evaluation

Like all harmonised standards, this part of the standard covers Factory Production Control and the internal quality control system and auto control testing of the fly ash carried out by the producer. A Quality Manual that details the organisational structure of the production facility, the responsible staff and their powers, the inspection and testing regimes carried out, etc is required. A nominated Management Representative will have to ensure internal audits are carried out, the production control system is reviewed, personnel are trained, quality records are kept, etc.

Blending and processing plants: There are some additional provisions for blending and processing plants. The fly ash must be from a coal fired power station, co-combustion ashes must be kept in separate silos, fly ashes for blending can only be blended to improve LOI, fineness and variation of fineness - all other requirements of EN450 must be met by the incoming fly ash.

Accreditation: The accreditation body will assess suppliers' systems, the quality manual, etc and issue a certificate of accreditation. Thereafter the supplier can use the CE mark on the PFA sold. The systems will be assessed at least annually and the accreditation body will take at least 6 samples per annum for plants in continuous production for independent checking of ash fineness, activity index, LOI, etc.

Much of the above is already familiar to suppliers of cement and BS3892 Part 1 PFA as these materials have been accredited for some years.

What a supplier has to do to comply with BS EN450:2005

The following are the basic requirements for the supplier of fly ash for concrete complying with EN450:2005.

The need for a quality manual and quality control system: Suppliers are obliged to have a quality manual based on EN450:2005 and a quality control system. The assessment by the third party accreditation body is against both the standard and the quality manual. If deemed satisfactory a certificate permitting production and supply will be given.

In due course a guidance document for the third party accreditation bodies will be produced by Sector Group 2, which will be the guide for the accreditation body on interpreting the requirements of conformity.

The frequency of testing the various parameters, for both the initial period and the routine situation, are given in detail in the BS EN450-1. Suppliers of fly ash will need a UKAS laboratory or will have to send samples to an independent accredited laboratory on a routine basis for testing. There must be a quality control system to analyse the resulting data, especially for non-conformity. Systems to record actions in the event of non-conformity must be in place.





What a concrete specifier has to do to use BS EN450:2005

Due to the similarity of EN450-1:2005 Category S fly ash and BS3892 Part 1 PFA, there are few changes to the specification other than the names used.

BS8500-1 & 2 "Concrete - Complementary British Standard to BS EN206-1" is being revised to encompass the changes, e.g. all references to BS3892 Part 1 PFA are being changed to BS EN450-1:2005 Category S fly ash. All references to EN450:1994 are to be changed to BS EN450-1:2005 Category N fly ash. Loss on ignition within the revised version will remain restricted to Category A and B fly ashes, i.e. a maximum of 7.0% as per UK practice.

However, for most of the specification clauses within BS8500, there are no differences between Category S and N fly ashes. Such clauses will simply state to use fly ash complying with BS EN450-1 and they will not specify a fineness category. The decision to use Category S or Category N fly ash will normally be one of the producers and based on availability, quality, consistency, suitability, commercial considerations, etc of a particular category of ash rather than being specified by the concrete standard.

Specification of concrete containing fly ash to BS EN206-1 and BS8500 1&2

The standard for specifying concrete, BS EN206-1^b, permits the use of additions, which are defined as:

A finely divided inorganic material used in concrete in order to improve certain properties or to achieve special properties. The standard deals with two types of additions:

- **Type I** These are classed as being nearly inert additions, e.g. some materials complying with BS EN12620^c.
- **Type II** These are pozzolanic or latent hydraulic additions, e.g. materials like BS EN450-1^d Fly Ash.

Properties of additions

BS EN450-1 Category S Fly Ash is effectively an equivalent material to BS3892 Part 1:1994 PFA, which is normally classified. Classification removes the coarser fractions of the PFA, as shown in figure 2 producing a very consistent product. BS3892 Part 1 will be withdrawn from February 2006 and thereafter the material under this name will then cease to be available. However it will still be available as BS EN450-1 Category S fly ash.

BS EN450-1 Category N fly ash is also eminently suitable for use in concrete. This form of PFA is particularly suited for applications where a water reduction is less critical, but the technical benefits of a pozzolanic material are needed. Such applications may be lean concretes, precast concrete, mass concrete, etc.



Most PFA is added to concrete as a Type II addition, that is it counts towards the cement content. However, it is also possible to include PFA in your concrete as a Type I addition complying with BS EN12620 as filler aggregate or BS EN13055-1^e as lightweight filler aggregate.

Use in Concrete

BS EN206-1 places little restriction on the use of additions simply stating that additions of Type I and Type II may be used in concrete in the quantities as used in the 'initial tests'. These initial tests may be in the form of laboratory work or from long term experience (BS EN206-1: Annex A). BS EN206-1 also contains an 'Equivalent concrete performance concept' [clause 5.2.5.3] which may be applied to a combination of any specified cement with any specified addition provided that the suitability has been established. Annex E (Informative) of BS EN206-1 outlines one approach to the concept.

BS EN206 is complemented in the UK by BS8500, which covers certain aspects such as durability of the concrete. BS8500 contains rules that permit additions to count fully towards the cement content. These rules are specific to EN450 Fly Ash for both category S and N, as well as GGBS and limestone filler. The procedure is based on the testing of the combination of the addition and the cement that are from specified sources. It is detailed in an Annex in BS 8500 and determines permitted proportions of PFA for a combination that can count fully towards cement content and water cement ratio. An example of a suitable procedure is given in an informative Annex in BS 8500. Further restrictions on allowable proportions are found in the various durability tables within BS 8500.





Source Dependency

As Category S fly ash is normally classified, the differences between sources can be, in the main, removed. The UK suppliers adjust the classification process deliberately to produce a demonstratively similar material from a number of sources. In fact, the Quality Scheme for Ready Mixed Concrete and the British Standards Institute third party quality assurance schemes for ready mixed concrete both accept that EN450-1 Category S fly ash from multiple sources can be shown to be demonstratively similar.

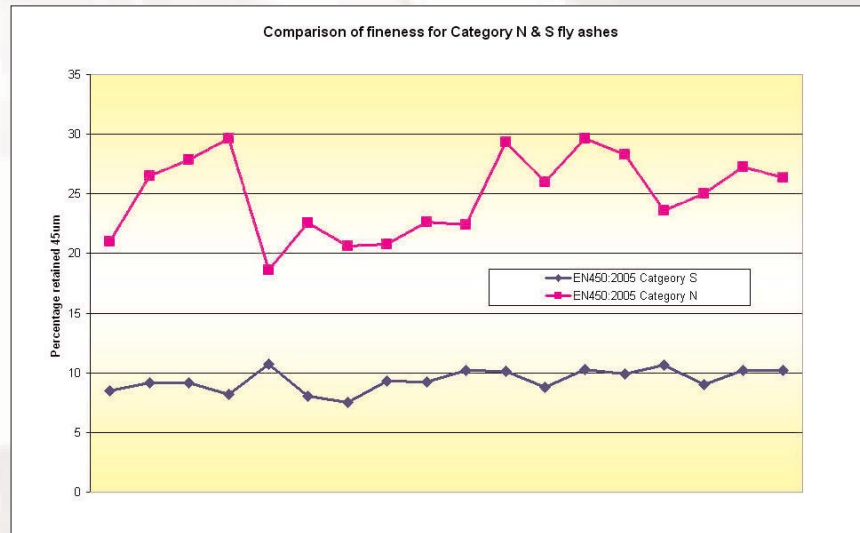


Figure 2 - BS EN450:2005 Category N Fly ash may be coarser than Category S

When to specify

Additions may be used within concrete for many reasons, e.g. to enhance the concrete's physical or chemical properties, for economical purposes, for aesthetic reasons, etc. Combinations of additions may also be used. This may make the specifying of additions somewhat complex.

PFA and Fly Ash may be specified to enhance durability. BS 8500 provides lists of exposure classes for both designed standard and designated mixes and limits on the types and quantities of additions that may be used. For example, PFA and Fly Ash will:

- **Improve sulfate resistance**
- **Improve chloride resistance**
- **Improve long term strengths**
- **Improve chemical resistance**
- **Improve protection of reinforcing from corrosion**
- **Improve concrete finish**
- **Improve abrasion resistance**
- **Reduce temperature effects**
- **Reduce environmental impact**
- **Reduce concrete permeability**

General

There are many additions available in the UK that can be used for a wide range of applications. Detailed advice is available from the many manufacturers and trade associations on how to use these additions most effectively and their suitability for particular purposes. The UKQAA publish a number of Technical Datasheets on PFA / fly ash in concrete, available on the website; see www.ukqaa.org.uk

^a BS 8500-1 & 2, "Concrete - Complementary British Standard to BS EN206-1", BSI, Chiswick, London

^b BS EN206-1:2000, "Concrete - Part 1: Specification, performance, production and conformity", BSI, Chiswick, London

^c BS EN12620, 2002, "Aggregates for concrete", BSI, Chiswick, London

^d BS EN450-1:2005, "Fly ash for concrete - Part 1, Definitions, specifications and conformity criteria", BSI, Chiswick, London

^e BS EN450-2:2005, "Fly ash for concrete - Part 2, Conformity Evaluation", BSI, Chiswick, London

^f BS EN 13055-1, 2002, "Lightweight aggregates Part 1 - Lightweight aggregates for concrete, mortar and grout", BSI, Chiswick, London

¹ 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 may 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.