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Testing aggregates —

Part 120: Method for testing and classifying drying shrinkage of aggregates in concrete

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee (CAB/-) to Technical Committee CAB/2, upon which the following bodies were represented:

Aggregate Concrete Block Association
Association of Consulting Engineers
Association of Consulting Scientists
Association of Lightweight Aggregate Manufacturers
Brick Development Association
British Aggregate Construction Materials Industries
British Cement Association
British Ceramic Research Ltd.
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Contents

Foreword

This Part of BS 812, prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee, forms part of a general revision that is being made of the 1975 edition of BS 812. As each of the tests, or collection of related tests, is prepared, it is intended to issue it as a separate Part or Section of BS 812.

This Part contains the test procedure for the determination of the drying shrinkage of aggregates. The test was not included in previous editions of BS 812 but has now been included because there is a need to identify "shrinkable aggregates". The increased shrinkage of concrete made with such aggregates may cause problems in structures whose design is based on the properties of "normal" concrete. Concrete made with such aggregates may also be less durable than equivalent "normal" concrete.

The test has its origins in a method developed at the Building Research Establishment and which is described in BRE Digest 35 (1968 edition). The present test offers considerable advantages as it is a simpler procedure and the results are available in much less time. The precision of both the original BRE Digest 35 test and the procedure described here have been determined. They are not judged good enough to justify the four classifications suggested in BRE Digest 35 and a simpler classification into two categories is therefore included in appendix A. It is important to note that the results of the procedure described here differ from those produced by the Digest 35 method and the classifications in Digest 35 should not be applied to the results of the Part 120 procedure. It is intended that Digest 35 will be withdrawn and a new BRE Digest on the drying shrinkage of aggregates issued taking account of the BS 812-120 method and classification and suggesting a method for testing aggregates which fall outside the scope of BS 812-120.

It is intended that BS 812 test methods should be called up by other British Standards as the basis for compliance. Nevertheless, it is *not* intended that all aggregates should be subjected regularly to all the listed tests. Requirements in other British Standard specifications will refer only to the relevant test methods.

Some of the tests in other Parts of BS 812 are of limited application, and advice on the use of simple tests is given, for example, when they can be used for a preliminary sorting of aggregates to see whether more expensive testing is justified.

Reference should be made to BS 812-101:1984 for general guidance on testing aggregates, precision of test methods and variance arising from sampling errors.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 812 describes the method for classifying the drying shrinkage of aggregates for use in concrete. It applies to aggregate combinations where the coarse aggregate nominal maximum size does not exceed 20 mm and uses concrete prisms made with the coarse and/or fine aggregate to be tested.

NOTE 1 In those cases where the drying shrinkage of a source of coarse aggregate only or a source of fine aggregate only is required, the other component to be used should be, respectively, a fine or coarse aggregate of known low shrinkage.

NOTE 2 Aggregates are generally used in a moist condition. However, this procedure uses constant mass proportions and aggregates prepared in an oven dry condition to minimize practical difficulties in carrying out the test. This may have an influence on the shrinkage value obtained and makes the method inappropriate for determining the shrinkage of particular concrete mixes.

The use of constant mass proportions imposes some restriction on the applicability of the procedure. Experience is limited to aggregates having oven dry particle densities not less than 2 450 kg/m^3 and to aggregate combinations in which the weighted combined water absorption is not greater than 3.5 % by mass when tested according to BS 812-107. Caution is necessary when interpreting results for aggregates with properties outside these values or where difficulty is experienced in compacting the specimens but advice on testing such aggregates will be given in a new BRE Digest on the shrinkage of natural aggregates in concrete (see foreword).

NOTE 3 The titles of the publications referred to in this standard are listed on inside back cover.

2 Definitions

For the purposes of this Part of BS 812 the definitions given in BS 812-101 and BS 812-102 apply.

3 Principle

Some aggregates change volume considerably from the wet to the dry state and this may affect the concrete in which they are incorporated. The drying shrinkage of a concrete containing such aggregate can be as much as four times greater than that of concrete made with non-shrinkable aggregate. To determine the drying shrinkage of the aggregate under test it is mixed with cement and water and cast into prisms of specified dimensions. The prisms are subjected to wetting followed by drying at 105 °C and the change in length from the wet to dry state determined. The drying shrinkage of the aggregate is then calculated as the average change in length of the prisms as a percentage of their final dry lengths.

4 Sampling

The samples used for the test (the laboratory samples) shall be taken in accordance with clause 5 of BS 812-102:1984.

5 Apparatus

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

NOTE A suitable divider is the riffle box illustrated in BS 812-102.

5.2 *Test sieves* of the sizes and apertures appropriate to the nominal size of aggregate to be tested. The test sieves shall comply with BS 410.

5.3 *A balance* of minimum capacity 5 kg having scale divisions of 1 g and having an error not greater than 2 g.

5.4 *A gang mould* suitable for casting three concrete prisms of dimensions 200 ± 2 mm × 50 ± 2 mm × 50 ± 2 mm with a hemispherical button 8 mm diameter securely fixed to the centre of the inside faces of the 50 mm × 50 mm ends of mould.

NOTE It is permissible for reference pieces (inserts) to be used as an alternative to cementing steel balls (see **6.3**) in the prisms. Typical details of inserts are given in Figure 5, method 5 of BS 1881-5:1970. If inserts are used the seatings of the measuring apparatus are required to be hemispherical, 6 mm in diameter, and the ends of the invar rod (see **5.6**) to be the same shape as that of the inserts.

5.5 *A vibrating table* complying with BS 1881-108:1983.

5.6 *Measuring apparatus* which shall incorporate a dial gauge with scale divisions of 0.002 mm having a maximum error of ± 0.002 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 6 mm diameter stainless steel balls cemented in the prisms (see **8.3**). 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. An invar steel rod, 205 ± 1 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 invar steel rod shall be marked so that the same end can be kept uppermost during measurements.

NOTE It is permissible for alternative measuring devices to 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.

5.7 *A well-ventilated oven,* thermostatically controlled and capable of maintaining temperatures of 50 ± 2 °C and 105 ± 2 °C. A thermometer complying with the requirements of BS 593 shall be used to verify the temperature.

NOTE It is permissible to use different ovens for each temperature range.

5.8 *A desiccator* large enough to contain three concrete prisms 200 mm × 50 mm × 50 mm containing anhydrous silica gel as the desiccant.

5.9 *Trays,* that can be heated in the ventilated oven without damage or change in mass.

6 Materials

6.1 Ordinary Portland cement complying with the requirements of BS 12.

6.2 Water of drinkable quality.

6.3 6 mm diameter stainless steel balls, or inserts (see note to **5.4**).

7 Preparation of aggregate test portions

7.1 Reduce the laboratory samples of coarse and fine aggregate by the procedure described in clause **6** of BS 812-102:1984 to produce sub-samples that can be sieved after oven drying to give approximately 1 600 g of 20 mm to 10 mm size fraction, 800 g of 10 mm to 5 mm size fraction and 1 300 g of fine aggregate.

7.2 Spread the sub-samples on shallow trays and dry for at least 16 hours in the oven (see **5.7**) set at a temperature of 50 °C.

7.3 Reject all oversize and undersize from the coarse aggregate to give fractions all passing the 20 mm sieve and retained on the 10 mm sieve, and all passing the 10 mm sieve and retained on the 5 mm sieve. Reject from the fine aggregate all aggregate retained on the 5 mm sieve.

8 Preparation of test specimens

8.1 Proportioning

Cast three test prisms, using the amount of cement, aggregates and water required to make the three prisms as follows:

Ordinary Portland cement	550 ± 5 g
Coarse aggregate (10 mm to 20 mm)	1 466 ± 5 g
Coarse aggregate (5 mm to 10 mm)	734 ± 5 g
Fine aggregate (5 mm)	1 100 ± 5 g
Water	330 ± 5 g

8.2 Mixing

8.2.1 Mix the concrete for the three prisms on a non-porous surface which has been wiped over with a damp cloth. Mix the cement and fine aggregate dry for 1 min with two trowels. Add the coarse aggregate and mix dry until the mixture is uniform. Add the water and mix the whole for 3 min with two trowels.

8.2.2 Transfer the concrete to the gang mould and use as a vibrating table to compact the concrete in the mould in two approximately equal layers, for sufficient time to achieve full compaction.

8.2.3 On completion of the compaction of the concrete, smooth the surfaces of the prisms with a trowel.

8.3 Storage of specimens

8.3.1 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 ± 5 °C.

8.3.2 After 24 ± 2 h, number the prisms for identification and designate one end of each as the top, this end always being uppermost during subsequent measurements.

8.3.3 Demould the prisms. Where inserts are not used, cement stainless steel balls 6 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.

8.3.4 Then place damp hessian over the prisms and cover with a polyethylene sheet for a further 24 ± 2 h at an ambient temperature of 20 ± 5 °C after which, wipe the surface of the balls clean, or where inserts have been used, wipe the ends of the inserts clean.

9 Test procedure

9.1 Carry out all measurements at a temperature of 20 ± 1 °C.

Measure each prism using the apparatus specified in **5.6** by placing the prism uppermost (previously marked) in the frame and obtaining 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 invar rod and if the difference in these readings is greater than 0.002 mm remeasure the prisms. Record the measured difference in length between the prism and the invar rod to the nearest 0.002 mm.

9.2 Within 48 ± 2 h of completion of compaction of the prisms immerse the prisms in water at a temperature of 20 ± 2 °C for 5 days ± 4 h. Then remove the prisms from the water, wipe the balls or inserts with a clean dry cloth and measure the length (w) of each prism as described in **9.1** before placing them in an oven (see **5.7**) at a temperature of 105 ± 2 °C. Ensure that there is free access of air to all sides of the prisms.

9.3 After 3 days ± 4 h, remove the prisms from the oven and allow them to cool until they have reached a temperature of 20 ± 1 °C in the desiccator. Measure the length (d) of each prism as described in **9.1**.

NOTE Cooling is likely to take most of a working day.

9.4 After the dry measurement has been taken, measure the length of the prisms adjacent to the balls or inserts to the nearest millimetre and take this as the dry length (l).

10 Calculation and expression of results

10.1 The drying shrinkage (S) of each prism is calculated as a percentage from the expression:

$$S = 100 \left\{ \frac{\langle w - d \rangle}{l} \right\}$$

where

w is the original wet measurement (in mm)

d is the dry measurement (in mm)

l is the dry length of the prism (in mm).

10.2 Express the drying shrinkage of the aggregate as the average of the three determinations to the nearest 0.001 %.

10.3 If the range between the shrinkage values of individual prisms exceeds the greater of 0.010 mm or 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.

11 Precision

11.1 An experiment involving 10 laboratories was carried out. The material tested consisted of three grades of aggregates. The laboratory samples were obtained by taking samples, from stockpiles of three grades, using the sampling procedure described in BS 812-102. Two randomly selected laboratory samples of each grade were sent to each participant, who was asked to prepare two test portions from each laboratory sample, using the sample reduction procedure described in BS 812-102, and then to make batches of prisms using one test portion of each grade in each batch. The data from the experiment were analysed following the principles set out in BS 5497-1.

11.2 The tests for outliers given in BS 5497-1 were applied to the data. The results from one batch of prisms from one laboratory were rejected because the between-prism range was an outlier.

11.3 Definitions of r_1, R_1 and R_2, and of V_{r1}, V_L and V_s are given in BS 812-101. For Table 1, r_1 has been calculated for the case when a "test result" consists of the average shrinkage of three prisms from one batch. 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 1 but not to r_1. Data on the precision of the BRE Digest 35 method which correlates well with this method suggests that the precision estimates vary in proportion to the average: this allows the precision at levels other than those examined in the experiment to be inferred from Table 1.

11.4 Use of the precision data are described in clause **5** of BS 812-101:1984.

11.5 The 95 % confidence limits shall be calculated as the test result plus or minus 15.5 % of the test result.

11.6 The precision data in Table 1 relate only to a single level of shrinkage, 0.115 %. Other precision data obtained on the BRE Digest 35 method support the assumption that the precision coefficients vary in proportion to the level of the results, so the calculation described in **11.5** may be used at levels of shrinkage other than 0.115 %. The value of 15.5 % in **11.5** is $R_2/\sqrt{2}$ expressed as a percentage of 0.115. It is appropriate when the test result is calculated as the average shrinkage of three prisms.

Table 1 — Precision estimates (%)

Experiment date	Average	r_1	R_1	R_2	$\sqrt{V_{r1}}$	$\sqrt{V_L}$	$\sqrt{V_S}$
1985	0.1150	0.0107	0.0251	0.0252	0.0038	0.0081	0.0010

12 Test report

The test report shall affirm that the drying shrinkage was determined in accordance with this Part of BS 812 and whether or not a certificate of sampling is available. If available, a copy of the certificate of sampling shall be provided.

The test report shall include the following additional information:

a) The drying shrinkage of the aggregate and the 95 % confidence limits calculated as in **11.5**.

b) The source, type and sizes of aggregate submitted for test.

c) The source, type and sizes of aggregate used, if any, as the other component(s).

Appendix A Classification of aggregate shrinkage

On the basis of the drying shrinkage determined using the procedure described in this Part of BS 812, aggregates with drying shrinkage up to and including 0.075 % should be classified as category A and aggregates with drying shrinkage exceeding 0.075 % should be classified as category B.

The uses for which aggregates in these categories are suitable and minimum frequencies of test are given in Table 2 and Table 3.

Table 2 — Categories of use

Category	Range of values	Use
A	0 to 0.075 %	All concreting purposes[a]
B	Greater than 0.075 %	Positions where complete drying out never occurs. Mass concrete surfaced with air entrained concrete. Members symmetrically and heavily reinforced not exposed to the weather.

[a] Guidance on structural design in respect of drying shrinkage of concrete is provided in section seven of BS 8110-2.
BS 1881-5 provides a method of assessing drying shrinkage of concrete.
Design checks to ensure deflections are not excessive may be needed when aggregates with drying shrinkage in excess of 0.06 % are used in very eccentrically prestressed concrete.

Table 3 — Recommended minimum testing frequency

Range of values	Frequency
0 to 0.05 %	Once every 5 years, provided essential character of material does not change
Greater than 0.05 %	Annual

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Publications referred to

BS 12, *Specification for ordinary and rapid-hardening Portland cement.*

BS 410, *Specification for test sieves.*

BS 593, *Specification for laboratory thermometers.*

BS 812, *Testing aggregates.*

BS 812-101, *Guide to sampling and testing aggregates.*

BS 812-102, *Methods for sampling.*

BS 907, *Specification for dial gauges for linear measurement.*

BS 1881, *Testing concrete.*

BS 1881-5, *Methods of testing hardened concrete for other than strength.*

BS 1881-108, *Method for making test cubes from fresh concrete.*

BS 5497, *Precision of test methods.*

BS 5497-1, *Guide to the determination of repeatability and reproducibility for a standard test method by inter-laboratory tests.*

BS 8110, *Structural use of concrete.*

BS 8110-2, *Code of practice for special circumstances.*

Building Research Establishment Digest No. 35 (New edition 1968) Shrinkage of natural aggregates in concrete.

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