British Standard

BRITISH STANDARD

BS 3892 :
Part 1 : 1997

Pulverized-fuel ash

Part 1. Specification for pulverized-fuel ash for use with Portland cement

ICS 91.100

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/516, Cement and lime, to Subcommittee B/516/101, Pozzolanas, upon which the following bodies were represented:

British Aggregate Construction Materials Industries
British Cement Association
British Precast Concrete Federation
British Ready Mixed Concrete Association
Cementitious Slag Makers' Association
Department of the Environment (Building Research Establishment)
Department of the Environment (Property Services Agency)
Department of Transport
Electricity Association
Federation of Civil Engineering Contractors
Quality Ash Association

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Contents

Foreword

This British Standard has been prepared by Subcommittee B/516/101. It supersedes BS 3892 : Part 1 : 1993 which is withdrawn. This standard takes account of the Draft for Development DD ENV 197-1 even though pulverized-fuel ash (pfa) is not included as a separate material in that standard. DD ENV 197-1 introduces the principle of conformity criteria by continuous inspection during manufacture for cements and this principle has been included in this new edition in order that users may be provided with a similar system for the purpose of demonstrating compliance. Whenever possible in this new edition, test methods from BS EN 196 have been adopted.

Pulverized-fuel ash is extracted from the flue gases of furnaces fired by pulverized bituminous or other hard coal. It is a fine material, predominantly of spherical glassy particles, the bulk of which passes a 45 µm mesh sieve. To utilize its water reducing and pozzolanic properties, the finer fraction has been developed for specific use as a cementitious component of concrete with requirements additional to those of BS EN 450. Processing to obtain this finer fraction is referred to in BS EN 450. General guidance on the use of pfa is given in annex A.

Pulverized-fuel ash has been used in composite cements conforming to BS 6588 and BS 6610 and as a cementitious component of concrete for many years. Guidance on its direct use in concrete can be found in BS 5328 : Part 1, BS 6543 and BS 8110 : Part 1. Guidance on its use in mortar can be found in BRE Digest 362[1].

Information from the producer to aid the control of such uses is given in annex B of this standard.

The principal changes from the 1993 edition are as follows.

a) The requirements are specified as characteristic values, except for strength factor and loss on ignition, and conformity is assessed by means of a statistical procedure for continuous inspection operated by the pfa producer (autocontrol) (see annex G). This includes the concept of major defects which are likely to reduce materially the usability of the pfa for its intended purpose. In addition, limits are given for acceptance inspection testing, to provide a means of assessing conformity at delivery.

b) The requirements for production in clause **4** allow any form of processing the run-of-station pfa that yields a material conforming to the standard.

c) The hard coal from which the pfa is obtained may be a blend of coals of specified gross calorific value.

BS 3892 : Part 2 specifies a grade of pfa of higher sieve residue and loss on ignition to be used as a type 1 (nearly inert) addition in concrete.

BS 3892 : Part 3 specifies a grade of pfa for use in cementitious grouts.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iii, pages 1 to 19, an inside back cover and a back cover.

Specification

1 Scope

This Part of BS 3892 specifies requirements for the composition, production and chemical and physical properties of processed pulverized-fuel ash (pfa) for use as a cementitious component in combination with Portland cement.

NOTE. Requirements are specified as characteristic values except for strength factor and loss on ignition for which an absolute upper limit is given.

2 References

2.1 Normative references

This Part of BS 3892 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate points in the text and the cited publications are listed on page 16. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 3892 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 3892 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 3892, the definitions given in BS 6100 : Section 6.1 apply, together with the following.

3.1 characteristic value

That value of a property corresponding to an acceptable percentage of defects, generally 10 %.

3.2 lot

Quantity of pfa produced under conditions presumed uniform. After specified tests, this quantity is regarded as a whole, conforming or not conforming to the requirements.

3.3 spot sample

Sample taken at the same time and from one and the same place relating to the intended tests. It can be obtained by combining one or more immediately consecutive increments.

3.4 hard coal

Coal blend giving a gross calorific value of not less than 24 MJ/kg on a dry ash-free basis when tested in accordance with BS 1016 : Part 105.

4 Composition, production and processing

Pfa is a fine powder of mainly spherical glass particles having pozzolanic properties which shall consist essentially of reactive silicon dioxide (SiO_2) and aluminium oxide (Al_2O_3), the remainder being iron (III) oxide (Fe_2O_3) and other oxides.

Pfa shall be obtained by electrostatic or mechanical precipitation of dust-like particles from the flue gases of power station furnaces fired with pulverized bituminous or other hard coal. Ash from other coals or obtained by other means is not considered in this standard.

Pfa conforming to this specification shall be produced by processing the run-of-station pfa in such a way that it meets the requirements specified in clauses **5** to **12** and does not contribute materials that have a deleterious effect on the properties of fresh or hardened concrete or give rise to a health or safety risk.

5 Moisture content

The moisture content of the pfa shall be not more than 0.5 % when determined in accordance with the method described in annex C.

6 Fineness

The fineness of the pfa expressed as the proportion by mass retained on a 45 μm test sieve shall be not more than 12.0 % when determined in accordance with the method described in annex D.

7 Particle density

The particle density of the pfa shall be not less than 2000 kg/m^3 when determined in accordance with **4.5.3** of BS EN 196-6 : 1992.

8 Water requirement

The water requirement of a combination by mass of 30 % pfa and 70 % Portland cement, conforming to BS 12 : 1996 standard strength class 42.5, intimately mixed together shall be not greater than 95 % of that for the Portland cement alone when determined in accordance with the method described in annex E.

The alkali content of the Portland cement shall be not less than 0.5 % and not more than 0.9 % when determined in accordance with clause **7** of BS EN 196-21 : 1992.

9 Strength factor

The strength factor of the combination of pfa and Portland cement given in clause **8** shall have a minimum limit value of 0.80 when determined in accordance with the method described in annex F.

10 Initial setting time

The initial setting time, when determined in accordance with BS EN 196-3, of a paste of standard consistence made from the combination of pfa and Portland cement given in clause **8** shall be not less than the initial setting time of the Portland cement when tested alone.

11 Soundness

The soundness of a paste made from the combination of pfa and Portland cement given in clause **8** shall have an expansion of not more than 10 mm when determined in accordance with BS EN 196-3.

12 Chemical composition

12.1 Sulfuric anhydride

The content of sulfuric anhydride, SO_3, shall be not more than 2.0 % (*m*/*m*) when determined in accordance with clause **8** of BS EN 196-2 : 1995.

12.2 Loss on ignition

The loss on ignition shall have a maximum limit value of 7 % (*m*/*m*) when determined in accordance with clause **7** of BS EN 196-2 : 1995 but using an ignition time of 1 h.

12.3 Chloride

The chloride ion content shall be not more than 0.10 % (*m*/*m*) when determined in accordance with clause **4** of BS EN 196-21 : 1992.

12.4 Calcium oxide

The calcium oxide content shall be not more than 10.0 % (*m*/*m*) when determined in accordance with clause **13** of BS EN 196-2 : 1995.

13 Marking

Pulverized-fuel ash shall be marked on the bag or the delivery note and on any certificate with the following particulars:

a) the name, trademark or other means of identification of the producer and the works at which the pfa was produced;

b) the name of the material, i.e. pulverized-fuel ash;

c) the number and date of this British Standard, i.e. BS 3892 : Part 1 : 1997[1].

14 Information to be provided

14.1 Test certificate

If a test certificate is requested, it shall include results of the following tests on samples of the pfa relating to the material delivered:

a) moisture content;

b) fineness (45 μm sieve residue);

c) particle density;

d) water requirement;

e) strength factor;

f) initial setting time;

g) soundness;

h) the source of the Portland cement used in the tests d) to g) and its initial setting time and soundness when determined in accordance with BS EN 196-3 and compressive strength at 28 days when determined in accordance with BS EN 196-1 in the laboratory which is testing the pfa;

i) sulfuric anhydride content;

j) loss on ignition;

k) chloride content;

l) calcium oxide content.

NOTE. The certificate should be available from the producer.

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[1] Marking BS 3892 : Part 1 : 1997 on or in relation to a product represents a producer's declaration of conformity, i.e. a claim by or on behalf of the producer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

14.2 Additional information

The following information shall also be made available, if requested at the time of ordering, relating to the pfa delivered:

a) an indication of the variability of the chloride content when its mean level exceeds 0.05 % by mass;

b) total acid soluble alkali content determined in accordance with **7.5.2** of BS EN 196-21 : 1992 or by an X-ray fluorescence technique calibrated against the method described in **NA.5.2** of BS EN 196-21 : 1992.

c) water soluble alkali content;

d) an indication of the variability of the alkali content.

15 Sampling and testing for acceptance inspection at delivery

15.1 When required by the purchaser for assessing conformity at delivery, a spot sample of the pfa shall be taken in accordance with **3.6** and **6.2**, **6.3**, **6.4** or **6.5** of BS EN 196-7 : 1992 either before, or at the time of delivery. A laboratory sample shall be prepared and packed in accordance with clauses **8** and **9** of BS EN 196-7 : 1992. A sampling report shall be completed at the time of sampling and shall be attached to the laboratory sample in accordance with clause **10** of BS EN 196-7 : 1992.

NOTE. Testing may be delayed for up to 5 weeks from the time of sampling, provided there is confirmation that the sample has been stored continuously as described in **9.2** of BS EN 196-7 : 1992.

15.2 When the pfa is tested for water requirement, strength factor, initial setting time and soundness, the source of the Portland cement and, where appropriate, of the CEN Standard sand, EN 196-1 and the compaction procedure used shall be those in use by the producer at the time when the combination was originally tested. Alternatively, they may be agreed between the purchaser and the producer.

15.3 When the pfa is tested for chemical composition (see clause **12**), the sample shall be prepared by the method described in clause **6** of BS EN 196-2 : 1995 except that it is not required to pass a magnet over the pfa to remove metallic iron, and that the pfa to be tested shall be dried in accordance with annex C.

15.4 The limiting values applicable to acceptance inspection shall be the same as the major defect levels, as defined in table G.3.

Annexes

Annex A (informative)

Product guidance

A.1 Safety warning

Dry pfa or cement in normal use has no harmful effect on dry skin. Precautions should however be taken to avoid such materials entering the eyes, mouth and nose and to prevent skin contact with wet pfa or cement.

Repeated skin contact with wet cement over a period may cause irritant contact dermatitis. Although no connection has been established between pfa and dermatitis, this possibility cannot be ruled out. The abrasiveness of the particles of cement, pfa and aggregate in mortar or concrete can contribute to this effect. Continued contact during a working day can lead to alkali burns with ulceration, but this is not common.

When working in places where dry pfa becomes airborne, protection for the eyes, mouth and nose should be worn.

When working with wet mortar or concrete, waterproof or other suitable protective clothing should be worn such as long-sleeved shirts, full length trousers, waterproof gloves and wellington boots. Clothing contaminated with wet pfa, cement, mortar or concrete should be removed as soon as possible and washed before further use.

If pfa enters the eye it should immediately be washed out thoroughly with clean water and medical treatment should be sought without delay. Wet mortar or concrete on the skin should be washed off immediately.

A.2 Storage

To protect the pfa after delivery, bulk silos should be waterproof and internal condensation minimized.

Pfa conforming to this standard supplied in paper bags should be stored clear of the ground and interlocked for stability, not more than eight high and protected by a waterproof structure. Deliveries should be controlled and used as soon as possible in order of receipt.

A.3 Heat generation

The cement hydration process generates heat, particularly in the first few days. Cements with higher early strength usually have a higher initial rate of heat generation than those with lower early strength. A higher initial rate of heat generation may be an advantage for thinner concrete sections in cold weather because it reduces the need for extended striking times and the tendency for early-age frost damage. Conversely, it may be a disadvantage for larger concrete sections in either hot or cold weather, on account of the temperature gradients which are set up.

The pozzolanic reaction generates heat at a slower rate than the hydration of Portland cement. Consequently, an increase in the proportion of pfa to Portland cement can be beneficial in limiting both the rate of heat generation and the peak temperature achieved by concrete.

A.4 Sulfate resistance

Practical experience and research have shown that a considerable degree of sulfate resistance is conferred on concrete containing combinations of pfa conforming to this standard and Portland cement conforming to BS 12 if the proportion of pfa is between 25 % and 40 % by mass of the combination (see BS 5328 : Part 1 and BRE Digest 363[2]).

A.5 Alkali–silica reaction

Advice on the use of combinations of Portland cement and pfa to reduce to an acceptable level the expansion caused by the alkali–silica reaction may be obtained from BRE Digest 330[3], BS 5328 : Part 1 and Part 4, Concrete Society Technical Report No. 30[4], BS 8110 : Part 1 and the Department of Transport *Specification for Highway Works*[5].

A.6 Chloride ingress

The use of concrete containing combinations of Portland cement conforming to BS 12 with at least 25 % of pfa conforming to this standard is recognized in BS 6349 : Part 1 as beneficial in avoiding the attack of steel reinforcement by chlorides.

A.7 Colour

Pulverized-fuel ash may vary in colour from light to dark grey with shades of brown occurring as well. An indication of consistency of colour may be given by the use of any test mutually agreed between producer and purchaser. Calibration on a Lovibond comparator is suitable for this purpose. When using exposed concrete it should be borne in mind that the colour of the pfa received may become significantly darker on mixing because the carbon particles become ground and behave as a pigment.

Annex B (informative)

Equivalence of within-mixer combinations to Portland pulverized-fuel ash cements

B.1 General

The following procedure has been designed for a combination of two materials which are manufactured, delivered and batched separately. There are necessarily distinct differences from the procedure used for the testing of a factory-blended Portland pulverized-fuel ash cement, e.g. the chemical composition of the combination is obtained by calculation using the chemical composition of the two components and their ratio. In the case of a factory-blended cement, the procedure for conformity criteria and autocontrol demonstrate that the cement as a single material conforms to the relevant standard. The procedure for combinations determines the range of proportions over which their properties equate to the relevant Portland pulverized-fuel ash cement specification and has been designed to provide the user with a similar degree of protection against non-conformity as in BS 6588 or BS 6610. Users may adopt any proportions within the declared range and these need not be identical to the proportions used for testing.

The requirements for properties specified in this standard are such that a combination of pfa conforming to it and of Portland cement conforming to BS 12 will have chemical and physical properties that conform to BS 6588 or BS 6610 (provided that the proportions of the combinations are within the limits specified in these standards).

Where Portland cement of standard strength class 52.5, having an initial setting time less than 60 min (in accordance with BS 12) is to be combined with pfa, it is necessary to demonstrate that, for the declared range of proportions, the initial setting time will conform to BS 6588 or BS 6610, as appropriate.

This annex sets out a procedure for strength testing that enables the strength characteristics of combinations to be related to the strength classes in BS 6588 and BS 6610. It applies to combinations of pfa conforming to this standard and Portland cement conforming to BS 12 and establishes the range of combination proportions within which the strength characteristics equate to the requirements of specific strength classes in BS 6588 or BS 6610.

B.2 Principles of the procedure

NOTE 1. The conformity criteria are the same as those in BS 6588 and BS 6610.

In principle, the overall percentage of defects in the lot from which the samples are taken is estimated from the test results. Conformity requires that the estimate does not exceed the acceptable percentage of defects.

The limitations on the acceptable percentage of defects can be found in table 8 of BS 6588 : 1996 and in table 6 of BS 6610 : 1996. Any plan satisfying the conformity criteria for strength in BS 6588 or BS 6610 is in principle acceptable for the conformity procedure.

As an example, a convenient procedure for the certification of equivalence to BS 6588 strength class 32.5 follows. It is suitable for the certification of one source of pfa with several sources of Portland cement. It establishes limits on the proportions of the pfa with each specific Portland cement to ensure that the conformity criteria for strength are met.

a) The relationship between strength and proportion of pfa is established for each Portland cement (see **B.3**).

b) Monthly composite samples of the pfa and each Portland cement are tested in combination and mean compressive strength values are determined over not less than 6 months, nor more than 12 months (see **B.4**).

c) Spot samples of the pfa and the nominated Portland cement are tested in combination and the standard deviation of the compressive strengths is calculated over the same period of between 6 months and 12 months as used in item b) (see **B.5**).

d) The relationships between strength and proportions, mean strength and standard deviation are used with the limits for strength in table 1 of BS 6588 : 1996, to determine the range of proportions within which the strength characteristics of the combination are equivalent to the requirements of strength class 32.5 (see **B.6**).

NOTE 2. In the case of a combination with a new Portland cement source, the period for assessing equivalence should be declared on the certificate. In the case of a new pfa source, the standard deviation should be determined from a minimum of 40 spot samples of the pfa taken over a period of not less than 2 weeks.

B.3 Establishment of the relationship between compressive strength and blend proportions

A composite sample of the pfa is obtained by blending a minimum of eight spot samples of similar mass obtained at regular intervals over at least one calendar month. A composite sample of each Portland cement is similarly obtained.

Strength tests are carried out at 2 days or 7 days and at 28 days, in accordance with BS EN 196 : Part 1 on the following blends of the composite samples.

mass of pfa (in %)	0	20	35	50
mass of Portland cement (in %)	100	80	65	50

The relationship between compressive strength and blend proportions should be re-established at least once every 2 years.

B.4 Monthly tests on individual Portland cements with pfa

Monthly bulk average samples of the pfa and each Portland cement source are obtained either from the producers or by combining at least eight spot samples taken regularly throughout the month. These monthly bulk average samples of the pfa and each Portland cement are blended in the proportion 30 : 70 and tests are carried out in accordance with BS EN 196 : Part 1 : 1995 for strength at 2 days or 7 days and at 28 days. The mean strength, $\bar{x}$, of each combination of pfa and a specific Portland cement is the average of the most recent monthly strength tests taken over a period of not less than 6 months and not more than 12 months.

B.5 Estimation of standard deviation

If tests on every source are to be avoided, the highest probable standard deviation should be determined from data based on the anticipated most variable combination of Portland cement and pfa. The choice of the nominated Portland cement for the most variable combination should be reviewed at least every 2 years. The basis of the review should be the variability of the monthly tests of the various combinations given in **B.4** or, where no historical data exist for combinations, the variability of the autocontrol data for the various Portland cements where such information is available.

At least once a week, a spot sample of the pfa and a spot sample of the nominated Portland cement are taken in accordance with BS EN 196 : Part 7 and blended in proportions 30 : 70 by mass. The blend is tested in accordance with BS EN 196 : Part 1 for strength at 2 days or 7 days and at 28 days. The standard deviation is determined from the results of tests carried out in the period corresponding to that used in **B.4**.

B.6 Establishment of limits on proportions for conformity to strength class 32.5

The conformity criteria are as follows.

$$\bar{x} \geq L + k_A s$$

and

$$\bar{x} \leq U - k_A s$$

where

k_A is the acceptability constant;

L is the specified lower limit;

U is the specified upper limit;

$\bar{x}$ is the mean strength determined in accordance with **B.4**;

s is the standard deviation determined in accordance with **B.5**.

The acceptability constant, k_A, depends on the number of samples, n, and differs between the upper (P_a = 10 %) and the lower (P_a = 5 %) limits (see table G.4 which is identical to table 8 of BS 6588 : 1996). For the certification of equivalence, n should be the number of spot samples taken in accordance with **B.5**.

To determine the limits on proportions for conformity to strength class 32.5, construct a diagram showing the relationship obtained in accordance with **B.3** between 28-day strength and proportion for the pfa and each specific Portland cement. On this diagram mark ($L + k_A s$) and ($U - k_A s$) where $k_A s$ is the margin determined from the standard deviation of the spot samples in **B.5** (see figure B.1).

Then mark the mean strength, $\bar{x}$, for the pfa in combination with the specific Portland cement, in proportion 30 : 70, on the diagram. Draw a line through this point parallel to the relationship between 28-day strength and proportion. Conformity to strength class 32.5 is achieved at proportions where the line exceeds ($L + k_A s$) but is less than ($U - k_A s$).

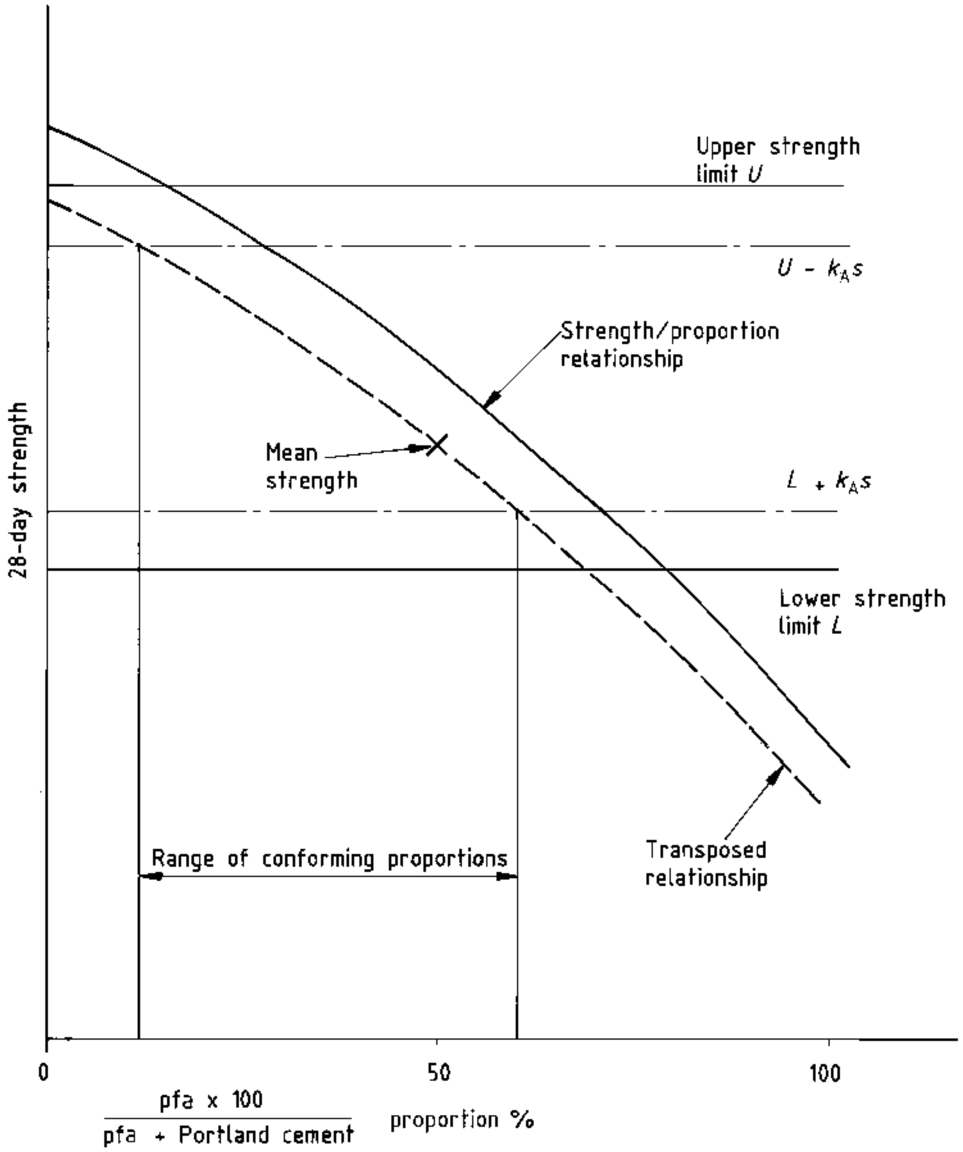


Figure B.1 Determination of conformity limits for combinations

Carry out a similar exercise for the 2-day or 7-day strength results (in this case no upper limit is applicable).

The range of proportions for conformity to strength class 32.5 is that for which both 2-day or 7-day and 28-day strength conformity are met.

B.7 Issue of certificates

Certificates should be issued monthly. A certificate should relate to pfa from a specific source used with Portland cement from a specific source. It should contain the following information:

a) identification of the materials sampled;

b) the period represented by the sample;

c) the means by which samples were obtained;

d) the blend composition tested;

e) the results of tests carried out on the blend of the latest composite samples, which should include tests for initial setting time and strength;

f) details of the blend compositions derived to give equivalent properties and proportions to the requirements of the relevant Portland pulverized-fuel ash cement standard, stating the strength class in the case of equivalence to BS 6588 : 1996;

g) the signature of the person responsible for the testing.

NOTE. The issue of a certificate is a declaration of the equivalence of the within-mixer blend to the requirements for properties and proportions of the relevant Portland pulverized-fuel ash cement standard. The accuracy of the claim is solely the responsibility of the issuer of the certificate. Such a claim should not be confused with third party certification of conformity which may also be desirable.

B.8 Inspection testing

When inspection testing is required, a spot sample of the pfa and a spot sample of the Portland cement should be taken in accordance with **3.6** and **6.2**, **6.3**, **6.4** or **6.5** of BS EN 196 : Part 7 : 1992. Laboratory samples should be prepared and packed in accordance with clauses **8** and **9** of BS EN 196 : Part 7 : 1992. A sampling report should be completed at the time of sampling and should be attached to the laboratory samples in accordance with clause **10** of BS EN 196 Part 7 : 1992. The sample of pfa and of Portland cement should be combined in the laboratory in the blend ratio being used. The laboratory combination should then be tested in accordance with clause **11** of BS 6588 : 1996 or clause **11** of BS 6610 : 1996 as appropriate.

Annex C (normative)

Method of determining the moisture content

C.1 Principle

The pfa is dried at (105 ± 5) °C by heating in an oven and the loss in mass determined by weighing.

C.2 Apparatus

C.2.1 *Ventilated electric oven*, capable of being controlled to (105 ± 5) °C.

C.2.2 *Balance*, capable of weighing 100 g to the nearest 0.001 g.

C.2.3 *Shallow container*, of about 20 g capacity made of non-corrodible material and capable of withstanding temperatures up to 150 °C without loss in mass.

C.2.4 *Desiccator*, containing a suitable desiccant.

C.3 Sample preparation

Thoroughly remix a spot sample taken in accordance with BS EN 196-7 : 1992 and reduce it by quartering and subdividing to obtain 2 laboratory samples each of approximately 25 g mass.

NOTE. It is recommended that the bulk of the sample is reconstituted and retained in an airtight container for reference purposes until testing is completed.

C.4 Procedure

Weigh to the nearest 0.01 g approximately 10 g of the pfa. Spread it in the shallow container (**C.2.3**), which has previously been dried, and dry in the oven (**C.2.1**) at (105 ± 5) °C for (60 ± 5) min. Allow the container and dried sample to cool to room temperature in the desiccator. Re-weigh to determine the loss in mass.

C.5 Calculation

Calculate the moisture content of each test sample as a percentage from the following equation:

$$\text{Moisture content} = \frac{m - d}{d} \times 100$$

where

m is the mass of the test sample before drying (in g);

d is the mass of the dried test sample (in g).

C.6 Reporting

Report the moisture content as the mean of two test results as a percentage to the nearest 0.1 %.

Annex D (normative)

Method of determining the fineness

D.1 Principle

The fineness of pfa is measured by wet sieving on a 45 µm test sieve and is expressed as the percentage by mass of the pfa that is retained.

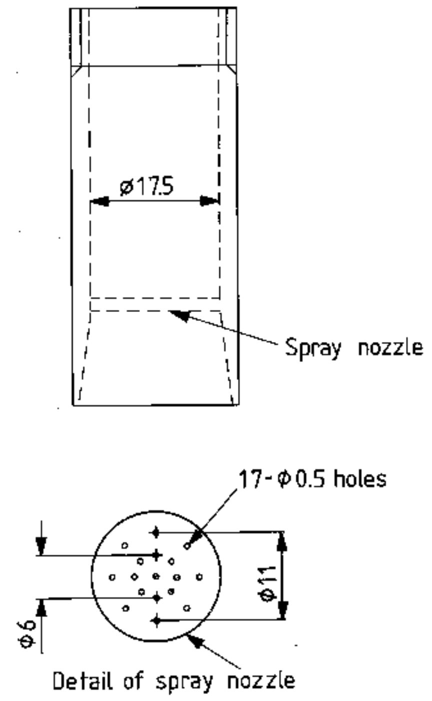
This annex describes the reference test method. When other test methods are used, it shall be demonstrated that they give results equivalent to those obtained by this reference method. In case of dispute, only this reference method shall be used.

D.2 Apparatus

D.2.1 *Sieve frame*, constructed of a durable material not subject to corrosion by water or distortion by heat. The frame shall be cylindrical and of nominal dimensions 50 mm diameter and 75 mm depth, as measured from the top of the frame to the sieve cloth. The frame shall also allow the regular removal and replacement of the sieve cloth.

D.2.2 *Sieve cloth*, 45 µm stainless steel mesh conforming to ISO 565 and capable of being sealed in the sieve frame. The sieve cloth shall be free of grease and visible irregularities when inspected as described in ISO 3310-1.

D.2.3 *Spray nozzle*, constructed of material not subject to corrosion by water and of nominal 17.5 mm inside diameter. The nozzle shall have 17 drilled holes of nominal 0.5 mm diameter, one being central in the nozzle in line with the longitudinal axis, a further eight holes drilled 6.0 mm centre-to-centre at an angle of about 5° from the longitudinal axis and an outer row of eight holes drilled at about 11.0 mm centre-to-centre at an angle of about 10° from the longitudinal axis (see figure D.1).



Dimensions in millimetres

Figure D.1 Spray nozzle

D.2.4 *Pressure gauge*, having a scale capacity of at least 160 kPa graduated in intervals of 5 kPa.

D.2.5 *Ventilated electric oven* (see **C.2.1**).

D.2.6 *Balance* (see **C.2.2**).

D.2.7 *Desiccator* (see **C.2.4**).

D.3 Calibration of test sieve

D.3.1 To determine the correction factor of the test sieve used for the determination of fineness, calibrate the sieve cloth using the standard reference ash[2] or alternatively BCR No. 69 Certified Reference Material[3] (correcting its stated 45 µm sieve residue by adding 0.07 % absolute[4]), appropriate to the grade of pfa specified in this standard. Prior to the sieve calibration, test a sample of pfa to simulate the condition the sieve will be in when used under normal conditions, i.e. the first test of a new sieve shall not be for calibration purposes.

D.3.2 Test sieves used for the determination of fineness shall be recalibrated at intervals not exceeding 100 tests or 3 months, whichever is the sooner. Imperfect or damaged sieve cloth shall be rejected. Each sieve shall be cleaned after every test, for example, by inverting and backflushing with spray from the nozzle.

D.3.3 Determine the fineness of the standard reference material by the method described in **D.4**. The two results shall not differ by more than 0.3 % absolute. If outside this limit, repeat the test only once more when the value shall not differ by more than 0.3 % from either of the previous values. If values do not conform, the sieve cloth shall be replaced. Where values do not differ by more than 0.3 %, calculate the mean of the two results and use it to determine the correction factor of the sieve as described in **D.3.4**.

D.3.4 Calculate the correction factor for the sieve, F, by the formula:

$$F = r_3/r_2$$

where

r_2 is the measured proportion of the standard reference material retained on the test sieve (in %);

r_3 is the known 45 µm sieve residue by mass of the standard reference material (in %).

Calculate the correction factor for the sieve to the nearest 0.001. If it does not lie within the range 0.800 to 1.200, reject the sieve cloth.

D.4 Procedure

Transfer 1.0 g to 1.1 g, weighed to the nearest 0.001 g, of the test sample of pfa, prepared and dried in accordance with the method described in annex C, to the calibrated, clean and dry test sieve. Wet the sample thoroughly with a gentle flow of water, for example by using a hand held wash bottle. Set the pressure of the water supply to the spray nozzle at 70 kPa to 80 kPa and place the sieve in position with the spray nozzle no more than 15 mm above the top of the sieve frame.

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[2] For information on the availability of the standard reference ash, write to Customer Services, BSI, 389 Chiswick High Road, London W4 4AL.

[3] BCR No. 69 Certified Reference Material, Commission of the European Communities, Brussels.

[4] This correction has been found necessary as a result of comparative trials of the two materials.

Rotate the sieve in a horizontal plane, at about 1 revolution per second for (60 ± 10) s. Remove the sieve from under the nozzle, rinse with alcohol or acetone or alternatively blot up residual moisture from the underside of the sieve cloth. Dry the sieve and residue in the oven at (105 ± 5) °C until there is no further loss in mass. Allow the sieve and residue to cool to room temperature in the desiccator. Weigh the sieve residue by either of the following two methods.

a) Carefully transfer the residue from the sieve onto the balance, ensuring that all the residue has been completely removed by using a suitable soft-haired brush. Weigh the residue to the nearest 0.001 g.

b) Weigh the sieve and residue to the nearest 0.001 g, remove the residue from the sieve, then reweigh the sieve alone to the nearest 0.001 g. The difference between the two values is the mass of the residue.

Repeat this procedure to give two values for the sieve residue. If the two corrected values differ by more than 0.3 % absolute, carry out a further test or tests until two values are obtained which differ by no more than 0.3 %.

D.5 Calculation

Calculate the corrected sieve residue of the test sample as a percentage by the formula:

Corrected sieve residue = $(r/m) \times F \times 100$

where

r is the mass of residue from the sample (in g);

m is the mass of sample before test (in g);

F is the sieve correction factor (in %).

Example

Sieve correction factor (F)	= 1.053
Mass of sample (m)	= 1.079 g
Mass of residue (r)	= 0.102 g
Corrected sieve residue	= (0.102/1.079) × × 1.053 × 100
	=10.0 %

D.6 Reporting

Report the 45 μm sieve residue as the mean of the two corrected values as a percentage to the nearest 0.1 %.

Annex E (normative)

Method of determining the water requirement

E.1 Principle

The reduction in water required when pfa is added to a mortar is measured by comparing the flow of a control and test mix.

E.2 Apparatus

E.2.1 *Mixer*, conforming to **4.4** of BS EN 196-1 : 1995.

E.2.2 *Flexible scraper*, of rubber or plastics material, suitable for removing mortar adhering to the mixer blades and inside surfaces of the mixer bowl.

E.2.3 *Balance*, of sufficient capacity and capable of weighing to the nearest 1.0 g.

E.2.4 *Flow table*, conforming to annex A of BS 4551 : 1980 and associated mould and tamper.

E.3 Materials

E.3.1 *CEN Standard sand, EN 196-1*, conforming to **5.1** of BS EN 196-1 : 1995.

E.3.2 *Reference Portland cement*, conforming to BS 12 : 1996 standard strength class 42.5 (see clause **8**).

E.3.3 *Water*, deionized or distilled.

E.4 Mix proportions

The mix composition shall be as given in table E.1.

Table E.1 Mix proportions

Material	Control mortar	Test mortar
Reference Portland cement	(450 ± 1) g	(315 ± 1) g
Pfa to be tested	nil	(135 ± 1) g
CEN standard sand	(1350 ± 5) g	(1350 ± 5) g
Water	(225 ± 1) g	to give flow value ± 5 units of control mortar

E.5 Procedure

Use the mixing procedure described in **6.3** of BS EN 196-1 : 1995. Immediately on completion of mixing determine the flow of the mortar in accordance with clause **12** of BS 4551 : 1980. Lift the mould from the table (60 ± 5) s after mixing has been completed and operate the table immediately. Operate the table 15 times (see note) in (15 ± 2) s and measure the flow.

Adjust the water content of the test mortar to obtain a flow value ± 5 units of that of the control mortar.

NOTE. The determination of consistence described in BS 4551 can be omitted. Owing to the high flow values obtained with these mortar mixes, the table is operated a reduced number of times from that given in BS 4551, which specifies 25 times.

E.6 Calculation

Calculate the water requirement of the pfa as a percentage by the formula:

$$\text{Water requirement} = \frac{X}{225} \times 100$$

where

X is the mass of water used in the test mortar (in g).

E.7 Reporting

Report the water requirement of the pfa to the nearest 1 %.

Annex F (normative)

Method of determining the strength factor

F.1 Principle

The strength of a control mortar at 28 days is compared to the strength of a test mortar containing the pfa at the same age.

F.2 Apparatus

As required by BS EN 196-1 : 1995 for the determination of compressive strength.

F.3 Materials

As required by **E.3**.

F.4 Mix proportions

As given in table E.1.

F.5 Procedure

After mixing the control and test mortars in accordance with annex E and within (60 ± 5) s of completing the flow test described in **E.5**, return the mortar to the uncleaned mixing bowl and remix for (30 ± 3) s at low speed. On completion of this additional mixing cycle prepare and use test specimens in accordance with **7.2** and clause **8**, respectively, of BS EN 196-1 : 1995. Test a minimum of four half prisms for compressive strength at 28 days in accordance with clause **9** of BS EN 196-1 : 1995. Use the strength determined for the control and test mortars to calculate the strength factor.

F.6 Calculation

Calculate the strength factor to the nearest 0.01 by the formula:

$$\text{Strength factor} = A/B$$

where

A is the strength of the test mortar as prepared in **E.5** (in N/mm^2);

B is the strength of the control mortar (in N/mm^2).

F.7 Reporting

Report the strength factor to the nearest 0.01.

Annex G (informative)

Conformity criteria

G.1 Introduction

G.1.1 A statistically formulated conformity criterion includes three elements as follows:

a) a definition of the requirements in terms of characteristic value, as given in clauses **5** to **12**;

b) the acceptable percentage, P_a, of defects or, in other words, the fractile of the normal (Gaussian) distribution to which the characteristic value corresponds. In this standard this is the 10 % fractile, or, for the strength factor, the 5 % fractile;

c) the probability of acceptance of a lot of pfa which does not conform to the requirements.

A sampling inspection procedure can only produce an approximate value for the percentage of defects in a lot. The bigger the sample, the better the approximation. The probability of acceptance, also named consumer's risk, controls the degree of approximation by the sampling plan and in this case should be 5 % for the continuous inspection which is the basis for the assessment of conformity.

G.1.2 The conformity criteria for continuous inspection (see **G.3**, **G.4** and **G.5**) are based upon the principles of **G.1.1**. This standard contains, however, an additional conformity criterion of a different type. In order to provide means for the rejection of pfa which is likely to reduce materially its usability for the intended purpose, this standard specifies (see **G.6**) that a quantity of pfa containing one or more major defects does not conform to the requirements.

G.2 Application of conformity procedures

G.2.1 Conformity of a pfa to this standard should be continuously assessed. This inspection is operated by the pfa producer (autocontrol).

NOTE. International or national regulations may require the autocontrol of pfa to be monitored by an officially recognized testing laboratory.

Terms of delivery or other contractual conditions normally included in documents exchanged between the supplier and the purchaser of pfa are outside the scope of this standard.

G.3 General procedure for assessing conformity with the characteristic value

G.3.1 The assessment should be based upon continuous inspection using spot samples of pfa taken in accordance with BS EN 196-7 : 1992.

G.3.2 The continuous inspection should take place either at the pfa processing plant or at a central testing laboratory, and should be operated by the producer (autocontrol). The series of samples used for assessing the conformity should be taken over a period of not less than 6 months and not more than 12 months. Minimum testing frequencies are given in table G.1.

Table G.1 Minimum testing frequencies

Property	Number of samples
Fineness Water requirement Strength factor Loss on ignition	2 per week
Initial setting time Soundness	1 per week
Moisture content Particle density Sulfuric anhydride Chloride Calcium oxide	1 per month

In the case of new production, the period for assessing the conformity should be declared by the producer on the certificate, but should not be less than 2 weeks.

G.3.3 An observed test value which does not conform to the appropriate values in clauses **5** to **12** is characterized as a defect. This standard distinguishes between minor and major defects. Separate limits are specified for major defects (see **G.6**).

G.4 Conformity criteria

G.4.1 In principle, the overall percentage of defects in the lot from which samples were taken is estimated from the test results. Conformity requires that the estimate does not exceed the acceptable percentage of defects.

NOTE. For practical calculations the acceptability constant, k_A, is used for the evaluation of conformity instead of the percentage of defects (see **G.7**).

G.4.2 The sampling (including the number of single spot samples to be taken) is established by means of two parameters which are tabulated in table G.2 :

a) acceptable overall percentage of defects;

b) acceptable consumer's risk.

Table G.2 Parameters determining the conformity procedure

	Physical and chemical properties (all limits)
Continuous inspection procedure	By attributes (by variables is allowed)
Percentage of defects, P_a	10 %
Consumer's risk	5 %

The two parameters together are used for the selection of sampling plans for continuous autocontrol.

Some convenient sampling plans for inspection by variables have been collected in **G.7**. Any other plan satisfying the values in table G.2 is, in principle, acceptable for the conformity procedure.

G.5 Conformity criteria and procedure for physical and chemical properties

G.5.1 Clauses **5**, **6**, **7**, **8**, **10**, **11** and **12** specify requirements for the following properties.

a) Physical properties:
  1) moisture content;
  2) fineness;
  3) particle density;
  4) water requirement;
  5) initial setting time;
  6) soundness.

b) Chemical properties:
  1) sulfuric anhydride content;
  2) loss on ignition;
  3) chloride content;
  4) calcium oxide content.

Conformity should be assessed for one property at a time.

G.5.2 In the case of physical and chemical requirements, the conformity procedure is based upon inspection by attributes. The number of defects is counted and compared with an estimated number of defects, calculated from the number of tests and the acceptable overall percentage of defects.

In order to improve inspection efficiency, the pfa producer is allowed to employ inspection by variables (see **G.4**). This is preferable for initial setting time and chloride content in the case where this is close to the specified limit.

G.5.3 The sampling plan (including the number of spot samples to be taken) is established on the same basis as in **G.4**, see also table G.2.

Some convenient sampling plans for inspection by attributes have been collected in **G.7**. Any other sampling plan satisfying the values given in table G.2 is, in principle, acceptable for the conformity procedure.

G.6 Limits for major defects

A quantity of pfa yielding one or more major defect samples does not conform to the requirements of this British Standard.

In general terms, a major defect is defined as a deviation from the requirements in clauses **5** to **12** so large that the usability of the pfa for its intended purpose is likely to be reduced and that in extreme cases even failure may be produced. Table G.3 presents the specific definition for the different properties. If a test result deviates by more than the value given in table G.3, it is denoted a major defect.

Table G.3 Major defects

Property	**Deviation from the requirements in clauses 5 to 12 in excess of**
Moisture content	+ 0.1 %
Fineness	+ 0.5 %
Particle density	− 50 kg/m^3
Water requirement	+ 2 %
Initial setting time	− 15 min
Soundness	+ 1 mm
Sulfuric anhydride content	+ 0.5 % (*m/m*)
Chloride content	+ 0.01 % (*m/m*)
Calcium oxide content	+ 1.0 % (*m/m*)

G.7 Sampling plans

G.7.1 *General*

This clause contains a number of sampling plans for the following two alternatives which satisfy the conditions of table G.2. The alternatives are as follows:

a) continuous inspection by variables;

b) continuous inspection by attributes.

The number of samples and the test frequency are given in **G.3.2**.

G.7.2 *Inspection by variables*

In this case the mean value, $\bar{x}$, and the standard deviation, s, of the complete series of test results (one result per sample) are calculated.

The conformity criteria are:

$$\bar{x} - k_A s \geq L$$

and

$$\bar{x} + k_A s \leq U$$

where

k_A is the acceptability constant;
L is the specified lower limit;
U is the specified upper limit.

The acceptability constant, k_A, depends on the parameters given in table G.2 and on the number of test results, n. Values of k_A are listed in table G.4.

Table G.4 Acceptability constant k_A

n	$P_a = 5\,\%$	$P_a = 10\,\%$
40 to 49	2.13	1.70
50 to 59	2.07	1.65
60 to 79	2.02	1.61
80 to 99	1.97	1.56
100 to 149	1.93	1.53
150 to 199	1.87	1.48
≥ 200	1.84	1.45

G.7.3 *Inspection by attributes*

In this case the number of defect test results, c_D, (one result per sample) in the complete series of samples is counted.

The conformity is checked by the equation:

$$c_D \leq c_A$$

where the acceptable number of defects, c_A, depends on the parameters given in table G.2 and on the number of test results, n. Values of c_A are listed in table G.5.

Table G.5 Acceptable number of defects c_A

n	c_A
0 to 39	0
40 to 54	1
55 to 69	2
70 to 84	3
85 to 99	4
100 to 109	5

NOTE. If $n \geq 110$, $c_A = 0.075\ (n - 30)$

blank

List of references (see clause **2**)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 12 : 1996	*Specification for Portland cement*
BS 1016 :	*Methods for analysis and testing of coal and coke*
BS 1016 : Part 105 : 1992	*Gross calorific value of coal and coke*
BS 4551 : 1980	*Methods of testing mortars, screeds and plasters*
BS 6100 :	*Glossary of building and civil engineering terms*
BS 6100 : Part 6 :	*Concrete and plaster*
BS 6100 : Section 6.1 : 1984	*Binders*
BS 6588 : 1996	*Specification for Portland pulverized-fuel ash cements*
BS 6610 : 1996	*Specification for pozzolanic pulverized-fuel ash cement*
BS EN 196 :	*Methods of testing cement*
BS EN 196-1 : 1995	*Determination of strength*
BS EN 196-2 : 1995	*Chemical analysis of cement*
BS EN 196-3 : 1995	*Determination of setting time and soundness*
BS EN 196-6 : 1992	*Determination of fineness*
BS EN 196-7 : 1992	*Methods of taking and preparing samples of cement*
BS EN 196-21 : 1992	*Determination of the chloride, carbon dioxide and alkali content of cement*

ISO publications

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO), Geneva. (All publications are available from Customer Services, BSI.)

ISO 565 : 1990	*Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*
ISO 3310 :	*Test sieves — Technical requirements and testing*
ISO 3310-1 : 1990	*Test sieves of metal wire cloth*

Informative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 3892 :	*Pulverized-fuel ash*
BS 3892 : Part 2 : 1984[7]	*Specification for pulverized-fuel ash for use in grouts and for miscellaneous uses in concrete*
BS 5328 :	*Concrete*
BS 5328 : Part 1 : 1997	*Guide to specifying concrete*
BS 5328 : Part 4 : 1990	*Specification for the procedures to be used in sampling, testing and assessing compliance of concrete*
BS 6349 :	*Maritime structures*
BS 6349 : Part 1 : 1984	*General criteria*
BS 6543 : 1985[7]	*Guide to use of industrial by-products and waste materials in building and civil engineering*
BS 8110 :	*Structural use of concrete*
BS 8110 : Part 1 : 1997	*Code of practice for design and construction*
BS EN 450 : 1995	*Fly ash for concrete — Definitions, requirements and quality control*
DD ENV 197 :	*Cement — Composition, specifications and conformity criteria*
DD ENV 197-1 : 1994	*Common cements*

Other references

[1] BRE Digest 362[8] *Building mortars*

[2] BRE Digest 363[8] *Sulphate and acid resistance of concrete in the ground*

[3] BRE Digest 330[8] *Alkali aggregate reactions in concrete*

[4] Concrete Society[9] Technical Report No. 30 *Alkali-silica reaction — minimizing the risk of damage to concrete*, 1987

[5] Department of Transport *Specification for Highway Works*. London: The Stationery Office

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[7] Referred to in the foreword only.

[8] Available from Construction Research Communications Ltd., 151 Rosebery Avenue, London EC1R 4QX or from The Stationery Office.

[9] Available from Concrete Society, 13 Eatongate, 112 Windsor Road, Slough SL1.

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