BRITISH STANDARD

Incorporating
Amendments Nos. 1
and 2

Testing aggregates

Part 2. Methods of determination of density

Corrected and reprinted, March 1999

Correction

Page 3 In **5.4.4** 2nd para., the second word "apparent" should be deleted.

ICS 91.100.15

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee B/502, Aggregates, upon which the following bodies were represented:

Aggregate Concrete Block Association
Association of Consulting Engineers
Association of Lightweight Aggregate Manufacturers
British Aggregate Construction Materials Industries
British Cement Association
British Civil Engineering Test Equipment Manufacturers' Association
British Geological Sciences
British Iron and Steel Producers' Association
British Precast Concrete Federation Ltd.
British Ready Mixed Concrete Association
County Surveyors' Society
Department of the Environment
Department of the Environment (Building Research Establishment)
Department of Transport
Department of Transport (Transport Research Laboratory)
Electricity Association
Institute of Concrete Technology
Institution of Civil Engineers
Institution of Highways and Transportation
Institution of Structural Engineers
Local Authority Organizations
Sand and Gravel Association Limited
Society of Chemical Industry

The following bodies were also represented in the drafting of this standard, through subcommittees and panels:

Department of Trade and Industry (National Measurement Accreditation Service)
Department of Transport (Highways Agency)

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Summary of pages

The following table identifies the current issue of each page. Issue 1 indicates that a page has been introduced for the first time by amendment. Subsequent issue numbers indicate an updated page. Vertical sidelining on replacement pages indicates the most recent changes (amendment, addition, deletion).

Page	Issue	Page	Issue
Front cover	3	4 to 9	original
Inside front cover	3	10	3
a	3	11	original
b	blank	12	original
i	original	13	2
ii	2	14	original
1	original	Inside back cover	original
2	original	Back cover	3
3	4		

b
blank

Contents

Foreword

This Part of BS 812 has been prepared by Technical Committee B/502. This edition introduces technical changes but does not reflect a full review or revision of the standard. Work on testing procedures for aggregates is being carried out in Europe under the auspices of CEN/TC 154, Aggregates. The methods described in this Part of BS 812 are included in the programme of work of CEN/TC 154 and will be superseded by European Standards which will be published in due course.

This standard supersedes BS 812 : Part 2 : 1975, which is withdrawn.

In this edition, for health and safety reasons, the use of toluene has been replaced by the use of kerosene in the method for the determination of bulk density of filler. The tests described in this Part are now based on particle density rather than relative density and, because the determination of moisture content of aggregates, formerly included in this Part, is now covered by BS 812 : Part 109, the title of the 1975 edition, *Methods for determination of physical properties* is no longer appropriate and has been amended to reflect the revised content. The opportunity has also been taken to update references to other Parts of BS 812 that have been published following the 1975 revision of this Part. BS 812 comprises the following Parts:

Part 100	*General requirements for apparatus and calibration*
Part 101	*Guide to sampling and testing aggregates*
Part 102	*Methods for sampling*
Part 103	*Methods for determination of particle size distribution*
Part 104	*Method for qualitative and quantitative petrographic examination of aggregates*
Part 105	*Methods for determination of particle shape*
Part 106	*Method for determination of shell content in coarse aggregate*
Part 109	*Methods for determination of moisture content*
Part 111	*Methods for determination of ten per cent fines values (TFV)*
Part 112	*Methods for determination of aggregate impact value (AIV)*
Part 113	*Method for determination of aggregate abrasion value (AVV)*
Part 114	*Method for determination of the polished-stone value*
Part 117	*Method for determination of water-soluble chloride salts*
Part 118	*Methods for determination of sulphate content*
Part 119	*Method for determination of acid-soluble material in fine aggregate*
Part 120	*Method for testing and classifying drying shrinkage of aggregates in concrete*
Part 121	*Method for determination of soundness*
Part 124	*Method for determination of frost-heave*

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Methods

1 Scope

This Part of BS 812 describes methods for the determination of the particle density, water absorption, bulk density, voids and bulking of aggregates and of the particle density, bulk density and voids of filler.

Some of the tests are intended for use in obtaining assurance that material complies with British Standard or other requirements, for research, production control or assessment of variation. However, other methods are not intended for assurance testing and their suitability for other purposes is defined.

NOTE. The density terms used are defined in clause **2** of BS 812 : Part 100 : 1990.

2 References

2.1 Normative references

This Part of BS 812 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 812 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 812 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 Reporting

3.1 General

The report shall affirm that the tests were done in accordance with this standard. Any departure from the specified test procedure shall be described with reasons for the departure and, if possible, estimates of its effect on the test results. The report shall also include details of any special processing of the sample, other than that required by the test methods, carried out in the laboratory, e.g. crushing to provide larger quantities of smaller sizes or the separation of constituents from an as-dug gravel.

3.2 Certificate of sampling

The report shall affirm that a certificate of sampling was received with the sample and shall declare all the information given on the certificate. If a certificate was not received this shall be stated in the report.

4 Significance of results

The distribution of the results of any test on any material stems from a number of contributing factors. In assessing the significance of the results the repeatability and reproducibility of the test should be recognized. Estimates of these are given in annex A and should be used in assessing test results.

5 Determination of particle densities and water absorption

5.1 General

Three main methods are described for aggregates, a wire basket method for aggregates larger than 10 mm, a gas jar method for aggregates between 40 mm and 5 mm and a pyknometer or gas jar method for aggregates 10 mm nominal size and smaller. A buoyancy method using a bucket, as described in BS 1881, is allowed as an alternative for aggregates between 40 mm and 5 mm nominal size.

The method for filler is by use of a density bottle.

As with any porous material the value obtained for the particle density of an aggregate depends on the details of the method of test. Furthermore, different sizes of the same aggregate often have different values of particle density and absorption. Therefore, when comparing different aggregates it is essential that the test be made on samples sensibly of the same grading.

The wire basket method for aggregates larger than 10 mm is not suitable for testing friable aggregates which may break down during the test, and therefore the gas jar method for aggregates between 40 mm and 5 mm should be used for such material.

5.2 Sampling

The sample for these tests shall be taken in accordance with BS 812 : Part 102.

5.3 Method for aggregates all larger than 10 mm

5.3.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

5.3.1.1 *Balance*, of capacity not less than 3 kg, accurate to 0. 5 g, and of such a type and size as to permit the basket containing the sample to be suspended from the beam and weighed in water.

5.3.1.2 *Well ventilated oven*, thermostatically controlled to maintain a temperature of $105\,°C \pm 5\,°C$.

5.3.1.3 *Wire mesh basket*, having apertures not larger than 6.5 mm, or a perforated container of convenient size, preferably chromium plated and polished, with wire hangers (not thicker than 1 mm) suspending it from the balance.

5.3.1.4 *Stout watertight container*, in which the basket may be freely suspended.

5.3.1.5 *Two dry soft absorbent cloths*, each no less than 750 mm × 450 mm.

5.3.1.6 *Shallow tray*, of area not less than 0.065 m^2.

5.3.1.7 *Airtight container*, of similar capacity to the basket.

5.3.1.8 10 mm *BS test sieve* (see **5. 4** of BS 812 : Section 103.1 : 1985).

5.3.1.9 *Supply of water*, free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

5.3.2 *Sample for test*

A sample of not less than 2 kg of aggregate shall be tested. Aggregates which have been artificially heated shall not normally be used; if such material is used, the fact shall be stated in the report. Two tests shall be made.

The sample for test shall be thoroughly washed on the test sieve to remove finer particles and drained.

5.3.3 *Test procedure*

Place the prepared test sample in the wire basket and immerse it in the water (**5.3.1.9**) at a temperature of 20 °C ± 5 °C with a cover of at least 50 mm of water above the top of the basket.

Immediately after immersion remove the entrapped air from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at a rate of about one per second. The basket and aggregate shall remain completely immersed during this operation and for a period of 24 h ± 0.5 h.

Again jolt the basket and sample and weigh them in water at a temperature of 20 °C ± 5 °C. If it is necessary for them to be transferred to a different tank for weighing, jolt them 25 times as described above in the new tank before weighing (mass *B*).

Then remove the basket and aggregate from the water and allow them to drain for a few minutes, after which gently empty the aggregate from the basket on to one of the dry cloths, and return the empty basket to the water, jolt it 25 times and weigh it in water (mass *C*).

With the cloth, gently surface-dry the aggregate placed on the dry cloth, transferring it to a second dry cloth when the first will remove no further moisture. Then spread it out not more than one stone deep on the second cloth, and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed, but the aggregate still has a damp appearance. Weigh the aggregate (mass *A*) . If the apparent particle density only is required the operations described in this paragraph may be omitted.

Place the aggregate in the oven in the shallow tray at a temperature of 105 °C ± 5 °C and maintain it at this temperature for 24 h ± 0.5 h. Then remove it from the oven, cool it in the airtight container, and weigh it (mass *D*). If the particle density on a saturated and surface-dried basis only is required, the operations described in this paragraph may be omitted.

5.3.4 *Calculations*

The particle density on an oven-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{D}{A - (B - C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{A}{A - (B - C)}$$

The apparent particle density (in Mg/m^3) is calculated from the formula:

$$\frac{D}{D - (B - C)}$$

The water absorption (as % of dry mass) is calculated from the formula:

$$\frac{100 \, (A - D)}{D}$$

where

A is the mass of the saturated surface-dry aggregate in air (in g);

B is the apparent mass in water of the basket containing the sample of saturated aggregate (in g);

C is the apparent mass in water of the empty basket (in g);

D is the mass of the oven-dried aggregate in air (in g).

5.3.5 *Reporting of results*

The mean result shall be reported for each form of particle density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title 'particle density' be used in relation to any values quoted. The size of aggregate tested, and whether it was artificially heated before the start of the test shall be stated. Values of particle density shall be reported to the nearest 0.01 Mg/m^3 and those for water absorption to the nearest 0.1 %.

5.4 Method for aggregates between 40 mm and 5 mm

5.4.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

5.4.1.1 *Balance,* of capacity not less than 3 kg, accurate to 0. 5 g and of such a type as to permit weighing of the vessel containing the aggregate and water.

5.4.1.2 *Well ventilated oven,* thermostatically controlled to maintain a temperature of 105 °C $\pm$ 5 °C.

5.4.1.3 *Wide-mouthed glass vessel,* such as a gas jar, of 1.0 l to 1.5 l capacity, with a flat ground lip and a plane-ground disc of plate glass to cover it, giving a watertight fit.

5.4.1.4 *Two dry soft absorbent cloths,* each not less than 750 mm $\times$ 450 mm.

5.4.1.5 *Shallow tray,* of area not less than 0.03 m^2.

5.4.1.6 *Airtight container,* large enough to take the sample.

5.4.1.7 5.0 mm *BS test sieve* (see **5.4** of BS 812 : Section 103.1 : 1985).

5.4.1.8 *Supply of water,* free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

5.4.2 *Sample for test*

A sample of about 1 kg of the aggregate shall be used. Aggregates which have been artificially heated shall not normally be used; if such material is used, the fact shall be stated in the report. Two tests shall be made. The sample for test shall be thoroughly washed on the test sieve to remove finer particles and drained.

5.4.3 *Test procedure*

Immerse the prepared test sample in water in the glass vessel; it shall remain immersed at a temperature of 20 °C $\pm$ 5 °C for 24 h $\pm$ 0.5 h. Soon after immersion and again at the end of the soaking period, remove air entrapped in, or bubbles on the surface of, the aggregate by gentle agitation. This may be achieved by rapid clockwise and anti-clockwise rotation of the vessel between the operator's hands.

Overfill the vessel by adding water and slide the plane-ground glass disc over the mouth so as to ensure that no air is trapped in the vessel. Then dry the vessel on the outside and weight it (mass B).

Then empty the vessel and allow the aggregate to drain while the vessel is refilled with water, sliding the glass disc into position as before. Then dry the vessel on the outside and weigh it (mass C).

The difference in the temperature of the water in the vessel during the first and second weighings shall not exceed 2 °C.

Place the aggregate on a dry cloth and gently surface-dry it with the cloth, transferring it to a second dry cloth when the first will remove no further moisture. Then spread it out not more than one stone deep on the second cloth and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed but the aggregate still has a damp appearance. Weigh the aggregate (mass A). If the apparent particle density only is required the operations described in this paragraph may be omitted.

Place the aggregate in the shallow tray in the oven at a temperature of 105 °C $\pm$ 5 °C for 24 h $\pm$ 0.5 h. Then cool it in the airtight container and weight it (mass D). If the particle density on a saturated and surface-dried basis only is required, the operations described in this paragraph may be omitted.

5.4.4 *Calculations*

The particle density on an oven-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{D}{A - (B - C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{A}{A - (B - C)}$$

The apparent particle density (in Mg/m^3) is calculated from the formula:

$$\frac{D}{D - (B - C)}$$

The water absorption (as % of dry mass) is calculated from the following formula:

$$\frac{100\,(A - D)}{D}$$

where

A   is the mass of the saturated surface-dry sample in air (in g);

B   is the mass of vessel containing sample and filled with water (in g);

C   is the mass of vessel filled with water only (in g);

D   is the mass of the oven-dry sample in air (in g).

5.4.5 *Reporting of results*

The mean result shall be reported for each form of particle density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title 'particle density' be used in relation to any values quoted. The size of aggregate tested, and whether it has been artificially heated before the start of the test shall be stated. The values of particle density shall be reported to the nearest $0.01\ \mathrm{Mg/m^3}$ and those for water absorption to the nearest 0.1 %.

5.5 Method for aggregates 10 mm nominal size and smaller

5.5.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

5.5.1.1 *Balance*, of capacity not less than 3 kg, accurate to 0. 5 g and of such a type as to permit the weighing of the vessel containing the aggregate and water.

5.5.1.2 *Well ventilated oven*, thermostatically controlled to maintain a temperature of $105\ ^\circ\mathrm{C} \pm 5\ ^\circ\mathrm{C}$.

5.5.1.3 *Vessel*, capable of holding 0.5 kg to 1.0 kg of material up to 10 mm nominal size and capable of being filled with water to a constant volume with an accuracy of ± 0.5 ml. The following vessels are suitable.

a) *Glass vessel*, referred to later as a *pyknometer*, of about 1 l capacity, having a metal conical screw top with an approximately 6 mm diameter hole at its apex. The screw top shall be watertight when it is screwed on to the jar, and, if necessary, a rubber or fibre washer shall be inserted in the joint. If such a washer is used, a mark shall be made on the jar to correspond with a mark on the screw top so that the screw is tightened to the same position every time and the volume contained by the jar is constant throughout the test. A suitable vessel can be made from a 1 kg fruit preserving jar in which the glass lid normally used is replaced by a sheet metal cone as shown in figure 1.

b) Wide-mouthed glass vessel, such as a gas jar, of 1.0 l to 1. 5 l capacity, with a flat-ground lip and a plane-ground disc of plate glass to cover it, giving a watertight fit.
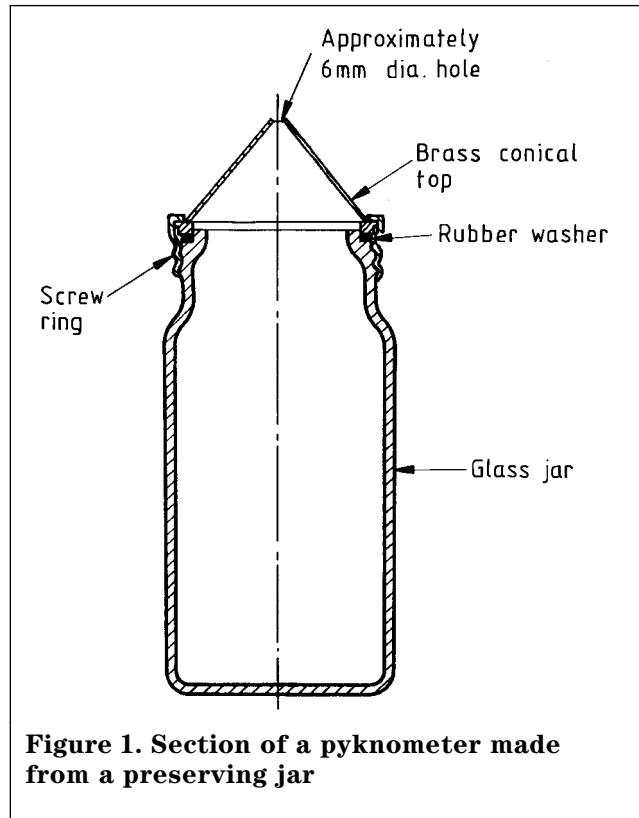

Figure 1. Section of a pyknometer made from a preserving jar

5.5.1.4 *Hair-dryer*, or other means of supplying a current of warm air.

5.5.1.5 *Watertight tray*, of area not less than $0.03\ \mathrm{m^2}$.

5.5.1.6 *Airtight container*, large enough to take the sample.

5.5.1.7 *Container*, of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

5.5.1.8 75 μm *BS test sieve* (see **5.4** of BS 812 : Section 103.1 : 1985) and a nesting sieve to protect the 75 μm test sieve, e.g. a 1.18 mm sieve.

5.5.1.9 *Supply of water*, free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

5.5.1.10 *Metal mould* (optional), in the form of a frustum of a cone 40 mm diameter at the top, 90 mm at the bottom and 75 mm high, the metal to have a minimum thickness of 900 μm.

5.5.1.11 *Metal tamper* (for use with the metal mould), of 340 g $\pm$ 15 g and having a flat circular tamping face 25 mm $\pm$ 3 mm in diameter.

5.5.1.12 *Plain glass funnel* (optional).

5.5.2 Sample for test

A sample of about 1 kg for material having a nominal size from 10 mm to 5 mm inclusive, or about 500 g if finer than 5 mm, shall be used. Aggregates which have been artificially heated shall not normally be used. If such material is used, the fact shall be stated in the report. Two tests shall be made.

The sample shall be thoroughly washed to remove all material finer than the 75 μm BS test sieve (**5.5.1.7**) using the following procedure.

Place the test sample in the container and add enough water to cover it. Agitate vigorously the contents of the container and immediately pour the wash water over the sieves, which have previously been wetted on both sides and arranged with the coarser sieve on top.

The agitation shall be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the 75 μm BS test sieve, and to bring the fine material into suspension in order that it will be removed by decantation of the wash water. Take care to avoid, as far as possible, decantation of the coarse particles of the sample. Repeat the operation until the wash water is clean. Return all material retained on the sieves to the washed sample.

5.5.3 Test procedure

The test procedure shall be as described in **5.5.3.1** or **5.5.3.2**.

5.5.3.1 *Using the pyknometer*

Transfer the washed aggregate to the tray and add further water to ensure that the sample is completely immersed. Soon after immersion, remove bubbles of entrapped air by gentle agitation with a rod.

Keep the sample immersed in water for 24 h $\pm$ 0.5 h, the water temperature being maintained at 20 °C $\pm$ 5 °C for at least the last 20 h of immersion.

Then carefully drain the water from the sample by decantation through a 75 μm BS test sieve, covered by the protective coarser sieve, any material retained being returned to the sample.

Then expose the aggregate to a gentle current of warm air to evaporate surface moisture and stir it at frequent intervals to ensure uniform drying until no free surface moisture can be seen and, in the case of aggregate finer than 5 mm, it just attains a 'free-running' condition (see note 1).

Then weigh the saturated and surface-dry sample (mass *A*).

If the apparent particle density only is required the draining and drying operations described above may be omitted, although for material finer than 5 mm some surface drying may be desirable to facilitate handling.

Then place the aggregate in the pyknometer and fill the pyknometer with water. Screw the cone into place and eliminate any trapped air by rotating the pyknometer on its side, the hole in the apex of the cone being covered with a finger. Top up the pyknometer with water to remove any froth from the surface and so that the surface of the water in the hole is flat. Then dry the pyknometer on the outside and weigh it (mass *B*).

Empty the contents of the pyknometer into the tray, taking care to ensure that all the aggregate is transferred. Refill the pyknometer with water (see note 2) to the same level as before, dry it on the outside and weigh it (mass *C*). The difference in the temperature of the water in the pyknometer during the first and second weighing shall not exceed 2 °C.

Then carefully drain the water from the sample by decantation through a 75 μm BS test sieve and return any material retained to the sample. Then place the sample in the tray, in the oven at a temperature of 105 °C $\pm$ 5 °C for 24 h $\pm$ 0.5 h, during which period it shall be stirred occasionally to facilitate drying. Then cool it in the airtight container and weigh it (mass *D*). Two tests shall be made. If the particle density on a saturated and surface-dried basis only is required, the operations described in this paragraph may be omitted.

NOTE.T 18>1. The 'free-running' or 'saturated surface-dry' condition of the fine aggregate (smaller than 5 mm) is sometimes difficult to identify and, in order to help in identification, two alternative methods are suggested as possible aids.

Method 1. The following test procedure should be adopted, making use of the conical mould and tamper referred to in **5.5.1.10** and **5.5.1.11**.

After drying the sample with a current of warm air allow it to cool to room temperature whilst thoroughly stirring it. Hold the mould with its larger diameter face downwards on a smooth non-absorbent level surface. Fill the mould loosely with part of the sample and lightly tamp 25 times through the hole at the top of the mould with the prescribed tamper. Do not refill the space left after tamping. Gently lift the mould clear of the aggregate and compare the moulded shape with figures 2a to 2d. If the shape resembles figures 2a or 2b, then there is still surface moisture present. Dry the sample further and repeat the test.

If the shape resembles figure 2c, a condition close to the saturated surface-dry condition has been achieved. If the shape resembles figure 2d, the aggregate has dried beyond the saturated surface-dry condition and is approaching the oven-dry condition. In this case, either reject the sample and repeat the tests on a fresh sample or re-soak the same sample in water for a further 24 h and restart the tests as from the beginning of the second paragraph of **5.5.3.1**.

It is recommended that at least one of the drying stages, as shown in figures 2a or 2b, should have been observed before the aggregate reaches the stage represented by figure 2c.

Method 2. As an alternative to method 1, a dry glass funnel (**5.5.1.12**) may be used to help determine the 'free-running' condition of aggregate finer than 5 mm.

With the funnel inverted over the sample tray pour some of the sample over the sloping sides by means of a small scoop. If still damp, particles of the aggregate will adhere to the sides of the funnel. Continue drying until subsequent pouring shows no sign of particles sticking to the glass.

NOTE.T 18>2. Thoroughly dry the glass and metal threads (and the washer if used) of the pyknometer before using a second time.
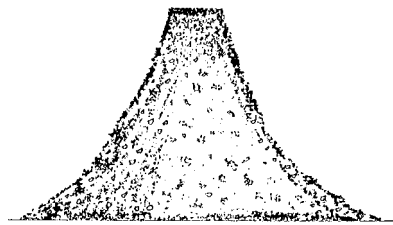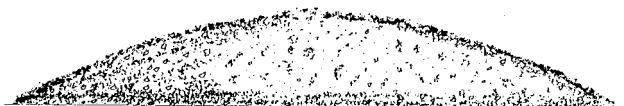

a) Aggregate moist; almost retains complete shape of metal mould

b) Aggregate slightly moist; appreciable slump observed

c) Aggregate saturated surface-dry; almost complete collapse but definite peak still visible and slopes are angular

d) Aggregate nearly oven dry; no distinct peak, surface outline close to being curvilinear

NOTE. These sketches are not to scale and are for reference purposes only.

Figure 2. Estimation of free-running condition of fine aggregate

5.5.3.2 *Using the wide-mouthed glass vessel*

The procedure shall be the same as in **5.5.3.1** except that in filling the jar with water it shall be filled just to overflowing and the glass plate slid over it to exclude any air bubbles.

5.5.4 *Calculations*

The particle density on an oven-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{D}{A - (B - C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) is calculated from the formula:

$$\frac{A}{A - (B - C)}$$

The apparent particle density (in Mg/m^3) is calculated from the formula:

$$\frac{D}{D - (B - C)}$$

The water absorption (as % of dry mass) is calculated from the formula:

$$\frac{100\,(A - D)}{D}$$

where

A is the mass of saturated surface-dry sample in air (in g);

B is the mass of pyknometer or wide-mouthed glass vessel containing sample and filled with water (in g);

C is the mass of pyknometer or wide-mouthed glass vessel filled with water only (in g);

D is the mass of oven-dried sample in air (in g).

5.5.5 *Reporting of results*

The mean result shall be reported for each form of particle density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title 'particle density' be used in relation to any values quoted. The size of aggregate tested, and whether it was artificially heated before the start of the test shall be stated. The values of particle density shall be reported to the nearest 0.01 Mg/m^3 and those for water absorption to the nearest 0.1 %.

5.6 Alternative method for aggregates between 40 mm and 5 mm nominal size

As an alternative to the method described in **5.4** the particle density and water absorption of aggregates between 40 mm and 5 mm nominal size may be determined by using the apparatus described in BS 1881 for the analysis of freshly mixed concrete.

The method shall be as described in **5.3** substituting the bucket for the wire basket, a 5.0 mm BS test sieve for the 10.0 mm BS test sieve (**5.3.1.8**) and stirring with a rod for jolting to remove air from the sample.

5.7 Method for determination of particle density of filler

5.7.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

5.7.1.1 *Density bottle*, of 50 ml or 100 ml.

5.7.1.2 *Small funnel.*

5.7.1.3 *Balance*, of capacity 200 g, accurate to 0.001 g.

5.7.1.4 *Vacuum desiccator and pump*, capable of reducing the pressure below 50 mbar[1].

5.7.1.5 *Well ventilated oven*, thermostatically controlled to maintain a temperature of 105 °C ± 5 °C.

5.7.1.6 *Water bath*, capable of maintaining a temperature of 25 °C ± 0.1 °C.

5.7.1.7 *Supply of water*, free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

5.7.2 *Dilatometric liquid*

Preferably purified xylene. Redistilled kerosene kept over a dehydrating and deacidifying agent, e.g. Portland cement, may be used. When the filler is known not to react with water, then water may be used as the dilatometric liquid.

5.7.3 *Test procedure*

5.7.3.1 *Calibration of density bottle*

Weigh the density bottle and stopper, both of which shall be clean and dry (mass A). Then fill the bottle with the water described in **5.7.1.7**, immerse it nearly up to the top of its neck in the water bath and maintain it for not less than 60 min at a temperature of 25 °C ± 0.1 °C. Then insert the stopper, remove the bottle from the bath, dry the outside thoroughly and weigh the full bottle as quickly as possible (mass B).

5.7.3.2 *Determination of density of dilatometric liquid*

Using the procedure described in **5.7.3.1** determine the mass of the density bottle and stopper when filled with the dilatometric liquid (mass C).

[1] mbar = 10^2 N/m^2 = 0.1 kPa.

5.7.3.3 *Determination of particle density of filler*

Dry the filler for 4 h in the oven at a temperature of 105 °C ± 5 °C and cool it in the desiccator to room temperature. The density bottle and stopper shall be clean and dry. Then add the filler to the bottle through the funnel, so as to fill the bottle approximately one-third full and weigh the bottle with filler and stopper (mass *D*). Then add sufficient dilatometric liquid to cover the filler and half fill the bottle. Release entrapped air by giving the bottle and its contents a few light taps on the bench and then gradually subjecting the bottle and contents to reduced pressure (approximately 50 mbar[1])) in a vacuum desiccator for at least 5 min. Repeat this procedure for releasing air until no further bubbles of air appear.

Then add dilatometric liquid to fill the bottle completely and keep the bottle with contents for not less than 60 min in the water bath controlled at a temperature of 25 °C ± 0.1 °C. Then insert the stopper, remove the bottle from the bath, dry the outside thoroughly and weigh the bottle with its contents (mass *E*).

5.7.4 *Calculations*

The density of the dilatometric liquid (d_L) is given by the formula:

$$\frac{C - A}{B - A}$$

The particle density of the filler is given by the formula:

$$\frac{(D - A)}{(B - A) - \dfrac{(E - D)}{d_L}}$$

where

A	is the mass of stopper and density bottle empty (in g);
B	is the mass of stopper, density bottle and water (in g);
C	is the mass of stopper, density bottle and dilatometric liquid (in g);
D	is the mass of stopper, density bottle and filler (in g);
E	is the mass of stopper, density bottle, filler and dilatometric liquid (in g).

Two separate determinations shall be made and both results recorded. If these results differ by more than 0.02, they shall be discarded and two fresh determinations made.

5.7.5 *Reporting results*

The mean result shall be reported to the nearest 0.01 as the particle density of the tested material.

[1) mbar = 10^2 N/m^2 = 0.1 kPa.

6 Determination of bulk density, voids and bulking

6.1 General

The method for aggregates is by determining the mass of a sample filling a specified container, either loose or compacted. The method for filler is by determining the volume of a sample of specified mass when settled in kerosene.

It is emphasized that this test is intended for comparing properties of different aggregates. It is not generally suitable for use as a basis for quoting conversion factors, and for this purpose a practical test appropriate to the application should be employed.

The value of the bulking of an aggregate, calculated by the standard method from the uncompacted bulk densities of the aggregate in the oven-dry condition and then containing a known moisture content, is also intended only for comparative purposes. Some other degree of compaction, provided it is the same for the material in both moisture conditions, may be more appropriate for practical purposes.

6.2 Sampling

The sample for these tests shall be taken in accordance with BS 812 : Part 102.

6.3 Method for the determination of bulk density, and calculation of voids and bulking of aggregate

6.3.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

6.3.1.1 *Cylindrical metal container*, conforming to the following requirements.

The container shall be made to the approximate dimensions given in table 1 appropriate to the size of aggregate, be smooth inside and preferably be fitted with handles. It shall be watertight, of sufficient rigidity to retain its form under rough usage, and shall be protected against corrosion.

6.3.1.2 *Scale or balance*, accurate to 0.2 % of the mass of the material to be weighed and of adequate capacity (this will vary according to the size of container used).

6.3.1.3 *Straight metal tamping rod*, of circular cross section, 16 mm in diameter and 600 mm long, rounded at one end.

6.3.2 *Calibration*

The container shall be calibrated by determining the mass of water at 20 °C ± 2 °C required to fill it so that no meniscus is present above the rim of the container. The actual volume in cubic metres shall then be obtained by dividing the mass of the water in kilograms by 1000.

6.3.3 *Condition of sample*

The test for bulk density shall be made on oven-dry or saturated surface-dry material. The test for voids shall be made on oven-dry material. The test for bulking shall be made initially on oven-dry material and then at the required test moisture content.

6.3.4 *Test procedure*

The size of the container to be used is given in table 1. The test procedure shall be as described in **6.3.4.1** and **6.3.4.2**.

6.3.4.1 *Compacted bulk density (not applicable to moist fine aggregate)*

Fill the container about one-third full with the thoroughly mixed aggregate by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 50 mm above the top of the container. Take care to prevent, so far as is possible, segregation of the particle sizes of which the sample is composed. Then give the required number of compactive blows (see table 1) to the aggregate, each blow being given by allowing the tamping rod to fall freely from a height of 50 mm above the surface of the aggregate, the blows being evenly distributed over the surface. Add a further similar quantity of aggregate in the same manner and give the same number of blows. Fill the container to overflowing, tamp it again with the same number of blows, and remove the surplus aggregate by rolling the tamping rod across and in contact with the top of the container, any aggregate which impedes its progress being removed by hand, and add aggregate to fill any obvious depressions. For 6 mm aggregate or smaller, the surface may be struck off, using the tamping rod as a straight edge. Then determine the mass of the aggregate in the container. Make two tests and calculate the bulk density in megagrams per cubic metre using the calibrated volume determined as in **6.3.2**, from the mean of the two masses.

6.3.4.2 *Uncompacted bulk density*

To determine the loose mass (uncompacted bulk density) carry out the test as described in (**6.3.4.1**) except that the compaction with the tamping rod shall be omitted.

6.3.5 *Calculation of voids*

In this test voids are expressed as a percentage of the volume of the test cylinder. They are determined from the difference between the volume of the test cylinder and the calculated volume of the aggregate.

The percentage of voids is given by the formula:

$$100 \left(\frac{a - b}{a} \right)$$

where

a is the particle density of the aggregate, on an oven-dry basis, determined in accordance with **5.3**, **5.4**, **5.5** or **5.6**;

b is the bulk density of oven-dry aggregate as determined in **6.3. 4** compacted or uncompacted as required.

6.3.6 *Calculation of bulking*

In this test, bulking is expressed as the increase in volume, as a percentage of original volume, of a mass of fine aggregate whose moisture content is increased from the oven-dry condition to a test moisture content.

The percentage bulking at test moisture content (M) is given by the formula:

$$\frac{b \,(\, 100 + M \,)}{c} - 100$$

where

b is the uncompacted bulk density of oven-dry fine aggregate determined according to **6.3.4**;

Table 1. Details of containers to be used for the bulk density tests

Nominal volume[1]	Internal diameter (approximate)	Internal depth (approximate)	Minimum thickness of metal	Compacted bulk density		Uncompacted bulk density
				Nominal size of aggregate up to and including:	Number of compactive blows per layer	Nominal size of aggregate up to and including
m³	mm	mm	mm	mm		mm
0.03	350	300	5.0	50	100	50
0.015	250	300	4.0	28	50	14
0.01[2]	200	320	4.0	20	40	20
0.007	200	225	3.0	14	30	6
0.003	150	150	3.0	6	20	—

[1] Containers of 1 ft³, 1/2 ft³, 1/4 ft³ and 1/10 ft³ nominal capacity respectively conforming to the requirements of the superseded 1967 edition of BS 812 shall be deemed to conform to these requirements.

[2] The container of nominal volume 0.01 m³ is equivalent to that used to determine the density of compacted fresh concrete as described in BS 1881. BS 1881 defines dimensional tolerances for the container.

c is the uncompacted bulk density, as determined in accordance with **6.3.4**, of fine aggregate at test moisture content;

M is the test moisture content on oven-dry basis in accordance with BS 812 : Part 109.

6.3.7 *Reporting of results*

The bulk density shall be reported as the compacted or uncompacted bulk density in megagrams per cubic metre to the nearest 0.01 Mg/m^3. The condition of the aggregate at the time of test shall be stated, i.e. oven-dry, saturated or surface-dry. The percentage voids and the percentage bulking, if required, shall be reported to the nearest whole number.

6.4 Method for the determination of bulk density of filler in kerosene

6.4.1 *Apparatus and materials*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

6.4.1.1 *50 ml glass-stoppered measuring cylinder*, of about 200 mm long and 22 mm to 25 mm internal diameter, calibrated in millilitres and conforming to BS 604.

6.4.1.2 *Balance*, of capacity not less than 100 g, readable to 0.01 g.

6.4.1.3 *Well ventilated oven*, thermostatically controlled to maintain a temperature of 105 °C $\pm$ 5 °C.

6.4.1.4 *Desiccator.*

6.4.1.5 *Redistilled kerosene (paraffin oil)*, petroleum distillate with a boiling range between 180 °C and 280 °C.

NOTE. The displacement liquid described in national annex NC.3 of BS EN 196-6 : 1992, used in the method of testing cement, is suitable.

6.4.2 *Test procedure*

Reduce the laboratory sample by the procedures described in clause **6** of BS 812 : Part 102 : 1989 to produce a test portion of sufficient mass to produce five test specimens.

Dry the test portion of filler at a temperature of 105 °C $\pm$ 5 °C for at least 4 h. Cool to room temperature in the desiccator. Weigh out three test specimens of filler, each of a mass of 10 g $\pm$ 0.01 g.

Place the first test specimen into a measuring cylinder, half fill the cylinder with kerosene, then stopper the cylinder and shake it until the filler is completely wetted. Add more kerosene to the cylinder so that the level is about 40 mm from the top. Stopper the cylinder and shake again.

To ensure that the filler is in complete suspension in the kerosene, carry out the following procedure immediately after the second shaking. Invert the cylinder and keep it in an inverted position whilst the air-bubble travels the length of the cylinder. Immediately return the cylinder to the upright position and hold it still until the air-bubble returns to the top. Repeat this procedure a further four times in rapid succession, then immediately stand the cylinder on a vibration-free surface. If any particles of filler stick to the side of the cylinder above the level of kerosene, carefully wash them back into the liquid using a small additional quantity of kerosene.

Leave the cylinder undisturbed for at least 6 h before reading and recording the observed level of the filler as its bulk volume (V) to the nearest millilitre.

Repeat this procedure for the second and third test specimens.

6.4.3 *Calculations*

The bulk density for each test specimen shall be calculated to the nearest 0.01 Mg/m^3 using the following formula:

$$10/V$$

where V is the bulk volume as determined in **6.4.2**.

Calculate the mean of the three values of bulk density determined using the above equation, to the nearest 0.01 Mg/m^3. If any of the individual results differ by more than 0.05 Mg/m^3 from the mean value, discard that individual result and determine the bulk density of two further test specimens taken from the same test portion.

6.4.4 *Reporting of results*

The mean value of the three or more results to the nearest 0. 1 Mg/m^3 shall be reported as the bulk density of the filler in kerosene.

NOTE. The value of the bulk density in megagrams per cubic metre is numerically identical to the value of the bulk density expressed in grams per millilitre.

6.4.5 *Test report*

The report shall affirm that the bulk density of filler in kerosene 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 shall be provided. The test report shall contain the following additional information:

a) sample identification;

b) the bulk density of filler in kerosene.

6.5 Method for the determination of voids of dry compacted filler

6.5.1 *Apparatus*

NOTE. All apparatus described should conform to the general requirements of BS 812 : Part 100.

6.5.1.1 *Apparatus*, of the form shown in figure 3, conforming to the following requirements.

It shall be made throughout of steel and shall consist of the following.

a) *Base*, of approximately the dimensions shown in figure 3.

b) *Cylinder*, of 25 mm $\pm$ 1.0 mm internal diameter and 63.5 mm internal depth, closed at one end.

c) *Plunger*, of such diameter as to slide freely in the cylinder without lateral play, provided with a hole of about 1.6 mm diameter along its axis to allow air to escape, and with a circumferential groove about 6 mm from its lower end to accommodate any filler which works up the side of the cylinder while in use. The mass of the plunger shall be 350 g $\pm$ 2 g.

d) Means for raising the cylinder and dropping it freely between vertical guides from a height of 100 mm $\pm$ 0.25 mm on to the base. The total mass dropped on to the base shall be 850 g to 900 g, including the filler.

e) Means for reading the depth of the compacted filler in the cylinder to an accuracy of 0.1 mm.

The apparatus shall be used dry, without lubricant on any part. During use the apparatus shall be held or clamped firmly on a rigid, level support; a position above the leg on a firm bench is recommended.

6.5.1.2 *Balance*, of capacity 50 g, accurate to 0.01 g.

6.5.1.3 *Well ventilated oven*, thermostatically controlled to maintain a temperature of 105 °C $\pm$ 5 °C.

6.5.1.4 *Desiccator*.
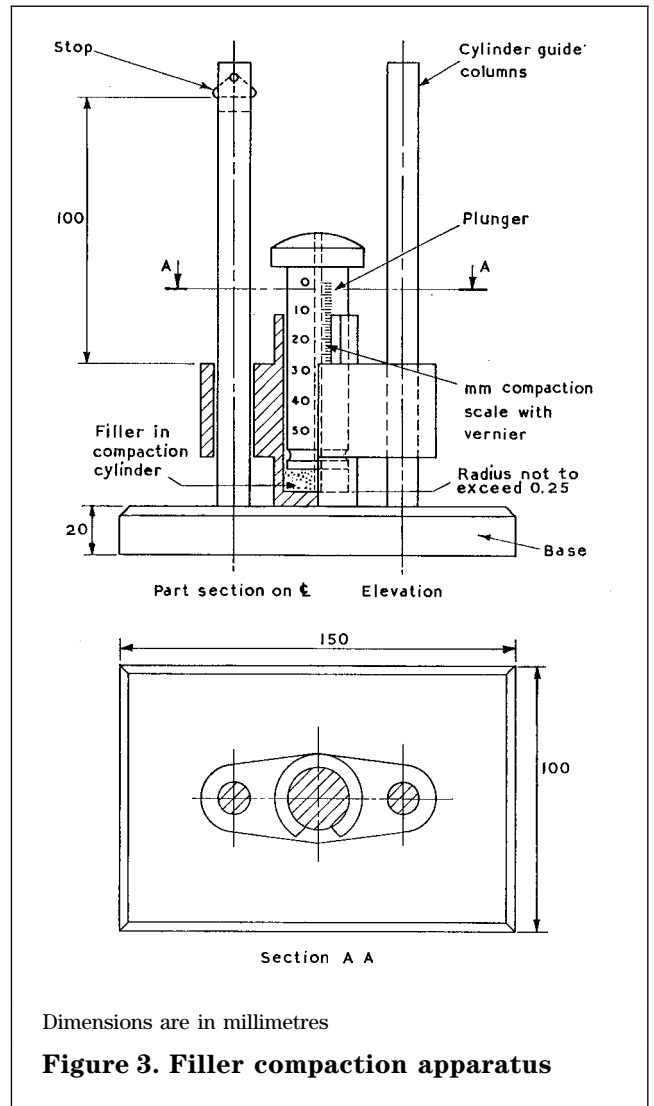
Dimensions are in millimetres

Figure 3. Filler compaction apparatus

6.5.2 *Test procedure*

Dry the filler for 4 h in the oven at 105 °C ± 5 °C and cool it to room temperature in the desiccator.

Put about 10 g of the dried filler into the compaction cylinder and distribute it uniformly in the bottom of the cylinder by tapping gently on the bench. Insert the plunger and allow it to slide slowly on to the filler, a finger being pressed on to the central hole in the plunger to prevent ejection of the filler from the cylinder. Then apply pressure to the plunger so as to form the filler into a slightly compacted bed. Then remove the plunger without disturbance of the filler, and wipe excess filler from the plunger and sides of the cylinder, the central hole in the plunger being cleaned if necessary. Then re-insert the plunger and gently place the cylinder in position on the base, which shall be clamped or otherwise firmly held on a firm level surface free from vibration or other movement. Then raise the cylinder with plunger in position and allow it to fall freely through a vertical height of 100 mm ± 0. 25 mm on to the base. Drop the cylinder 100 times, allowing a pause of about 1 s each time before dropping. The plunger shall remain free to move in the cylinder throughout this operation, and to ensure this, ease it frequently by twisting it in the cylinder and, if necessary, remove it and wipe it free of clogging filler.

After 100 impacts read the depth (d) of the compacted filler in millimetres, to an accuracy of 0.1 mm. Then dismantle the apparatus without damaging the bed of filler, and wipe it clean of any uncompacted filler. Then remove the filler forming the compacted bed and weigh it to an accuracy of 0.01 g (mass M).

6.5.3 *Calculations*

The dry void content shall be calculated using the following formula:

$$1 - \frac{1000\,M}{A \times d \times d_\mathrm{F}}$$

where

M	is the mass of filler bed (in g);
d_F	is the particle density of filler determined as in **5.7**;
d	is the depth of compacted bed (in mm);
A	is the cross-sectional area of cylinder (in mm^2).

Three determinations shall be made using a separate sample of filler for each determination. If any of these values differs by more than 0.01 from the mean value, that result shall be discarded and two further determinations made.

6.5.4 *Reporting of results*

The mean value of the three or more results shall be reported to the nearest 0.01 as the voids of the dry compacted filler.

Annexes

Annex A (informative)

Repeatability and reproducibility of test results

A.1 General

The distribution of results of any test on any material stems from a number of contributing factors and to allow for these factors in comparing results by the same test operator or results by test operators working in different laboratories estimates of the distribution are required. Such estimates are given in this annex together with the definition of the terms 'repeatability' and 'reproducibility' which are used in assessing the distribution of test results. An example of the application of the estimate is also given. The values may also be useful in setting limits in specifications for materials and in assessing the difference between different materials.

A.2 Definitions

For the purposes of this annex the following definitions apply.

A.2.1 value

Where results are reported as a mean of two or more determinations the figures for repeatability and reproducibility are based on this mean value.

A.2.2 repeatability (r)

Quantitative expression of the random error associated with a single test operator in a given laboratory obtaining successive results with the same apparatus under constant operating conditions on identical test material. It is defined as that difference between two such single results as would be exceeded in the long run in only 1 case in 20 in the normal and correct operation of the test method.

For the purposes of this standard the identical test material for repeatability tests is obtained by dividing a sample of twice[2] the amount required to obtain a single test result by the sample reduction procedure described in clause **6** of BS 812 : Part 102 : 1989.

A.2.3 reproducibility (R)

Quantitative expression of the random error associated with test operators working in different laboratories, each obtaining single results on identical test material when applying the same method. It is defined as that difference between two such single and independent results as would be exceeded in the long run in only 1 case in 20 in the normal and correct operation of the test method.

For the purposes of this standard the identical test material is obtained by first dividing a sample of twice[2] the amount required to obtain a single test result into two equal portions, one for each laboratory and then, where appropriate, each laboratory reduces each portion to the amount required for single determinations by the sample reduction procedure described in clause **6** of BS 812 : Part 102 : 1989.

Mathematically, the precision statements are of the form:

$$r = 1.96 \ \sqrt{2}\sigma_1$$

$$R = 1.96 \ \sqrt{2} \ \ \sqrt{\sigma_1{}^2 + \sigma_2{}^2}$$

where

σ_1 is the best estimate of single-operator standard deviation[3] within a laboratory;

σ_2 is the standard deviation[3] applicable to all causes of variability other than repeatability of testing when results of different operators in different laboratories are compared.

A.3 Estimates of repeatability and reproducibility

Table A.1 gives estimates of repeatability and reproducibility for the tests in this standard for which figures are at present available. These values represent the greatest differences that can be expected between test results on duplicate samples in the normal run of testing within and between laboratories respectively.

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[2] These quantities are given for the purpose of defining 'identical material'. Estimates of (r) and reproducibility (R) should be based on a larger number of tests and laboratories.
[3] Standard deviation is defined in BS 2846.

Table A.1 Estimates of repeatability and reproducibility		
Test	Repeatability r	Reproducibility R
Particle density (wire-basket method, saturated surface-dried basis):		
most aggregates	0.02 Mg/m^3	0.04 Mg/m^3
some porous aggregates of low density (<2.60)	up to 0.04 Mg/m^3	up to 0.08 Mg/m^3
Water absorption	5 % of value recorded	10 % of value recorded
Bulk density	0.01 Mg/m^3	0.02 Mg/m^3

A.4 An example of the application of estimates

A laboratory purchases secondhand equipment for the polished-stone value determination and wishes to reassure itself that its technique and equipment are satisfactory. It prepares a number of identical subsamples from a large sample of aggregate and tests two of them, obtaining results of 61 and 64 respectively. Because the difference between these results (3 units) is less than the repeatability of the test (4.9), the laboratory has no reason to doubt the consistency of its testing. However, this gives no guarantee that its equipment is satisfactory or that its technique has no bias. Therefore two more of the identical samples are sent to another laboratory experienced in the test, which obtains values of 59 and 57. The means for the two laboratories are thus 62.5 and 58.0 respectively.

Were these the results of single determinations the difference (4.5) would be less than the reproducibility of the test (6.0) and there would be no cause for concern, but the difference should be compared with $6.0/\sqrt{2} = 4.2$ because the values of reproducibility (and repeatability) for the means of results are inversely proportional to the square root of the number of tests used to derive the mean. It can be seen that the difference slightly exceeds the reproducibility figure calculated above and hence further investigation is necessary to establish the cause of the discrepancy. This could be the 1 in 20 case, the sample subdivision may not have produced identical subsamples or the results produced by the second laboratory may not be correct. Where a check of the apparatus and procedure does not reveal anything incorrect it is recommended that further cooperative tests be arranged with additional laboratories.

List of references

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 604 : 1982	*Specification for graduated glass measuring cylinders*
BS 812 :	*Testing aggregates*
BS 812 : Part 102 : 1989	*Methods for sampling*
BS 812 : Part 109 : 1990	*Methods for determination of moisture content*
BS 1881 :	*Testing concrete*

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 2846 :	*Guide to statistical interpretation of data*
BS EN 196 :	*Methods of testing cement*
BS EN 196-6 : 1992	*Determination of fineness*