

BRITISH STANDARD

**BS EN
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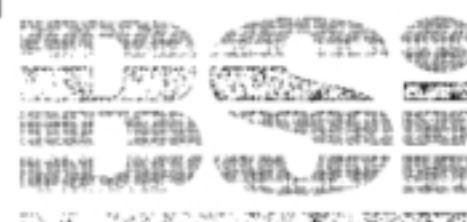
Tests for thermal and weathering properties of aggregates —

Part 4: Determination of drying shrinkage

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British Standard

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National foreword

This British Standard is the English language version of EN 1367-4:1998. It is included in a package of European Standards declared by CEN/TC 154 and it will supersede BS 812-120:1989 which, it is intended, will be withdrawn on 1999-12-01 if all the European Standards included in the package are available.

The UK participation in its preparation was entrusted by Technical Committee B/502, Aggregates, to Subcommittee B/502/6, Test methods, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

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Descriptors: Aggregates, tests, determination, thermal properties, liability to deterioration, drying, shrinkage, test specimen, sensitivity, water

English version

Tests for thermal and weathering properties of aggregates — Part 4: Determination of drying shrinkage

Essais pour déterminer les propriétés thermiques et
l'altérabilité des granulats —
Partie 4: Détermination du retrait au séchage

Prüfverfahren für thermische Eigenschaften und
Verwitterungsbeständigkeit von
Gesteinskörnungen —
Teil 4: Bestimmung der Trockenschwindung

This European Standard was approved by CEN on 19 February 1998.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 154, Aggregates, the secretariat of which is held by BSI.

Testing in accordance with this standard is intended to provide information to assist in judging the performance of aggregates subject to weathering action. This standard is intended to identify aggregates with high moisture sensitivity, which in concrete may cause excessive cracking, deflection and loss of durability. This test may not be suitable for lightweight aggregates.

This European Standard is one of a series of tests for thermal and weathering properties of aggregates as listed below.

prEN 1367-1, *Tests for thermal and weathering properties of aggregates — Part 1: Determination of resistance to freezing and thawing.*

EN 1367-2, *Tests for thermal and weathering properties of aggregates — Part 2: Magnesium sulfate test.*

prEN 1367-3, *Tests for thermal and weathering properties of aggregates — Part 3: Boiling test for "Sonnenbrenner basalt" and disintegration of steel slag.*

prEN 1367-5, *Tests for thermal and weathering properties of aggregates — Part 5: Determination of resistance to thermal shock.*

Test methods for other properties of aggregates will be covered by parts of the following European Standards:

EN 932, *Tests for general properties of aggregates.*

EN 933, *Tests for geometrical properties of aggregates.*

EN 1097, *Tests for mechanical and physical properties of aggregates.*

EN 1744, *Tests for chemical properties of aggregates.*

A European Standard *Tests for filler aggregate used in bituminous mixtures* is in course of preparation.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 1998, and conflicting national standards shall be withdrawn at the latest by December 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

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1 Scope

This European Standard specifies a method for determining the effect of aggregates on the drying shrinkage of concrete.

This standard is based on the testing of concretes of fixed mix proportions and aggregates of 20 mm maximum size.

NOTE 1 Guidance on the use of larger size is given in annex A. Precision data is not available for variations in size and for variations in the water content of the test concrete.

NOTE 2 In those cases where the drying shrinkage of a source of coarse aggregate only or a source of fine aggregate (sand) only are required, the other component to be used should be, respectively, a fine or coarse aggregate of known low shrinkage.

2 Normative references

This European Standard incorporates by dated or by undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ENV 197-1, *Cement — composition, specifications and conformity criteria — Part 1: Common cements.*

EN 932-1, *Tests for general properties of aggregates — Part 1: Methods for sampling.*

prEN 932-2, *Tests for general properties of aggregates — Part 2: Methods for reducing laboratory samples.*

prEN 932-5, *Tests for general properties of aggregates — Part 5: Common equipment and calibration.*

EN 933-2, *Tests for geometrical properties of aggregates — Part 2: Determination of particle size distribution — Test sieves, nominal size of apertures.*

3 Definitions

For the purposes of this standard, the following definitions apply:

3.1

laboratory sample

a sample intended for laboratory testing

NOTE The laboratory sample is generally the penultimate stage in a multi-stage sampling procedure.

3.2

subsample

a sample obtained from sampling increments or a bulk sample by means of a sample reduction procedure

3.3

test portion

the sample used as a whole in a single test

4 Principle

The aggregate under test is mixed with cement and water and cast into prisms of specified dimensions. The prisms are subjected to wetting followed by drying at $(110 \pm 5)^\circ\text{C}$ and the change in length from the wet to the dry state is determined. The excess drying shrinkage of the concrete is attributed to the aggregate, and is expressed as the average change in length of the prisms, as a percentage of their final dry lengths.

5 Sampling

The laboratory sample to be used for the test shall be taken in accordance with EN 932-1.

6 Apparatus

Unless otherwise stated, all apparatus shall conform to the general requirements of prEN 932-5.

6.1 Sample divider, of size appropriate to the maximum particle size to be handled or, alternatively, a flat shovel and a clean, hard horizontal surface, e.g. a metal tray for use in quartering.

6.2 Test sieves, conforming to EN 933-2, appropriate to the sizes of aggregate to be tested.

6.3 Balance, of minimum capacity 5 kg and minimum accuracy of 0,1 %.

6.4 Single or gang moulds, suitable for casting three concrete prisms of dimensions $(200 \pm 2) \text{ mm} \times (50 \pm 2) \text{ mm} \times (50 \pm 2) \text{ mm}$ with 8 mm diameter stainless steel balls or hemispherical buttons or recessed inserts, securely fixed to the centre of the inside faces of the 50 mm \times 50 mm ends of the mould.

6.5 Vibrating table, capable of fully compacting the concrete in the moulds.

6.6 Measuring apparatus, incorporating a dial gauge with scale divisions of 0,002 mm and having a maximum error of $\pm 0,002 \text{ mm}$ in any half revolution. This gauge shall be rigidly mounted in a measuring frame and shall have a recessed end which can be located upon 8 mm diameter stainless steel balls or hemispherical buttons or inserts cemented in the prisms (see 9.3). The other end of the frame shall have a similar recessed seating which can be located upon balls in the opposite end of the prisms.

A reference alloy steel rod of low thermal expansion, $(205 \pm 1) \text{ mm}$ long, with 6 mm hemispherical ends shall be used as a standard of length against which the readings of the gauge can be tested, thus enabling corrections to be made for any changes in the dimensions of the apparatus between successive measurements of the prisms. The reference rod shall be marked so that the same end can be kept uppermost during measurements.

NOTE Alternative measuring devices can be used in place of the dial gauge, e.g. linear variable differential transducers, provided they are of at least equal performance and fitted with seatings compatible with the stainless steel balls or inserts as appropriate.

6.7 Ventilated oven, thermostatically controlled and capable of maintaining temperatures of $(50 \pm 2)^\circ\text{C}$ and $(110 \pm 5)^\circ\text{C}$.

NOTE Different ovens for each temperature range can be used.

6.8 Thermometer, capable of measuring the oven temperatures of 50 °C and 110 °C to a precision of 0,5 °C.

6.9 Desiccators, large enough to contain three concrete prisms 200 mm × 50 mm × 50 mm containing anhydrous silica gel as the desiccant.

6.10 Trays, that are capable of being heated in the ventilated oven without damage or change in mass.

6.11 Timing device, such that the full range of timed periods can be measured to an accuracy of ±1 min.

6.12 Mechanical mixer, capable of mixing all constituents thoroughly within specified time limits.

NOTE Alternatively, hand mixing can be used.

6.13 Flat impervious cover sheet, of suitable size, of rubber, polythene or steel.

7 Materials

7.1 Cement, conforming to type CEM 1 Class 42,5 of ENV 197-1.

7.2 Water, distilled or de-ionized.

7.3 8 mm diameter stainless steel balls or hemispherical buttons or inserts (see 6.4).

8 Preparation of subsamples

8.1 Reduce the laboratory samples of the coarse and fine aggregate (sand) by the procedure specified in prEN 932-2 to produce subsamples that can be sieved after oven drying to give approximately 1 600 g of 10 mm to 20 mm size fraction, 800 g of 4 mm to 10 mm size fraction and 1 300 g of 0 mm to 4 mm fine aggregate (sand).

8.2 Spread the subsamples on shallow trays and dry for at least 16 h in the oven (see 6.7) set at a temperature of (50 ± 2) °C.

8.3 Reject all oversize material from the fine aggregate (sand) and all oversize and undersize material from each of the two coarse aggregate subsamples.

9 Preparation of test prisms

9.1 Proportioning

Cast three test prisms, using the amount of cement, aggregates and water required to make the three prisms as specified in Table 1.

Table 1 — Masses of constituents in test prisms

Constituent	Mass g
Cement	550 ± 5
Coarse aggregate (20 mm to 4 mm) and fine aggregate (sand)	$3\,300 \pm 5$
Water	300 ± 5

The coarse aggregate and fine aggregate (sand) shall comply with the limits specified in Table 2 and the grading curves shown in Figure 1.

Table 2 — Grading limits of aggregate in concrete prisms

Sieve size mm	Overall grading limits		
	Lower % passing	Preferred % passing	Upper % passing
20	100	100	100
16	76	82	92
14	65	69	83
12,5	60	64	78
11,2	56	60	76
10	50	55	70
8	41	46	61
5,6	32	38	52
4	26	30	43
2	20	22	33
1	14	17	25
0,5	10	12	18
0,25	5	8	12
0,125	0	2	6

9.2 Mixing and casting

9.2.1 Mix the concrete for the three prisms using a suitable small laboratory mechanical mixer. Initially mix the cement and fine aggregate (sand) dry for 2 min minimum. Add the coarse aggregate and mix dry until the mixture is uniform. Add the water and mix for 2 min to 3 min.

9.2.2 Transfer the concrete to the moulds, single or ganged, and use a vibrating table to compact the concrete in the moulds in two approximately equal layers for sufficient time to achieve full compaction. If full compaction cannot be achieved the test shall be abandoned.

9.2.3 On completion of the compaction of the concrete, smooth the surfaces of the prism with a trowel.

9.3 Storage of prisms

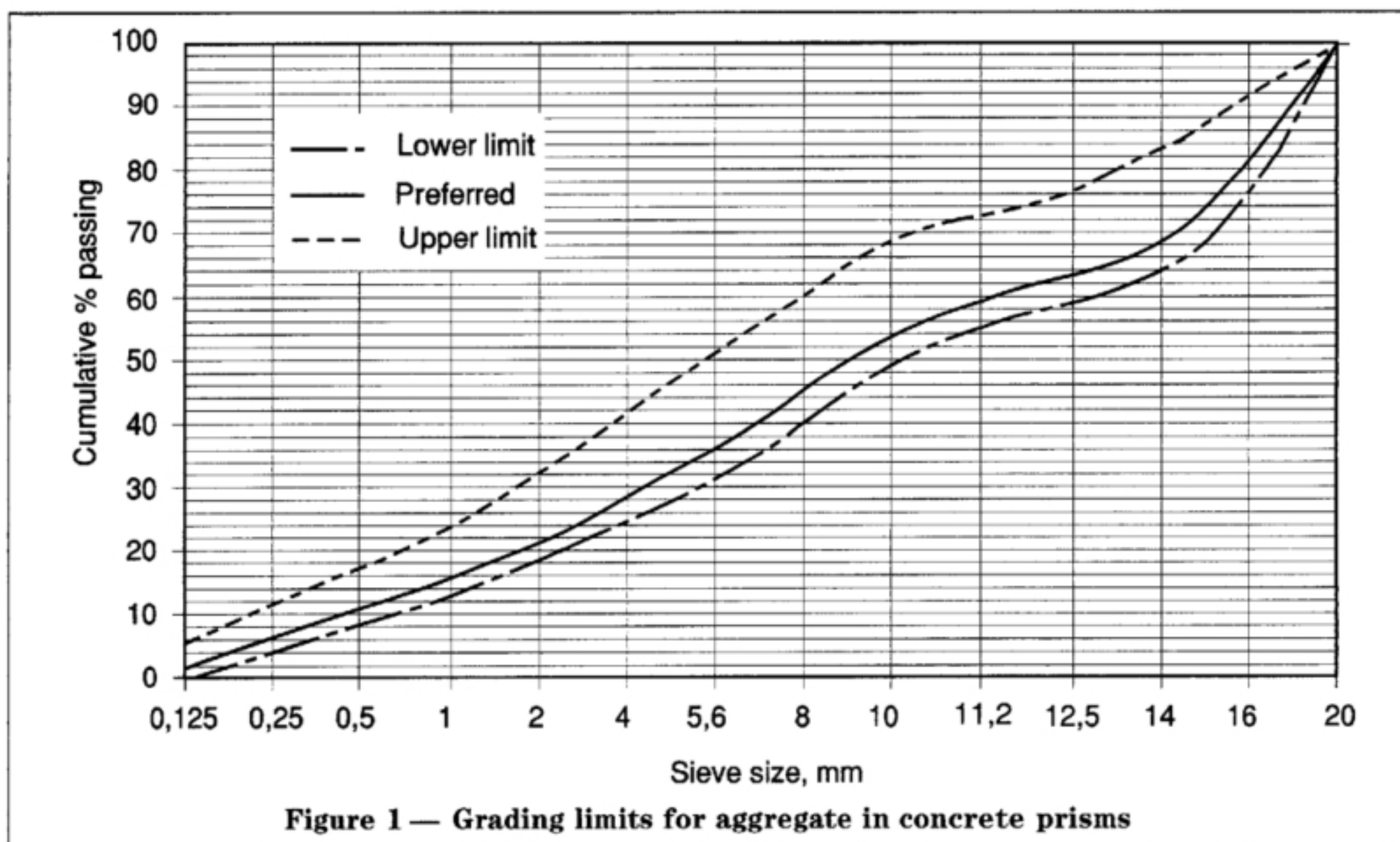
9.3.1 Immediately after completion of compaction, cover the prisms with a flat impervious sheet (e.g. thin rubber, polyethylene or steel) making contact with the upper edges of the moulds. Leave the prisms in this condition for (24 ± 2) h at an ambient temperature of (20 ± 2) °C.

9.3.2 After (24 ± 2) h, number the prisms for identification and designate one end of each as the top, ensuring that this end is always uppermost during subsequent measurements.

9.3.3 Demould the prisms. Where inserts are not used, cement stainless steel balls 8 mm in diameter into the indentations at the ends of the prisms.

NOTE A cement/water grout has been found satisfactory for cementing balls in place. More than half of each ball should be embedded in the grout to aid retention.

9.3.4 Place the prisms in a fog room with greater than 95 % relative humidity or place damp hessian over the prisms and cover with a polyethylene sheet for a further (24 ± 2) h at an ambient temperature of (20 ± 2) °C after which, wipe the surface of the balls, hemispherical buttons or inserts clean.



10 Procedure

10.1 Carry out all measurement at a temperature of $(20 \pm 2)^\circ\text{C}$. At the time periods specified in **10.2** and **10.3**, measure each prism using the apparatus specified in **6.6** by placing the prism (with the top uppermost as marked) in the frame and obtain a minimum reading to the nearest division while slowly rotating the prism. Before and after each measurement, check the length of the measuring apparatus against the reference rod and if the difference in these readings is greater than 0,002 mm, re-measure the prisms. Record the measured difference in length between the prism and the reference rod to the nearest 0,002 mm.

10.2 Within (48 ± 2) h of completion of compaction of the prisms immerse the prisms in water at a temperature of $(20 \pm 2)^\circ\text{C}$ for (120 ± 2) h. Then remove the prisms from the water, wipe the balls, hemispherical buttons or inserts with a clean dry cloth and measure each prism as described in **10.1**, recording the difference in length (w) between each prism and the reference rod. Place the prisms in an oven (see **6.7**) at a temperature of $(110 \pm 5)^\circ\text{C}$ ensuring that there is free access of air to all sides of the prisms.

10.3 After (72 ± 2) h, remove the prisms from the oven and allow them to cool in the desiccator for (24 ± 2) h. Measure each prism as specified in **10.1**, recording the difference in length (d) between each prism and the reference rod.

10.4 After the dry measurement has been taken, measure the actual length of the prisms adjacent to the balls, hemispherical buttons or inserts to the nearest millimetre and record this as the dry length (l).

11 Calculation and expression of results

11.1 Calculate drying shrinkage (S) of each prism as a percentage from the expression:

$$S = \frac{(w - d)}{l} \times 100$$

where:

- w is the initial measurement (wet), in millimetres;
- d is the dry measurement, in millimetres;
- l is the dry length, in millimetres.

11.2 Express the drying shrinkage as the average of the three determinations to the nearest 0,001 %.

11.3 If the range between the shrinkage values of individual prisms exceeds 0,006 mm and 12 % of the average drying shrinkage, the test shall be deemed to be unsatisfactory and a further test shall be carried out using fresh prisms.

12 Test report

The test report shall be accompanied by an affirmation that the drying shrinkage was determined in accordance with this standard.

The test report shall include the following additional information:

- a) the source, type and sizes of aggregate submitted for test;
- b) the source, type and sizes of aggregates used, if any, as the other components;
- c) date of test and name of laboratory.

Annex A (informative)

Conditions of larger aggregate size

Aggregates larger than 20 mm may be used if the linear dimensions of the test prisms are increased in proportion to the maximum size of aggregate used, and the sample size and concrete mix proportions increased accordingly. For appreciable increases in size longer wetting and drying times may be necessary. The precision data in annex B does not apply to this variation.

Annex B (informative)

Precision

B.1 An experiment involving 10 laboratories was carried out in 1985 on one aggregate combination. A representative sample (laboratory sample) was taken from a stockpile of each of the three size fractions required. The identical procedure was repeated 19 times to produce a total of 20 laboratory samples for each size fraction. Two laboratory samples randomly selected from each fraction were sent to each participating laboratory. Each was asked, using the same representative sampling procedure, to prepare two test portions from each laboratory sample, and then to make batches of prisms using one test portion of each size fraction in each batch. The data from the experiment were analyzed following the principles set out in ISO 5725:1986 and the results from one batch of prisms from one laboratory were rejected because the between-prism range was an outlier.

B.2 Precision data are given in Table B.1 for the case when a "test result" consists of the average shrinkage of three prisms from one batch. Definitions of r_1 , R_1 and R_2 are given in prEN 932-6.

Table B.1 — Precision estimates

Average shrinkage (S) %	r_1 %	R_1 %	R_2 %
0,1150	0,0107	0,0251	0,0252

Any variation arising through differences in the performance of the drying oven from one run to the next, or any other long-term variations which may arise between one test and the next, will have contributed to R_1 and R_2 in Table B.1 but not to r_1 .

B.3 The precision data in Table B.1 relate only to a single level of shrinkage, 0,115 %. Other precision data for a closely related method of test support the assumption that the precision coefficients vary in proportion to the level of the results, so the 95 % confidence limits can be calculated as the test result plus or minus a percentage of the test result.

B.4 Based on $R_2 / \sqrt{2}$ from Table B.1 expressed as a percentage of 0,115, the 95 % confidence limits should be calculated as the test result plus or minus 15,5 % of the test result.

Annex C (informative)

Bibliography

prEN 932-6, *Tests for general properties of aggregates — Part 6: Definitions of repeatability and reproducibility*

ISO 5725:1986, *Precision of testing methods — Determination of repeatability and reproducibility by inter-laboratory tests*.