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Fly ash for concrete - Part 1: Definition, specifications and conformity criteria

Flugasche für Beton - Teil 1: Definition, Anforderungen und Konformitätskriterien

Cendres volantes pour béton - Partie 1: Définition, spécification et critères de conformité

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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 450-1

August 2012

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English Version

Fly ash for concrete - Part 1: Definition, specifications and conformity criteria

Cendres volantes pour béton - Partie 1: Définition, spécifications et critères de conformité

Flugasche für Beton - Teil 1: Definition, Anforderungen und Konformitätskriterien

This European Standard was approved by CEN on 6 July 2012.

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Contents

	Page
Foreword.....	3
Introduction	4
1 Scope	5
2 Normative references	5
3 Terms and definitions	6
4 Specific provisions for fly ash from co-combustion.....	7
4.1 Co-combustion materials.....	7
4.2 Establishment of suitability of fly ash from co-combustion	8
5 Specifications.....	8
5.1 General.....	8
5.2 Chemical requirements	8
5.3 Physical requirements	10
5.4 Other requirements.....	11
5.5 Information to be supplied upon request.....	12
6 Packaging and labelling.....	12
7 Sampling.....	12
8 Conformity criteria.....	12
8.1 General requirements.....	12
8.2 Statistical conformity criteria.....	14
8.3 Single result conformity criteria.....	17
Annex A (normative) Release of dangerous substances and emission of radioactivity.....	18
Annex B (normative) Determination of the water requirement for Category S fly ash	19
Annex C (normative) Determination method on the content of soluble phosphate (expressed as P ₂ O ₅).....	21
Annex ZA (informative) Clauses of this European Standard addressing the provisions of the EU Construction Product Directive.....	23
Bibliography	30

Foreword

This document (EN 450-1:2012) has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2013, and conflicting national standards shall be withdrawn at the latest by February 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 450-1:2005+A1:2007.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 89/106/EEC.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This document is supported by standards of the series EN 451 for test methods for the determination of free calcium oxide content and of the fineness by sieving.

The main changes with respect to the previous edition are listed below:

- extension of the permissible content of solid co-combustion materials;
- extension of the permissible content of liquid and gaseous co-combustion materials;
- fixed limits for loss on ignition;
- incorporation of the specifications from EN 450-1+A1:2007;
- general editorial revision.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

EN 450-1:2012 (E)**Introduction**

The use of coal for electricity production results in the generation of large quantities of fly ash.

Different types of coal and the type of boiler used in this process produce different fly ashes, such as siliceous, silico-calcareous, or calcareous fly ashes with pozzolanic and/or latent hydraulic properties. All these types of fly ash are used in concrete production in some European countries, based on national experience and tradition.

Before use, fly ash may be subject to processing, for example by classification, selection, sieving, drying, blending, grinding or carbon reduction, to optimize its fineness, reduce its water demand or to improve other properties. Such processed fly ashes may conform to this document to which reference is made in such case. If they are out of the scope of this document, their suitability for use as Type II additions in concrete according to EN 206-1 may also be established from national standards or provisions or European Technical Approvals valid in the place of use of the concrete and which refer specifically to the use of the addition in concrete conforming to EN 206-1.

When using fly ashes conforming to this document, it should be noted that, apart from the effect from the pozzolanicity of the fly ash, certain properties of fresh and hardened concrete may be affected. Where relevant, such effects need to be considered in concrete mix design (see EN 206-1).

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1 Scope

This European Standard specifies requirements for the chemical and physical properties as well as quality control procedures for siliceous fly ash, as defined in 3.2, for use as a type II addition for production of concrete conforming to EN 206-1. Fly ash according to this document may also be used in mortars and grouts.

Fly ash produced with other types or higher percentages of co-combustion materials than those provided for in Clause 4 is outside the scope of this European Standard.

It is beyond the scope of this European Standard to specify provisions governing the practical application of fly ash in the production of concrete, i.e. requirements concerning composition, mixing, placing, curing etc. of concrete containing fly ash. Regarding such provisions, reference should be made to other European or national standards for concrete, such as EN 206-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 196-1:2005, *Methods of testing cement — Part 1: Determination of strength*

EN 196-2:2005 *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 196-3, *Methods of testing cement — Part 3: Determination of setting times and soundness*

EN 196-7, *Methods of testing cement — Part 7: Methods of taking and preparing samples of cement*

EN 197-1:2011, *Cement — Part 1: Composition, specification and conformity criteria for common cements*
<https://standards.iteh.ai/catalog/standards/sist/1cc224b8-35b6-4443-a161-12482b78c1e1/en-197-1-2011>

EN 206-1, *Concrete — Part 1: Specification, performance, production and conformity*

EN 450-2:2005, *Fly ash for concrete — Part 2: Conformity evaluation*

EN 451-1, *Method of testing fly ash — Part 1: Determination of free calcium oxide content*

EN 451-2, *Method of testing fly ash — Part 2: Determination of fineness by wet sieving*

EN 933-10, *Tests for geometrical properties of aggregates — Part 10: Assessment of fines — Grading of filler aggregates (air jet sieving)*

EN 1015-3:1999, *Methods of test for mortar for masonry — Part 3: Determination of consistence of fresh mortar (by flow table)*

EN 1097-7, *Tests for mechanical and physical properties of aggregates — Part 7: Determination of the particle density of filler — Pycnometer method*

EN ISO 11885, *Water quality — Determination of selected elements by inductively coupled plasma optical emission spectrometry (ICPOES) (ISO 11885)*

EN 14588:2010, *Solid biofuels — Terminology, definitions and descriptions*

ISO 10694, *Soil quality — Determination of organic and total carbon after dry combustion (elementary analysis)*

ISO 29581-2, *Cement — Test methods — Part 2: Chemical analysis by X-ray fluorescence*

EN 450-1:2012 (E)**3 Terms and definitions**

For the purpose of this document, the following terms and definitions apply.

3.1**type II addition**

finely divided inorganic, pozzolanic or latent hydraulic material that may be added to concrete in order to improve certain properties or to achieve special properties

Note 1 to entry: See EN 206-1.

3.2**fly ash**

fine powder of mainly spherical, glassy particles, derived from burning of pulverised coal, with or without co-combustion materials, which has pozzolanic properties and consists essentially of SiO_2 and Al_2O_3 and which:

- is obtained by electrostatic or mechanical precipitation of dust-like particles from the flue gases of the power stations; and
- may be processed, for example by classification, selection, sieving, drying, blending, grinding or carbon reduction, or by combination of these processes, in adequate production plants, in which case it may consist of fly ashes from different sources, each conforming to the definition given in this clause

Note 1 to entry: Municipal and industrial waste incineration ashes do not conform to the definition given in this clause.

3.3**test cement**

selected brand of Portland cement of type CEM I, strength class 42,5 or higher, conforming to EN 197-1 to be used for carrying out the tests needed to evaluate conformity to the requirements of 5.3.2, 5.3.3, 5.3.5 and 5.3.6

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3.4**particle density**

average density of fly ash particles, including voids inside the particles

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3.5**activity index**

ratio (in percent) of the compressive strength of standard mortar bars, prepared with 75 % test cement plus 25 % fly ash by mass, to the compressive strength of standard mortar bars prepared with 100 % test cement, when tested at the same age

3.6**autocontrol**

continuous statistical quality control of the fly ash based on the testing of samples taken by the producer or their agent at point(s) of release from the fly ash producing facility

3.7**control period**

period of production and/or dispatch identified for the evaluation of the autocontrol test results

3.8**characteristic value**

value of the required property outside of which lies a specified percentage, the percentile P_k , of all the values of the population

3.9**single result limit value**

value of a chemical or physical property which – for any single test result – in the case of an upper limit is not to be exceeded or in the case of a lower limit is, as a minimum, to be reached

3.10**allowable probability of acceptance CR**

for a given sampling plan, the allowed probability of acceptance of fly ash with a characteristic value outside the specified minimum or maximum values

3.11**sampling plan**

specific plan which states the (statistical) sample size(s) to be used, the percentile P_k , and the allowable probability of acceptance CR

3.12**spot sample**

sample taken at the same time and from one and the same place, relating to the intended tests which can be obtained by combining one or more immediately consecutive increments

Note 1 to entry: See EN 196-7.

3.13**green wood**

wood originating from trees, bushes and shrubs that is created when processing wood as cross-cut ends, planings, saw dust and shavings used in the form of dust, chips and pellets

4 Specific provisions for fly ash from co-combustion**4.1 Co-combustion materials**

Fly ash from co-combustion as defined in 3.2 is obtained from pulverised coal fired simultaneously with at least one co-combustion material as listed in Table 1. The minimum percentage, by dry mass, of coal (K_c) shall be not less than 60 %, or 50 % if the co-combustion material is only from green wood (see 3.13). The maximum proportion of ash derived from co-combustion materials (M) shall not be greater than 30 % by dry mass when calculated from Formula (1).

The proportion of ash derived from co-combustion shall be calculated with Formula (1):

$$M = 100 (K_1 \times A_1 + K_2 \times A_2 \dots K_n \times A_n) / (K_c \times A_c + (K_1 \times A_1 + K_2 \times A_2 \dots K_n \times A_n)) \quad (1)$$

where

M is the proportion of co-combustion ash in total fly ash, in % by mass;

A_i is the ash content of co-combustion material no. i , in % by mass;

n is the number of co-combustion materials being used;

A_c is the ash content of coal, in % by mass;

K_i and K_c are respectively the proportions of co-combustion material(s) and coal being fired;

and where

$(K_c + K_1 + K_2 + \dots K_n) = 1$ and $K_c \geq 0,60$, or $0,50$ if the co-combustion material consists of green wood only.

In addition, if virtually ash free liquid and gaseous fuels are used as co-combustion materials, their percentage by net calorific value shall be determined and shall not exceed 40 % of the total net calorific value.

Higher percentages of virtually ash free liquid and gaseous fuel may be used during the start-up process of a power plant.

Table 1 — Types of co-combustion materials

1	Solid Bio Fuels conforming to EN14588:2010 including animal husbandry residues as defined in 4.5 and excluding waste wood as defined in 4.52, 4.132 and 4.174.
2	Animal meal (meat and bone meal)
3	Municipal sewage sludge
4	Paper sludge
5	Petroleum coke
6	Virtually ash free liquid and gaseous fuels

NOTE Other types of co-combustion materials not included in Table 1 might be subject to an ETA.

4.2 Establishment of suitability of fly ash from co-combustion

The suitability of fly ash obtained from combustion of coal with co-combustion materials given in Table 1 shall be established and documented by the producer. An initial co-combustion in the furnace using the highest intended amount of co-combustion material shall be performed. A representative sample of fly ash taken from this co-combustion (see Clause 7) shall be used to establish the suitability.

The suitability of fly ash obtained from co-combustion with one of the co-combustion materials specified in Table 1 is established if conformity to the requirements in 5.2, 5.3 and 5.4 has been proven.

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5 Specifications

5.1 General

SIST EN 450-1:2013

The chemical and physical requirements in 5.2 and 5.3 are specified as characteristic values. Conformity to a characteristic value is assessed by means of a statistical quality control procedure as described in Clause 8.

The test methods prescribed in this document are reference methods. Other test methods may be used provided they give results equivalent to those obtained with the reference method. In case of a dispute, only the reference method shall be used.

5.2 Chemical requirements

5.2.1 General

The chemical composition shall be expressed as proportions by mass of dry fly ash (see Clause 7 for a method of obtaining a sample of dry fly ash).

In performing the test methods for major elements described in EN 196-2:2005, Clause 13, the following modifications shall be observed:

- a) When heating the sample-peroxide mixture (EN 196-2:2005, 13.2) a furnace temperature of 550 °C shall be used and maintained for 60 min. Timing to start is when the temperature has recovered to 540 °C;
- b) When dispersing the sintered mass from the furnace (EN 196-2:2005, 13.2), proceed with the test even though the melting may not be clear;
- c) To decompose the evaporation residue (EN 196-2:2005, 13.7), add 2,0 g potassium bisulphate instead of the sodium carbonate/sodium chloride mixture.

5.2.2 Loss on ignition

The loss on ignition shall be determined in accordance with the principles of the method described in EN 196-2 but using an ignition time of 1 h, and shall fall within the limits of the categories specified below:

- Category A: not greater than 5,0 % by mass;
- Category B: not greater than 7,0 % by mass;
- Category C: not greater than 9,0 % by mass.

The purpose of this requirement is to limit the residue of unburnt carbon in the fly ash. It is sufficient, therefore, to show, through direct measurement of unburnt carbon residue, that the content of unburnt carbon falls within the limits of the categories specified above. The content of unburnt carbon shall be determined in accordance with ISO 10694.

NOTE As the magnitude of the loss on ignition may have an influence on the effect of air-entraining admixtures used for the manufacture of concrete resistant to freezing and thawing, the three loss on ignition categories defined in this document allow the user to take this into account by choosing the appropriate category for each particular application and exposure class, thus following the standards and/or regulations for concrete valid in the place of use.

5.2.3 Chloride

The content of chloride, expressed as Cl^- , shall be determined in accordance with EN 196-2 and shall not be greater than 0,10 % by mass.

5.2.4 Sulphate (SO_3) content

The sulphate (SO_3) content, shall be determined in accordance with EN 196-2 and shall not be greater than 3,0 % by mass.

5.2.5 Free calcium oxide

The content of free calcium oxide shall be determined by the method described in EN 451-1. If the content of free calcium oxide is greater than 1,5 % by mass, the fly ash shall be tested for conformity to the requirements for soundness in 5.3.3.

5.2.6 Reactive calcium oxide

The content of reactive calcium oxide shall be calculated as stipulated in EN 197-1:2011, 3.1 and shall not exceed 10,0 % by mass.

If the total content of calcium oxide determined in accordance with 5.2.1 does not exceed 10,0 % by mass, the requirement for reactive calcium oxide shall be deemed to be satisfied.

5.2.7 Reactive silicon dioxide

In the initial type test for fly ash from co-combustion (4.2) the amount of reactive silicon shall be analysed in accordance with EN 197-1 and shall not be less than 25 % by mass. Fly ash obtained from combustion of pulverised coal only shall be deemed to satisfy this requirement.

5.2.8 Silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3)

The sum of the contents of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) shall be determined in accordance with EN 196-2, modified as indicated in 5.2.1, and shall not be less than 70 % by mass. Fly ash obtained from combustion of pulverised coal only shall be deemed to satisfy this requirement.

EN 450-1:2012 (E)**5.2.9 Total content of alkalis**

The total content of alkalis shall be determined in accordance with EN 196-2 and calculated as $\text{Na}_2\text{O}_{\text{eq}}$ and shall not exceed 5,0 % by mass. Fly ash obtained from combustion of pulverised coal only shall be deemed to satisfy this requirement.

5.2.10 Magnesium oxide

In the initial type test for fly ash from co-combustion (4.2), the content of magnesium oxide (MgO) shall be determined in accordance with EN 196-2 and shall not be greater than 4,0 % by mass. Fly ash obtained from combustion of pulverised coal only shall be deemed to satisfy this requirement.

5.2.11 Phosphate

The content of total phosphate (P_2O_5) shall be determined in accordance with ISO 29581-2 and shall not be greater than 5,0 % by mass. Fly ash obtained from combustion of pulverised coal only shall be deemed to satisfy this requirement.

In the initial type test for fly ash from co-combustion (4.2), the content of soluble phosphate (P_2O_5) shall be determined in accordance with the method described in Annex C and shall not be greater than 100 mg/kg.

5.3 Physical requirements**5.3.1 Fineness**

The fineness of fly ash shall be expressed as the mass proportion in percent of the ash retained when sieved on a 0,045 mm mesh sieve. The fineness may be determined by wet sieving in accordance with EN 451-2 or by air jet sieving in accordance with EN 933-10 and shall fall within the limits of the categories specified below:

Category N: the fineness shall not exceed 40 % by mass, and it shall not vary by more than ± 10 percentage points from the declared value.

Category S: the fineness shall not exceed 12 % by mass. The ± 10 percentage points fineness variation limits are not applicable.

In case of dispute, the wet sieving method according to EN 451-2 shall be used as the reference method.

5.3.2 Activity index

Preparation of standard mortar bars and determination of the compressive strength shall be carried out in accordance with EN 196-1.

The activity index at 28 days and at 90 days shall not be less than 75 % and 85 %, respectively.

The test cement used, as defined in 3.3, is selected by the fly ash producer and is further characterised by its fineness and contents of tricalcium aluminate and alkalis as follows:

- Fineness (Blaine): at least 300 m^2/kg ;
- Tricalcium aluminate: 6 % by mass to 12 % by mass;
- Alkalis ($\text{Na}_2\text{O}_{\text{eq}}$): 0,5 % by mass to 1,2 % by mass.

NOTE The result of the activity index tests gives no direct information on the strength contribution of fly ash in concrete, nor is the use of the fly ash limited to the mixing ratio used in these tests.