BRITISH STANDARD

BS 6588 : 1996

Specification for

Portland pulverized-fuel ash cements

Committees responsible for this British Standard

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British Cement Association
British Precast Concrete Federation
British Ready Mixed Concrete Association
Cement Admixtures Association
Cementitious Slag Makers' Association
County Surveyors' Society
Department of the Environment (Building Research Establishment)
Department of Transport (Highways Agency)
Electricity Association
National Rivers Authority
Quality Ash Association
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Foreword

This edition of this British Standard has been prepared by Subcommittee B/516/6. It introduces technical changes but it does not reflect a full review or revision of the standard, which will be undertaken in due course. It is based on the work of Technical Committee 51, Cement and building limes, of the European Committee for Standardization (CEN), which has prepared a European Prestandard specification for cements published as DD ENV 197-1. As an intrinsic part of this activity, CEN has published EN 196, a series of methods of testing cement, which the UK is implementing to replace the relevant Parts of BS 4550. In consequence, this British Standard specifies requirements in terms of the test procedures in BS EN 196. It supersedes BS 6588 : 1991 which is withdrawn.

The requirements for compressive strength, physical and chemical properties are specified as characteristic values and conformity is assessed by means of a statistical procedure for continuous inspection operated by the cement manufacturer (autocontrol) (see annex A). This includes the concept of 'major defects' which are 'likely to reduce materially the usability of the cement for its intended purpose'. However, DD ENV 197-1 is considered to be inappropriate in its entirety for the manufacture of cement in the UK and the annex therefore incorporates several footnotes identifying specific aspects. In particular, it is assumed, for this edition of this British Standard, that some limits are required for acceptance inspection. Clause **12** therefore gives appropriate values which in several cases are more stringent than those for major defects given in annex A derived from DD ENV 197-1.

The strength requirements are based on the BS EN 196 : Part 1 mortar prism test at 28 days. In addition to the two classes of standard strength, 32.5 and 42.5, each with two subclasses of early strength, this British Standard includes a higher class of standard strength, 52.5, to cover all Portland pulverized-fuel ash cements available in the UK (see table 2). It should be noted that for prescribed or standard mixes, as described in BS 5328 : Part 1, unless the cement content is increased appropriately, the use of cements of the 32.5 standard strength class will lead to concrete of lower compressive strength and may reduce durability, compared with cements of a higher strength class.

This edition introduces the following changes.

(a) The names of the two types of pulverized-fuel ash cement have been changed to avoid confusion with the pozzolanic pulverized-fuel ash cement specified in BS 6610. Portland fly ash cement is now called Portland fly ash cement A and pozzolanic cement is now called Portland fly ash cement B.

(b) The two methods of producing Portland pulverized-fuel ash cements, i.e. by intergrinding and by dry blending, have been retained (see **6.3**). A procedure for combining Portland cement and pulverized-fuel ash in the concrete mixer is included in BS 5328 : Part 1.

(c) Compositional requirements are expressed as a percentage of the total mass of the constituents but excluding calcium sulfate and any additives. This departure from the traditional method of calculation in the UK is fully explained in annex B.

(d) The pulverized-fuel ash constituent is required to be siliceous with a minimum reactive silicon dioxide (SiO_2) content of 25 % (*m/m*). The proportion of siliceous pulverized-fuel ash is specified as 6 % (*m/m*) to 20 % (*m/m*) for Portland fly ash cement A or as 21 % (*m/m*) to 35 % (*m/m*) for Portland fly ash cement B. These proportions are expressed as a percentage of the total mass of the constituents but excluding calcium sulfate and any additives. Thus, the maximum permissible pulverized-fuel ash content of cement complying with BS 6588 has been reduced from 40 % (*m/m*) to 35 % (*m/m*), expressed as a percentage of the final cement which corresponds to 37 % (*m/m*), but it should be noted that the highest proportions may not produce a cement complying with the higher strength requirements. (A cement with a proportion of pulverized-fuel ash of 36 % (*m/m*) to 55 % (*m/m*) is specified in BS 6610 with the name pozzolanic pulverized-fuel ash cement.)

(e) The limit for total sulfur (expressed as SO_3) of 3.0 % (*m/m*) has been changed to an autocontrol maximum limit for sulfate of 3.5 % (*m/m*) (corresponding to an acceptance inspection limit of 3.6 % (*m/m*) of the final cement).

(f) Guidance on the use of cement is included in annex C and attention is drawn to the safety precautions recommended therein when working with cement. Cement will partially hydrate when exposed to water vapour; annex C also includes guidance on storage.

New editions of other British Standards for cement, i.e. BS 12, BS 146, BS 4027, BS 4246, BS 6610 and BS 7583 have been prepared at the same time.

Product certification. Purchasers are recommended to specify cement manufactured and supplied to a nationally recognized third party product certification scheme.

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

Specification

1 Scope

This British Standard[1)] specifies requirements for the composition and the manufacture and for the strength, physical and chemical properties of two Portland pulverized-fuel ash cements as characteristic values. Requirements for marking, provision of information, sampling and testing for acceptance at delivery are also specified. It gives the procedures for the manufacturer's autocontrol system to ensure conformity.

2 References

2.1 Normative references

This British Standard incorporates, by reference, provisions from specific editions of other publications. These normative references are made at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this British Standard only when incorporated in it by updating or revision.

2.2 Informative references

This British Standard 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 British Standard the definitions 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 % but 5 % for the lower strength limits.

4 Cement

NOTE 1. Cement is a hydraulic binder, i.e. it is a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.

Cement conforming to this British Standard shall, when appropriately batched and mixed with aggregate and water, be capable of producing mortar or concrete which retains workability for a sufficient time and shall after defined periods attain specified strength levels and also possess long-term volume stability.

NOTE 2. Hydraulic hardening of cement conforming to this British Standard is primarily due to the hydration of calcium silicates[2)], but other chemical compounds may also participate in the hardening process, e.g. aluminates.

The sum of the proportions of reactive calcium oxide (CaO)[3)] and reactive silicon dioxide (SiO_2)[4)] shall be not less than 50 % (*m/m*).

Cement conforming to this British Standard ultimately consists of individual small grains of different materials but it shall be statistically homogeneous in composition. A high degree of uniformity in all cement properties shall be obtained through continuous mass production processes, in particular adequate grinding and homogenization processes.

NOTE 3. Qualified and skilled personnel and the facilities to test, evaluate and adjust product quality are essential for producing cement conforming to this British Standard.

During the cement manufacturing process and its control, the composition of the cement shall be kept within the limits specified in this British Standard.

5 Constituents

5.1 Portland cement clinker

Portland cement clinker is a hydraulic material which shall consist of not less than two-thirds by mass of calcium silicates ($(CaO)_3.SiO_2$ and $(CaO)_2.SiO_2$), the remainder containing aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3) and other oxides. The ratio by mass (CaO)/(SiO_2) shall be not less than 2.0. The content of magnesium oxide (MgO) shall not exceed 5.0 % (*m/m*).

[1)] Other types of cement standardized in the UK are specified in BS 12, BS 146, BS 915, BS 1370, BS 4027, BS 4246, BS 4248, BS 6610 and BS 7583.

[2)] There are also cements whose hardening is mainly due to other compounds, e.g. calcium aluminate in high alumina cement.

[3)] Reactive calcium oxide (CaO) is considered to be only that fraction of the CaO which under normal hardening conditions can form calcium silicate hydrates or calcium aluminate hydrates. To evaluate this fraction, the total CaO content is to be reduced by the part calculated as calcium carbonate ($CaCO_3$) on the basis of the measured carbon dioxide (CO_2) content and the part calculated as calcium sulfate ($CaSO_4$) on the basis of the measured sulfate content (expressed as SO_3) disregarding the SO_3 taken up by alkalis.

[4)] Reactive silicon dioxide (SiO_2) is defined as that fraction of the SiO_2 which, after treatment with hydrochloric acid (HCl), is soluble in boiling potassium hydroxide (KOH) solution. The quantity of reactive SiO_2 is determined by subtracting from the total SiO_2 content (see **13.9** of BS EN 196 : Part 2 : 1995) that fraction of the SiO_2 contained in the insoluble residue (see clause **10** of BS EN 196 : Part 2 : 1995), both on a dry basis.

Portland cement clinker shall be made by burning, at least to sintering, a precisely specified mixture of raw materials (raw meal, paste or slurry) containing CaO, SiO_2, Al_2O_3 and small quantities of other materials. The raw meal, paste or slurry shall be finely divided, intimately mixed and therefore homogeneous.

5.2 Pulverized-fuel ash (siliceous fly ash)

Siliceous fly ash, a fine powder of mainly spherical particles having pozzolanic properties, shall contain at least two-thirds by mass of glassy particles. It shall consist essentially of reactive SiO_2 and Al_2O_3.

NOTE. The remainder contains Fe_2O_3 and other oxides.

The proportion of reactive CaO shall be less than 5 % (*m/m*).

The reactive SiO_2 content in siliceous fly ash conforming to this British Standard shall be not less than 25 % (*m/m*) and the loss on ignition shall not exceed 5.0 % (*m/m*) (see also **6.3**).

NOTE 1. During the lifetime of DD ENV 197-1, siliceous fly ash with a maximum loss on ignition of 6.0 % (*m/m*) may be used, provided that this is reported on the test certificate and that the acceptance inspection limit does not exceed 7.0 % (*m/m*) (see **11.1** f) and table 4).

NOTE 2. Siliceous fly ash is obtained by electrostatic or mechanical precipitation of dust-like particles from the flue gases from furnaces fired with pulverized hard coal. Ash obtained by other methods is not considered in this British Standard.

NOTE 3. The term 'siliceous fly ash' in this British Standard covers pulverized-fuel ash (pfa) which has been in common use in the UK for many years. The latter is the more precise term for describing siliceous fly ash produced from electricity generating power stations burning pulverized hard coal.

5.3 Minor additional constituents

Minor additional constituents if present shall be one or more of granulated blastfurnace slag, natural pozzolana, or filler.

NOTE 1. The minor additional constituents should not promote corrosion of the reinforcement or impair the properties of the cement or of the mortar or concrete made from the cement.

NOTE 2. Granulated blastfurnace slag is made by rapid cooling of a slag melt of suitable composition, as obtained in smelting iron ore in a blastfurnace.

Natural pozzolanas are usually substances of volcanic origin or sedimentary rocks with appropriate chemical and mineralogical composition.

For the purposes of this British Standard, the term 'filler' covers any natural or artificial inorganic mineral materials other than blastfurnace slag, natural pozzolana or pulverized-fuel ash, e.g. calcareous materials, which, after appropriate preparation, due to their particle size distribution, improve the physical properties of the cement (such as workability or concrete bleeding).

5.4 Calcium sulfate

Calcium sulfate shall be added in small quantities to the other constituents of cement during its manufacture in order to control setting.

NOTE. Calcium sulfate can be gypsum (calcium sulfate dihydrate, $CaSO_4.2H_2O$), hemihydrate (partially dehydrated gypsum, $CaSO_4.\frac{1}{2}H_2O$) or anhydrite (anhydrous calcium sulfate, $CaSO_4$) or any mixture of them. Gypsum and anhydrite are found naturally. Calcium sulfate is also available as a by-product of certain industrial processes.

5.5 Additives

If the total quantity of additives exceeds 1.0 % (*m/m*) of the cement, the type and quantity shall be stated on the packaging and/or on the delivery note.

NOTE 1. These additives are constituents not specified in **5.1** to **5.4** which are added to improve the manufacture or the properties of the cement, e.g. grinding aids. They should not promote corrosion of the reinforcement or impair the properties of the cement or of the mortar or concrete made from the cement.

NOTE 2. The total quantity of additives should not exceed 1.0 % (*m/m*).

6 Composition, notation and manufacture

6.1 Composition

The composition of the 'nucleus' (see **B.1**) of Portland pulverized-fuel ash cements shall be as given in table 1.

NOTE. For clarity in definition, calcium sulfate (see **5.4**) and additives (see **5.5**) are excluded. The final cement is to be understood as the nucleus plus the necessary calcium sulfate and any additives to the cement.

Table 1. Composition

	Portland fly ash cement A % (*m/m*)	**Portland fly ash cement B** % (*m/m*)
Portland cement clinker	80 to 94	65 to 79
Pulverized-fuel ash (fly ash)	6 to 20	21 to 35
Minor additional constituents	0 to 5	0 to 5

6.2 Notation

Portland pulverized-fuel ash cements shall be identified by at least the name, i.e. Portland fly ash cement A or Portland fly ash cement B, a figure indicating the standard strength class (see note 1 to table 2) and a letter indicating the subclass of early strength (see note 2 to table 2).

6.3 Manufacture

The materials shall be thoroughly and intimately mixed together in a dry state to form a uniform mixture.

When the cement is produced by intergrinding, the Portland cement clinker shall be capable of producing a cement conforming to BS 12. The pulverized-fuel ash shall conform to all the requirements specified in BS 3892 : Part 1 except that for fineness. The Portland cement clinker, pulverized-fuel ash and set retarder, as specified in **5.4**, with minor additional constituents and additives if required, shall be mixed together and ground.

When the cement is produced by dry blending, the Portland cement shall conform to BS 12 and the pulverized-fuel ash shall conform to all the requirements specified in BS 3892 : Part 1. The Portland cement and the pulverized-fuel ash shall be thoroughly mixed to form a homogeneous blend.

7 Compressive strength

The compressive strength, determined in accordance with BS EN 196 : Part 1, shall conform to table 2.

Table 2. Compressive strength

Strength class	Early strength		Standard strength	
	2 day N/mm²	7 day N/mm²	28 day N/mm²	
32.5N	—	≥ 16	≥ 32.5	≤ 52.5
32.5R	≥ 10	—		
42.5N	≥ 10	—	≥ 42.5	≤ 62.5
42.5R	≥ 20	—		
52.5N	≥ 20	—	≥ 52.5	–

NOTE 1. The standard strength of cement is the compressive strength determined in accordance with BS EN 196 : Part 1 at 28 days.

Three classes of standard strength are covered: class 32.5, class 42.5 and class 52.5.

The classification of a cement according to standard strength is indicated by the figure 32.5, 42.5 or 52.5.

NOTE 2. The early strength of cement is the compressive strength determined in accordance with BS EN 196 : Part 1 at either 2 days or 7 days.

Two subclasses of early strength are defined for standard strength classes 32.5 and 42.5, a class with ordinary early strength and a class with high early strength.

The classification of a cement according to early strength is indicated by the letter N or R, for ordinary or high early strength respectively, following the figure indicating the standard strength class.

8 Physical properties

8.1 Initial setting time

The initial setting time, determined in accordance with BS EN 196 : Part 3, shall be not less than 60 min for the 32.5N, 32.5R, 42.5N and 42.5R strength classes nor less than 45 min for the 52.5N strength class.

8.2 Soundness

The expansion, determined in accordance with BS EN 196 : Part 3, shall be not more than 10 mm.

9 Chemical properties

The properties shall conform to table 3 when tested in accordance with the tests referred to in column 2 of table 3.

10 Marking

Portland pulverized-fuel ash cements shall be marked on the bag or the delivery note, and on any test certificate, with the following particulars:

a) the name, trade mark or other means of identification of the manufacturer to facilitate traceability to the works in which the cement was manufactured;

b) the name and strength class of the material, e.g. Portland fly ash cement B, class 32.5R;

c) the number and date of this British Standard, i.e. BS 6588 : 1996[5)]

Table 3. Chemical properties

1	2	3	4
Property	**Test reference**	**Strength class**	**Requirement[1)]** % (*m/m*)
Sulfate (expressed as SO_3)	Clause **8** of BS EN 196 : Part 2 : 1995	All classes	≤ 3.5
Chloride	Clause **4** of BS EN 196 : Part 21 : 1992	All classes	≤ 0.10[2)]

[1)]Requirements are given as percentages by mass of the final cement.

[2)]BS 5328 : Part 1 and BS 8110 : Part 1 give recommendations for the maximum total chloride content of the concrete mix for various applications.

[5)]Marking BS 6588 : 1996 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity.

11 Information to be provided

11.1 Test certificate

If a test certificate is requested, it shall be provided and shall include the method of manufacture, i.e. intergrinding or dry blending, the proportion of pulverized-fuel ash to the nearest 5 % (*m/m*) and results of the following tests on samples of the cement relating to the material delivered:

a) compressive strength at either 2 days or 7 days as appropriate, and also at 28 days, obtained from tests on mortar prisms in accordance with BS EN 196 : Part 1 (see clause **6**);

b) initial setting time (see **8.1**);

c) soundness (see **8.2**);

d) chloride content (see clause **9**);

e) type and quantity of additives, if exceeding 1.0 % (*m/m*) (see **5.5**);

f) loss on ignition of pulverized-fuel ash, if exceeding 5.0 % (*m/m*) (see **5.2**).

NOTE. The certificate should be available from the manufacturer.

11.2 Additional information

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

a) the type and quantity of any minor additional constituent;

b) the fineness;

c) the silicon dioxide, aluminium oxide, iron (III) oxide, calcium oxide and magnesium oxide contents of the clinker;

d) the sulfate content expressed as SO_3 (see clause **9**);

e) an indication of the variability of the chloride content when its mean level exceeds 0.05 % (*m/m*);

f) the reactive alkali content, expressed as the certified sodium oxide equivalent averaged over the manufacturer's latest 25 consecutive composite samples, when calculated by adding one-sixth of the total alkali content of the pulverized-fuel ash constituent to the acid soluble alkali content of the other constituents, together with an indication of its variability;

g) an indication of the water soluble alkali content of the pulverized-fuel ash constituent;

h) an indication of the acid soluble alkali content of the other constituents.

12 Sampling and testing for acceptance inspection at delivery

12.1 For assessing conformity at delivery, when requested a spot sample of the cement shall be taken in accordance with **3.6** and **6.2**, **6.3**, **6.4** or **6.5** of BS EN 196 : Part 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 : Part 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 : Part 7 : 1992.

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

12.2 When the cement is tested for strength (see clause **7**), unless otherwise agreed between the purchaser and the manufacturer, the pit/quarry from which the CEN Standard sand is obtained and the compaction procedure to be used shall be those in use by the manufacturer at the time when the cement was originally tested.

12.3 When the cement is tested for chemical properties (see clause **9**) the sample shall be prepared by the method described in clause **6** of BS EN 196 : Part 2 : 1995.

12.4 The limiting values applicable to acceptance inspection shall be those given in table 4.

NOTE. These values are, in general, based on the 'major defects', defined in annex A which, however, does not contain values of deviation for strength upper limit or loss on ignition of pulverized-fuel ash.

Table 4. Acceptance inspection limits

Property		Deviation from the requirements in 5.2 and clauses 7, 8 and 9 in excess of
Strength lower limit	28 day	− 2.5 N/mm^2
	2 day (7 day)	− 2.0 N/mm^2
Strength upper limit	28 day	+ 4.0 N/mm^2
Initial setting time		− 15 min
Soundness		+ 1 mm
Sulfate content		+ 0.1 % (*m/m*)
Chloride content		+ 0.01 % (*m/m*)
Loss on ignition of pulverized-fuel ash		+ 2.0 % (*m/m*)

NOTE. The deviation for sulfate content of 0.1 % (*m/m*) in this table for acceptance inspection limits is reduced from the value of 0.5 % (*m/m*) in table A.3 for major defects.

Annexes

Annex A (informative)

Conformity criteria (cement manufacturer's autocontrol)

NOTE. This annex is based on the text of clause **10** 'Conformity criteria' from the June 1989 draft European Prestandard specification for cements, which has been retained in ENV 197-1. However, some of the details are considered to be inappropriate for the manufacture of cement in the UK and the annex therefore incorporates several footnotes identifying these aspects.

In particular, the concept of 'major defects' (see **A.6**), i.e. a non-conformity with a requirement 'which is likely to reduce materially the usability of the cement for the intended purpose', is not considered to form a meaningful part of a statistically controlled autocontrol system operated by the cement manufacturer. However, a method for assessment by the purchaser of compliance at delivery has been incorporated into clause **11**.

A.1 Introduction

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

a) a definition of the requirement in terms of characteristic value, as given in clauses **7**, **8** and **9**;

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 lower strength limits, the 5 % fractile;

c) the probability of acceptance of a lot[6] of cement 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 known as 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.

A.1.2 The conformity criteria for continuous inspection (see **A.3**, **A.4** and **A.5**) are based upon the principles of **A.1.1**. The European Prestandard specification for cements contains, however, an additional conformity criterion of a different type. In order to provide means for the rejection of cement which is likely to reduce materially the usability of the cement for the intended purpose, the prestandard specifies (see **A.6**) that a quantity of cement containing one or more so-called major defects does not conform to the requirements[7].

A.2 Application of conformity procedures

A.2.1 Conformity of cements to this standard should be continuously assessed. In consequence this standard specifies that the conformity of such cements should be verified by means of a statistical quality control scheme based upon continuous inspection of the manufactured cement. This inspection is operated by the cement producer (autocontrol).

NOTE. International or national regulations may require the autocontrol of cements 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 cement, are outside the scope of this standard.

A.2.2 The European Prestandard specification for cements does not deal with acceptance inspection at delivery[8]. However, application in this standard of the principles of statistical quality control puts some constraints on any additional acceptance inspection at delivery of cements which have been found to conform to this standard according to **A.3**, **A.4** and **A.5** on continuous inspection.

A sampling plan for additional acceptance inspection at delivery of a cement should not be allowed to increase the producer's risk of rejection to a higher value than that deduced from the scheme of continuous inspection, according to **A.3**, **A.4** and **A.5**.

Pending additional standards on acceptance and other terms of delivery for cements, specification of additional acceptance inspection at delivery has not been dealt with in the European Prestandard specification for cements.

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[6]For the purposes of this standard a lot is defined as a quantity of cement produced under conditions presumed uniform. After specified tests, this quantity is regarded as a whole 'conforming' or 'not conforming' to the requirements.

[7]For the purposes of this standard the concept of 'major defects' is not considered to be a meaningful part of a statistically controlled autocontrol system operated by the cement manufacturer (see footnote to **A.6**) which is to be assessed as in **A.7**. Clause **12** gives the method for assessment by the purchaser of conformity at delivery.

[8]Acceptance inspection at delivery has been included in this British Standard. The relevant requirements are given in clause **12** and may increase the producer's risk of rejection beyond that of the autocontrol procedure.

A.3 General procedure for assessing conformity with the characteristic values

A.3.1 The assessment should be based upon continuous sampling inspection using spot samples[9] of cement taken in accordance with BS EN 196 : Part 7.

A.3.2 The continuous inspection should take place at the cement plant and 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 except in the cases[10] of a new factory or a new type or strength class of cement at an existing factory.

Minimum testing frequencies are specified in table A.1.

Table A.1 Minimum testing frequencies

Property	Number of samples
Strength Sulfate content Initial setting time Soundness	2 per week
Chloride content	1 per month

A.3.3 An observed test value which does not conform to the appropriate values in clauses **6**, **7** and **8** is characterized as a defect. The European Prestandard distinguishes between minor and major defects. Separate limits are specified for major defects (see **A.6**).

A.4 Conformity criteria and procedure for strength

A.4.1 The strength requirements of clause **7** comprise:

28 day strength,	lower limit (L) and upper limit (U);
2 (or 7) day strength,	lower limit (L).

A.4.2 In the case of the strength requirements, the conformity procedure is based upon sampling inspection by variables[11].

In principle, the overall percentage of defects in the lot from which samples are 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 so-called acceptability constant, k_A, is used for the evaluation of conformity instead of the percentage of defects (see **A.7.2**).

A.4.3 The sampling plan (including the number of single spot samples to be taken) is established by means of the following two parameters which are tabulated in table A.2:

a) acceptable overall percentage of defects;

b) acceptable consumer's risk.

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 **A.7**. Any other plan satisfying the values in table A.2 is, in principle, acceptable for the conformity procedure.

Table A.2 Parameters determining the conformity procedure

	2 (or 7) day and 28 day strength (lower limit L)	28 day strength (upper limit U)	Physical and chemical properties (all limits)
Continuous inspection procedure	By variables	By variables	By attributes (by variables is allowed)
Percentage of defects, P_a	5 %	10 %	10 %
Consumer's risk	5 %	5 %	5 %

NOTE. In the European Prestandard specification for cements, sampling plans for additional acceptance inspection at delivery of a consignment of cement are, in accordance with **A.2.2**, chosen on the basis of the producer's risk instead of the consumer's risk.

The consumer's risk is represented by a point on the operating characteristic curve corresponding to a predetermined low probability of acceptance (in this annex, 5 %).

The producer's risk is represented by a point on the operating characteristic curve corresponding to a predetermined low probability of rejection (in this annex, 5 %).

This note is not appropriate to this British Standard.

[9] A spot sample is defined as a 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.

[10] In these cases, the period for assessing the conformity should be declared by the manufacturer on the certificate but should not be less than 2 weeks.

[11] **A.7.2** gives the relevant assessment criteria for inspection by variables.

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

A.5.1 Clauses **8** and **9** specify requirements for the following properties:

a) physical properties:

1) initial setting time;

2) soundness;

b) chemical properties:

1) sulfate content;

2) chloride content.

Conformity should be assessed for one property at a time.

A.5.2 In the case of the physical and chemical requirements, the conformity procedure is based upon sampling inspection by attributes[12].

The number of defective items is counted and compared with an estimated number of defects, calculated from the number of tests and the specified acceptable overall percentage of defects.

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

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

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

A.6 Limits for major defects[13]

A quantity of cement yielding one or more major defective samples does not conform to the requirements of the European Prestandard specification for cements.

In general terms, a major defect is defined as a deviation from the requirements in clauses **7**, **8** and **9** so large that the usability of the cement for its intended purpose is likely to be reduced and that in extreme cases even failure may be produced. Table A.3 presents a more specific definition for the different properties. If a test result deviates by more than the value in this table it is denoted major defective.

Table A.3 Major defects

Property		Deviation from the requirements in clauses 7, 8 and 9 in excess of
Strength lower limit	28 day	-2.5 N/mm^2
	2 day (7 day)	-2.0 N/mm^2
Strength upper limit	28 day	Value of deviation not specified
Initial setting time		− 15 min
Soundness		+ 1 mm
Sulfate content		+ 0.5 % (m/m)
Chloride content		+ 0.01 % (m/m)

A.7 Sampling plans

A.7.1 *General*

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

a) continuous inspection by variables;

b) continuous inspection by attributes.

The number of samples and the minimum testing frequency are specified in table A.1.

A.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.

[12] **A.7.3** gives the relevant assessment criteria to be used for inspection by attributes.

[13] The limits for major defects are not appropriate to this British Standard.

The acceptability constant k_A depends on the parameters specified in table A.2 and on the number of test results (n). Values of k_A are listed in table A.4.

Table A.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

A.7.3 *Inspection by attributes*

In this case the number c_D of defective test results (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 specified in table A.2 and on the number n of test results. Values of c_A are listed in table A.5.

Table A.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 $n \geq 110$, $c_A = 0.075\ (n - 30)$.

Annex B (informative)

Compositional requirements for all cement types

B.1 The constituents of any cement type may comprise:

a) Portland cement clinker;

b) other main constituents such as granulated blastfurnace slag, natural pozzolana, pulverized-fuel ash or limestone;

c) minor additional constituents (materials not used as a main constituent);

d) calcium sulfate (gypsum or anhydrite or other forms of calcium sulfate, or any combination of them);

e) additives.

The British Standard specifications for cement now adopt the common European convention of assuming that the sum of a), b) and c) amounts to 100 %. This is referred to as the cement nucleus. The alternative approach, which is no longer adopted in the British Standards, would regard the sum of a) to e) as amounting to 100 %.

B.2 Calcium sulfate and any additives typically amount to about 5 % (*m/m*) of the final cement and table B.1 illustrates the extreme compositional possibilities using the method of calculation given in the British Standards. The bracketed values are those which would be obtained if the calculation were based on the sum of all constituents amounting to 100 %.

B.3 It is important to note that the calculations based on the cement nucleus refer only to compositional requirements. The chemical requirements specified in the British Standards are given as percentages of the final cement, i.e. cement nucleus plus calcium sulfate and any additives.

Table B.1 Extreme compositional possibilities

All units are percentages

British Standard	Clinker (see B.1a))	Other main constituent (see B.1b))		Minor additional constituents (see B.1c))	Calcium sulfate plus additives (see B.1d) and e))
		Current edition[1)]	1985 edition		
	(Minimum)	(Maximum)	(Maximum)	(Maximum)	(Typical)
BS 12	95 (90.4)	0	0	5 (4.8)	5 (4.8)
BS 146	65 (62.0)	35 (33.2)	n.a.	1)	5 (4.8)
	35 (33.2)	65 (62.0)	(65)	1)	5 (4.8)
BS 4027	100 (95.2)	0	0	0	5 (4.8)
BS 4246	15 (14.3)	85 (80.9)	(90)	1)	5 (4.8)
BS 6588	80 (76.2)	20 (19.0)	n.a.	1)	5 (4.8)
	65 (62.0)	35 (33.2)	(35)	1)	5 (4.8)
BS 6610	45 (42.8)	55 (52.4)	(50)	1)	5 (4.8)
BS 7583	80 (76.2)	20 (19.0)	n.a.	1)	5 (4.8)

[1)]'Other main constituent' can include not more than 5 % of 'minor additional constituents'.

Annex C (informative)
Product guidance

C.1 General

Guidance on the use of Portland pulverized-fuel ash cements in concrete can be found in BS 5328 : Part 1, BS 6543, BS 8000 : Part 2 and BS 8110 : Part 1.

C.2 Safety warning

Dry cement in normal use has no harmful effect on dry skin. When cement is mixed with water, alkali is released. Precautions should therefore be taken to avoid dry cement entering the eyes, mouth and nose and to prevent skin contact with wet cement.

Repeated skin contact with wet cement over a period may cause irritant contact dermatitis. The abrasiveness of the particles of cement and aggregate in mortar or concrete can contribute to this effect. Continued contact during a working day can lead to cement burns with ulceration but this is not common. Some people are sensitive to the small amounts of chromate which may be present in cements and can develop allergic contact dermatitis, but this is rare.

When working in places where dry cement 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 cement, mortar or concrete should be removed and washed before further use.

If cement enters the eye is 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.

C.3 Storage

To protect cement from premature hydration after delivery, bulk silos should be waterproof and internal condensation should be minimized.

Paper bags should be stored clear of the ground, not more than eight bags high and protected by a waterproof structure. As significant strength losses begin after 4 weeks to 6 weeks of storage in bags in normal conditions, and considerably sooner under adverse weather conditions or high humidity, deliveries should be controlled and used in order of receipt. Manufacturers are able to provide a system of marking a high proportion of the bags in each delivery to indicate when they were filled.

C.4 Test temperature

BS EN 196 requires that the strength and setting time tests are carried out at a temperature of (20 ± 1) °C. When cement is tested at a different temperature the results are likely to be affected. Appropriate advice may be obtained from the manufacturer.

C.5 Grouting and rendering

Where cement is to be used in grouts or renders that are pumped through small apertures, such as spray nozzles, it is recommended that the user passes the cement or suspension through a screen of suitable mesh aperture to retain any occasional coarse particles.

C.6 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.

C.7 Alkali-silica reaction

Portland fly ash cement B, conforming to this standard, may be beneficial in counteracting alkali-silica reaction (see **4.2.4** of BS 5328 : Part 1 : 1991 and **6.2.5.4** of BS 8110 : Part 1 : 1985).

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 12 : 1996	*Specification for Portland cement*
BS 3892 :	*Pulverized-fuel ash*
BS 3892 : Part 1 : 1993	*Specification for pulverized-fuel ash for use with Portland cement*
BS 6100 :	*Glossary of building and civil engineering terms*
BS 6100 : Part 6:	*Concrete and plaster*
BS 6100 : Section 6.1 : 1984	*Binders*
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 196-7 : 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*

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 146 : 1996	*Specification for Portland blastfurnace cements*
BS 915 :	*Specification for high alumina cement*
BS 915 : Part 1 : 1972	*Metric units*
BS 1370 : 1979	*Specification for low heat Portland cement*
BS 4027 : 1996	*Specification for sulfate-resisting Portland cement*
BS 4246 : 1996	*Specification for high slag blastfurnace cement*
BS 4248 : 1974	*Specification for supersulphated cement*
BS 5328 :	*Concrete*
BS 5328 : Part 1 : 1991	*Guide to specifying concrete*
BS 6543 : 1985	*Guide to the use of industrial by-products and waste materials in civil engineering*
BS 6610 : 1996	*Specification for pozzolanic pulverized-fuel ash cement*
BS 7583 : 1996	*Specification for Portland limestone cement*
BS 8000 :	*Workmanship on building sites*
BS 8000 : Part 2:	*Code of practice for concrete work*
BS 8000 : Section 2.1 : 1990	*Mixing and transporting concrete*
BS 8000 : Section 2.2 : 1990	*Sitework with in situ and precast concrete*
BS 8110 :	*Structural use of concrete*
BS 8110 : Part 1 : 1995	*Code of practice for design and construction*
BS EN 196 :	*Methods of testing cement*
BS EN 196-5 : 1995	*Pozzolanicity test for pozzolanic cements*
DD ENV 197 :	*Cement. Composition, specifications and conformity criteria*
DD ENV 197-1 : 1995	*Common cements*
DD ENV 197-2 : 1996	*Conformity evaluation*

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