

Tests for mechanical and physical properties of aggregates —

Part 6: Determination of particle density and water absorption

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British Standard

ICS 91.100.15

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National foreword

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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.

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Summary of pages

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English version

**Tests for mechanical and physical properties of aggregates -
Part 6: Determination of particle density and water absorption**

Essais pour déterminer les caractéristiques mécaniques et
physiques des granulats - Partie 6: Détermination de la
masse volumique réelle et du coefficient d'absorption d'eau

Prüfverfahren für mechanische und physikalische
Eigenschaften von Gesteinskörnungen - Teil 6:
Bestimmung der Rohdichte und der Wasseraufnahme

This European Standard was approved by CEN on 18 August 2000.

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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.

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of an identical text or by endorsement, at the latest by December 2003, and conflicting national standards shall be withdrawn at the latest by December 2003.

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.

This European Standard forms part of a series of tests for mechanical and physical properties of aggregates. 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 1367	Tests for thermal and weathering properties of aggregates;
EN 1744	Tests for chemical properties of aggregates;
EN 13179	Tests for filler aggregate used in bituminous mixtures.

The other parts of EN 1097 will be:

- Part 1: Determination of the resistance to wear (micro-Deval);
- Part 2: Methods for the determination of resistance to fragmentation;
- Part 3: Determination of loose bulk density and voids;
- Part 4: Determination of the voids of dry compacted filler;
- Part 5: Determination of water content by drying in a ventilated oven;
- Part 7: Determination of the particle density of filler - Pyknometer method;
- Part 8: Determination of the polished stone value;
- Part 9: Determination of the resistance to wear by abrasion from studded tyres - Nordic test;
- Part 10: Water suction height.

1 Scope

This European Standard specifies methods for the determination of the particle density and water absorption of aggregates. The first five methods are applicable to normal aggregates with a sixth method for lightweight aggregates.

The principal methods specified are:

- a) a wire basket method for aggregates passing a 63 mm sieve but retained on a 31,5 mm sieve;
- b) pycnometer methods for aggregates passing a 31,5 mm sieve but retained on a 0,063 mm sieve.

NOTE 1 The wire basket method may be used as an alternative to the pycnometer method for aggregates between 4 mm and 31,5 mm. In case of dispute, the pycnometer method described in clause 8 should be used as the reference method.

NOTE 2 The wire basket method can also be used for single aggregate particles retained on a 63 mm sieve.

A method for the determination of pre-dried particle density of dense aggregates is specified in annex A.

NOTE 3 As the absorption of dense aggregates is low, pre-dried particle density can be determined directly in water. This method is different to the determination of particle density on an oven dried basis.

A modified version of the wire-basket method suitable for determining the particle density and water absorption of coarse aggregates saturated to constant mass is specified in annex B.

For lightweight aggregates, a modified version of the pycnometer test specified in annex A is specified in annex C.

2 Normative references

This European Standard incorporates by dated or 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 (including amendments).

EN 932-1	<i>Tests for general properties of aggregates - Part 1: Methods for sampling.</i>
EN 932-2	<i>Tests for general properties of aggregates - Part 2: Methods for reducing laboratory samples.</i>
EN 932-5	<i>Tests for general properties of aggregates - Part 5: Common equipment and calibration.</i>
EN 933-2	<i>Tests for geometrical properties of aggregates - Part 2: Determination of particle size distribution - Test sieves, nominal size of apertures.</i>

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

3.1

test portion

sample used as a whole in a single test

3.2

particle density on an oven dried basis

ratio of the oven dried mass of a sample of aggregate to the volume it occupies in water including both internal sealed voids and water accessible voids

3.3

apparent particle density

ratio of the oven dried mass of a sample of aggregate to the volume it occupies in water including any internal sealed voids but excluding water accessible voids

3.4

particle density on a saturated and surface-dried basis

ratio of the combined mass of a sample of aggregate and the mass of water in the water accessible voids to the volume it occupies in water including both internal sealed voids and water accessible voids when present

3.5

pre-dried particle density

mass of dry particles per unit volume

NOTE The volume is determined as the volume of the particles inclusive of both internal sealed voids and water accessible voids.

3.6

water absorption

increase in mass of a sample of oven dried aggregate due to the penetration of water into the water accessible voids

3.7

constant mass

successive weighings after drying at least 1 h apart not differing by more than 0,1 %

NOTE In many cases constant mass can be achieved after a test portion has been dried for a pre-determined period in a specified oven at $(110 \pm 5) ^\circ\text{C}$. Test laboratories can determine the time required to achieve constant mass for specific types and sizes of sample dependent upon the drying capacity of the oven used.

4 Principle

Particle density is calculated from the ratio of mass to volume. The mass is determined by weighing the test portion in the saturated and surface dried condition and again in the oven-dried condition. Volume is determined from the mass of the water displaced, either by mass reduction in the wire-basket method or by weighings in the pycnometer method.

NOTE 1 Due to the influence on the absorption, no artificial heating of the test portion should be applied before testing. However, if such material is used, this fact should be stated in the report.

NOTE 2 For porous aggregates, the values of absorption and density depend on the size fractions which are tested. For this reason, the determined values are referenced to the size fractions actually tested.

If the aggregate consists of a number of different size fractions, it is necessary to separate the sample into fractions, 0,063 mm to 4 mm, 4 mm to 31,5 mm and 31,5 mm to 63 mm, before preparing the test portion. The percentage of each fraction shall be stated in the test report.

5 Materials

Water, boiled and cooled before use.

NOTE Fresh tap water and demineralized water are both suitable. The water should be free from any impurity (for example dissolved air) that could significantly affect its density. Dissolved air can also be removed by applying a vacuum.

6 Apparatus

6.1 General

All apparatus, unless otherwise stated, shall conform to the general requirements of EN 932-5.

6.2 Apparatus for general purposes

6.2.1 Ventilated oven, thermostatically controlled to maintain a temperature of $(110 \pm 5) ^\circ\text{C}$.

6.2.2 Balance, accurate to 0,1 % of the mass of the test portion. The capacity of the balance shall be suitable to allow the wire basket containing the sample to be suspended and weighed in water.

6.2.3 Water bath, thermostatically controlled, capable of being maintained at $(22 \pm 3) ^\circ\text{C}$.

6.2.4 Thermometer, accurate to 0,1 $^\circ\text{C}$.

6.2.5 Test sieves, 0,063 mm, 4 mm, 31,5 mm and 63 mm, with apertures as specified in EN 933-2.

6.2.6 Trays, of suitable size which can be heated in a ventilated oven without change in mass.

6.2.7 Dry soft absorbent cloths.

6.2.8 Washing equipment.

6.2.9 Timer.

6.3 Special apparatus for the wire-basket method (see clause 7, A.3, and B.2)

6.3.1 Wire basket, or perforated container of suitable size to allow suspension from the balance. The basket or container shall be resistant to corrosion.

6.3.2 Watertight tank, containing water at $(22 \pm 3) ^\circ\text{C}$ in which the basket may be freely suspended with a minimum clearance of 50 mm between the basket and the sides of the tank.

NOTE A watertight tank can be used instead of a water bath specified in 6.2.3.

6.4 Special apparatus for pycnometer method for aggregate particles between 4 mm and 31,5 mm (see clause 8)

Pycnometer, consisting of a glass flask or other suitable vessel with volume between 1 000 ml and 5 000 ml, constant to 0,5 ml for the duration of the test.

NOTE The required volume of the pycnometer should be chosen to suit the size of the test portion. Two smaller pycnometers can be used instead of one large one, by summing the weighings before the calculation is carried out.

6.5 Special apparatus for pyknometer method for aggregate particles between 0,063 mm and 4 mm (see clause 9)

6.5.1 Pyknometer, consisting of a glass flask or other suitable vessel with volume between 500 ml and 5 000 ml, constant to 0,5 ml for the duration of the test.

NOTE The required volume of the pyknometer is to be chosen to suit the size of the test portion.

6.5.2 Metal mould, in the form of a frustum of a cone (40 ± 3) mm at the top, (90 ± 3) mm at the bottom and (75 ± 3) mm high. The metal shall have a minimum thickness of 0,8 mm.

6.5.3 Metal tamper, of mass (340 ± 15) g and having a flat circular tamping face of diameter (25 ± 3) mm, for use with the metal mould.

6.5.4 Funnel, plain glass (alternative to use of the metal mould and tamper).

6.5.5 Shallow tray, of non-water absorbing material having a plane bottom of area not less than $0,1 \text{ m}^2$ and an edge of not less than 50 mm in height.

6.5.6 Warm air supply, such as a hair dryer.

6.6 Special apparatus for the pyknometer method for aggregate particles between 0,063 mm and 31,5 mm (see A.4)

Pyknometer, consisting of a glass flask with a volume between 250 ml and 2 000 ml, constant to 0,5 ml for the duration of the test, and a corresponding glass funnel.

NOTE 1 The volume of the pyknometer is to be chosen to suit the size of the test specimen.

NOTE 2 An example of a suitable pyknometer is shown in Figure 1.

6.7 Special apparatus for the determination of particle density and water absorption of coarse aggregates saturated to constant mass (see annex B)

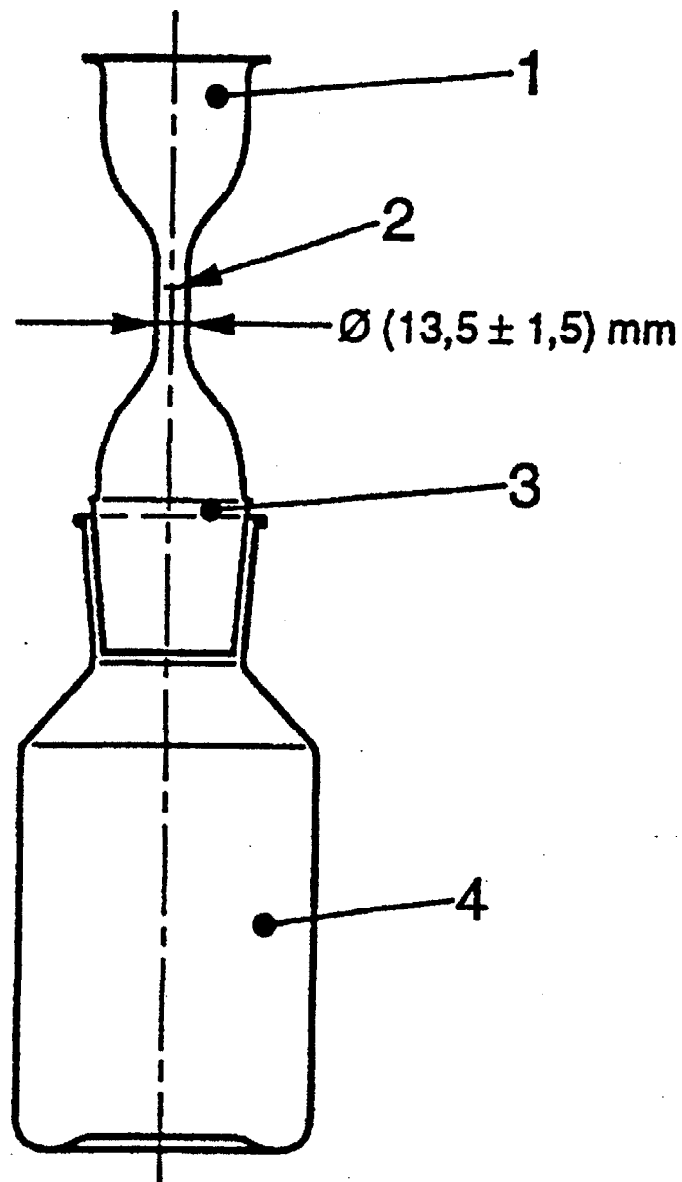
Container, of similar capacity to the wire basket specified in 6.3.1 for storage of the sample in water.

6.8 Special apparatus for the determination of particle density and water absorption of pre-dried lightweight aggregates (see annex C)

Pyknometer, consisting of a glass flask with a volume between 1 000 ml and 2 000 ml, constant to 0,5 ml for the duration of the test, and a corresponding glass funnel. If appropriate, the pyknometer shall contain a flexible grid to prevent aggregates floating.

NOTE 1 The volume of the pyknometer is to be chosen to suit the size of the test portion.

NOTE 2 An example of a suitable pyknometer is given in Figure 1.



Key

- 1 Glass funnel
- 2 Mark
- 3 Ground section to fit the wide-neck flat bottom flask
- 4 Wide-neck flat bottom flask

Figure 1 — Example of pyknometer

7 Wire-basket method for aggregate particles between 31,5 mm and 63 mm**7.1 General**

The wire basket method shall be used on aggregate particles between 31,5 mm and 63 mm. In the case of pieces of rock, reduce the sample in size to pass the 63 mm sieve and to be retained on the 31,5 mm sieve.

NOTE A modified version of this method for determining the particle density and water absorption of coarse aggregates saturated to constant mass is given in annex B.

7.2 Preparation of test portion

Sampling of the aggregates shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2. The mass of the test portion of aggregate shall be not less than the mass given in Table 1.

Table 1 — Minimum mass of test portions (wire-basket method)

Maximum size of aggregates mm	Minimum mass of test portions kg
63	15
45	7
NOTE For other sizes the minimum mass of the test portion may be interpolated from the masses specified in Table 1.	

Wash the test portion on the 63 mm sieve and the 31,5 mm sieve to remove finer particles and let the sample drain. Discard any particles retained on the 63 mm sieve.

7.3 Test procedure

Place the prepared test portion in the wire-basket and immerse it in the tank containing water at a temperature of $(22 \pm 3) ^\circ\text{C}$, 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 prepared test portion by lifting the basket about 25 mm above the base of the tank and allowing it to drop 25 times at about once per second.

Allow the basket and aggregate to remain completely immersed in the water at $(22 \pm 3) ^\circ\text{C}$ for a period of $(24 \pm 0,5) \text{ h}$.

Shake the basket and test portion and weigh them in water at a temperature of $(22 \pm 3) ^\circ\text{C}$ (M_2). Record the temperature of the water when mass (M_2) was determined.

NOTE If it is necessary for the test portion to be transferred to a different tank for weighing, shake the basket and test portion 25 times as before in the new tank before weighing (M_2).

Remove the basket and aggregate from the water and allow them to drain for a few minutes. Gently empty the aggregate from the basket on to one of the dry cloths. Return the empty basket to the water, shake it 25 times and weigh it in water (M_3).

Gently surface-dry the aggregate and transfer the aggregate to a second dry soft absorbent cloth when the first will remove no further moisture. Spread the aggregate out not more than one stone deep on the second sheet, 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 (M_1).

Transfer the aggregate to a tray and place in the oven at a temperature of $(110 \pm 5) ^\circ\text{C}$ until it has reached constant mass (M_4).

Record all weights to an accuracy of 0,1 % of the mass of the test portion (M_4) or better.

7.4 Calculation and expression of results

Calculate the particle densities (ρ_a , ρ_{rd} , and ρ_{ssd} as appropriate), in megagrams per cubic metre, in accordance with the following equations:

$$\text{Apparent particle density} \quad \rho_a = \rho_w \frac{M_4}{M_4 - (M_2 - M_3)}$$

$$\text{Particle density on an oven-dried basis} \quad \rho_{rd} = \rho_w \frac{M_4}{M_1 - (M_2 - M_3)}$$

$$\text{Particle density on a saturated and surface-dried basis} \quad \rho_{ssd} = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)}$$

Calculate the water absorption (as a percentage of the dry mass) after immersion for 24 h (WA_{24}) in accordance with the following numerical equation:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4}$$

where

- M_1 is the mass of the saturated and surface dried aggregate in the air, in grams;
- M_2 is the apparent mass in water of the basket containing the sample of saturated aggregate, in grams;
- M_3 is the apparent mass in water of the empty basket, in grams;
- M_4 is the mass of the oven-dried test portion in air, in grams;
- ρ_w is the density of water at the temperature recorded when M_2 was determined, see annex D, in megagrams per cubic metre.

Express the values of particle density to the nearest 0,01 Mg/m³ and for the water absorption to the nearest 0,1 %.

NOTE 1 The calculations can be checked using the following equation:

$$\rho_{ssd} = 1 + \rho_{rd} - \frac{\rho_{rd}}{\rho_a}$$

NOTE 2 An indication of precision is given in annex E.

8 Pyknometer method for aggregate particles between 4 mm and 31,5 mm

8.1 General

The pyknometer method specified in this clause shall be used on aggregate particles between 4 mm and 31,5 mm.

8.2 Preparation of test portion

Sampling of the aggregate shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2. The mass of the test portion of aggregate shall be not less than the mass given in Table 2.

Table 2 — Minimum mass of test portions (pycnometer method)

Maximum size of aggregates mm	Minimum mass of test portion kg
31,5	5
16	2
8	1
NOTE For other sizes the minimum mass of the test portion may be interpolated from the masses given in Table 2.	

Wash the test portion on a 31,5 mm and a 4 mm sieve to remove finer particles. Discard any particle retained on the 31,5 mm sieve. Let the sample drain.

8.3 Test procedure

Immerse the prepared test portion in water at $(22 \pm 3) ^\circ\text{C}$ in the pycnometer and remove entrapped air by gently rolling and jolting the pycnometer in a tipped position. Stand the pycnometer in the water bath and keep the test portion at a temperature of $(22 \pm 3) ^\circ\text{C}$ for $(24 \pm 0,5)$ h. At the end of the soaking period, take the pycnometer from the water bath and remove any remaining entrapped air by gentle rolling and jolting.

NOTE 1 Entrapped air may also be removed by applying a vacuum.

Overfill the pycnometer by adding water and place the cover on top without trapping air in the vessel. Then dry the pycnometer on the outside and weigh it (M_2). Record the temperature of the water.

Remove the aggregate from the water and allow to drain for a few minutes. Refill the pycnometer with water and place the cover in position as before. Then dry the pycnometer on the outside and weigh it (M_3). Record the temperature of the water.

The difference in the temperature of the water in the pycnometer during the M_2 and M_3 weighings shall not exceed $2 ^\circ\text{C}$.

NOTE 2 Instead of measuring the pycnometer volume at each test it can be pre-calibrated. In that case the pycnometer should be tempered in a thermostatic bath to the calibration temperature $\pm 0,5 ^\circ\text{C}$.

Transfer the drained test portion onto one of the dry cloths. Gently surface-dry the aggregate placed upon it and transfer the aggregate to a second absorbent cloth when the first will remove no further moisture. Spread the aggregate out not more than one stone deep on the second sheet, 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.

Transfer the saturated and surface dry test portion to a tray and weigh the aggregate (M_1). Dry the aggregate in a ventilated oven at a temperature of $(110 \pm 5) ^\circ\text{C}$ until it has reached a constant mass (M_4).

Record all masses to an accuracy of 0,1 % of the mass of the test portion (M_4) or better.

8.4 Calculation and expression of results

Calculate the particle densities (ρ_a , ρ_{rd} , and ρ_{ssd} as appropriate), in megagrams per cubic metre, in accordance with the following equations:

$$\text{Apparent particle density} \quad \rho_a = \frac{M_4}{M_4 - (M_2 - M_3)}$$

$$\text{Particle density on an oven-dried basis} \quad \rho_{rd} = \frac{M_4}{M_1 - (M_2 - M_3)}$$

$$\text{Particle density on a saturated and surface-dried basis} \quad \rho_{ssd} = \frac{M_1}{M_1 - (M_2 - M_3)}$$

Calculate the water absorption (as a percentage of the dry mass) after immersion for 24 h (WA_{24}) from the following equation:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4}$$

where

- M_1 is the mass of the saturated and surface dried aggregate in the air, in grams;
- M_2 is the mass of the pyknometer containing the sample of saturated aggregate, in grams;
- M_3 is the mass of the pyknometer filled with water only, in grams;
- M_4 is the mass of the oven-dried test portion in air, in grams.

Express the values of particle density to the nearest 0,01 Mg/m³ and for the water absorption to the nearest 0,1 %.

NOTE 1 The calculations can be checked using the following equation:

$$\rho_{ssd} = 1 + \rho_{rd} - \frac{\rho_{rd}}{\rho_a}$$

NOTE 2 An indication of precision is given in annex E.

9 Pyknometer method for aggregate particles between 0,063 mm and 4 mm

9.1 General

The pyknometer method specified in this clause shall be used on aggregate particles between 0,063 mm and 4 mm.

NOTE The pyknometer method described in clause 8 can be used as an alternative for aggregates passing the 4 mm sieve but all retained on the 2 mm sieve.

9.2 Preparation of test portion

Sampling of the aggregate shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2. The mass of the test portion of aggregate shall be not less than 1 kg.

Wash the test portion on a 4 mm and a 0,063 mm sieve to remove finer particles. Discard particles retained on the 4 mm sieve.

9.3 Test procedure

Immerse the prepared test portion in water at $(22 \pm 3)^\circ\text{C}$ in the pycnometer and remove entrapped air by gently rolling and jolting the pycnometer in a tipped position. Stand the pycnometer in the water bath and keep the test portion at a temperature of $(22 \pm 3)^\circ\text{C}$ for $(24 \pm 0,5)$ h. At the end of the soaking period, take the pycnometer from the water bath and remove any remaining entrapped air by gentle rolling and jolting.

NOTE 1 Entrapped air may also be removed by applying a vacuum.

Overfill the pycnometer by adding water and place the cover on top without trapping air in the vessel. Then dry the pycnometer on the outside and weigh it (M_2). Record the temperature of the water.

Decant most of the water covering the test portion and empty the pycnometer into a tray.

Refill the pycnometer with water and place the cover in position as before. Then dry the pycnometer on the outside and weigh it (M_3). Record the temperature of the water.

The difference in the temperature of the water in the pycnometer during the M_2 and M_3 weighings shall not exceed 2°C .

NOTE 2 Instead of measuring the pycnometer volume at each test it can be pre-calibrated. In that case the pycnometer should be tempered in a thermostatic bath to the calibration temperature $\pm 0,5^\circ\text{C}$.

Spread the soaked test portion in a uniform layer over the bottom of the tray. Expose the aggregate to a gentle current of warm air to evaporate surface moisture. Stir it at frequent intervals to ensure uniform drying until no free surface moisture can be seen and the aggregate particles no longer adhere to one another. Allow the sample to cool to room temperature whilst stirring it.

To assess whether the surface dry state has been achieved, hold the metal cone mould with its largest diameter face downwards on the bottom of the tray. Fill the cone mould loosely with part of the drying test portion and use the tamper to lightly tamp the surface 25 times, through the hole at the top of the mould. Do not refill the mould after tamping. Gently lift the mould clear of the aggregate. If the aggregate cone does not collapse, continue drying and repeat the cone test just until the collapse situation occurs at mould removal.

NOTE 3 Further guidance is given in the figures shown in annex F.

Weigh the saturated and surface dry test portion (M_1). Dry the aggregate in a ventilated oven at a temperature of $(110 \pm 5)^\circ\text{C}$ until it has reached a constant mass (M_4).

Record all masses to an accuracy of 0,1 % of the mass of the test portion (M_4) or better.

9.4 Calculation and expression of results

Calculate the particle densities (ρ_a , ρ_{rd} , and ρ_{ssd} as appropriate), in megagrams per cubic metre, in accordance with the following equations:

Apparent particle density
$$\rho_a = \frac{M_4}{M_4 - (M_2 - M_3)}$$

Particle density on an oven-dried basis
$$\rho_{rd} = \frac{M_4}{M_1 - (M_2 - M_3)}$$

Particle density on a saturated and surface-dried basis
$$\rho_{ssd} = \frac{M_1}{M_1 - (M_2 - M_3)}$$

Calculate the water absorption (as a percentage of the dry mass) after immersion for 24 h (WA_{24}) in accordance with the following equation:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4}$$

where

- M_1 is the mass of the saturated and surface dried aggregate in the air, in grams;
- M_2 is the mass of the pyknometer containing the sample of saturated aggregate, in grams;
- M_3 is the mass of the pyknometer filled with water only, in grams;
- M_4 is the mass of the oven-dried test portion in air, in grams.

Express the values of particle density to the nearest 0,01 Mg/m³ and for the water absorption to the nearest 0,1 %.

NOTE 1 The calculations can be checked using the following equation:

$$\rho_{ssd} = 1 + \rho_{rd} - \frac{\rho_{rd}}{\rho_a}$$

NOTE 2 An indication of precision is given in annex E.

10 Test report

10.1 Required data

The test report shall include the following information:

- a) reference to this European Standard;
- b) identification of the sample;
- c) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each size fraction;
- d) mass of dry sample tested;
- e) the method used to determine the particle density and absorption (clauses 7, 8 or 9);
- f) the test results (four values for each test);
- g) date of test;
- h) name and location of the test laboratory.

10.2 Optional data

The test report can include the following information:

- a) name and location of the sample source;
- b) description of the sampling procedure;
- c) petrographic description (see EN 932-3).

Annex A (normative)

Determination of pre-dried particle density of aggregates

A.1 General

This annex specifies methods for the determination of the pre-dried particle density of aggregates with a particle density greater than 1 Mg/m^3 . It applies to aggregate particles between 0,063 mm and 63 mm using the following methods:

- a) Wire basket method for aggregates between 31,5 mm and 63 mm;
- b) Pycnometer method for aggregates between 0,063 mm and 31,5 mm.

NOTE The wire basket method can be used as an alternative to the pycnometer method for aggregates between 4 mm and 31,5 mm. In case of dispute, the pycnometer method should be used as the reference method.

A.2 Principle

The purpose of this test is to determine the mass and volume of the test specimen and calculate its particle density as the ratio mass to volume. The mass is obtained by weighing the specimen in an oven-dry condition. The volume is determined as the water displacement of the dry particles either by weight reduction in a wire basket or in a pycnometer of known volume.

A.3 Wire basket method for aggregate particles between 31,5 mm to 63 mm

A.3.1 Preparation of test portion

The test portion shall be prepared as specified in 7.2.

A.3.2 Procedure

Dry the test portion in the oven at $(110 \pm 5)^\circ\text{C}$ until constant mass is achieved. Allow to cool to ambient temperature and weigh the test portion (M_1).

Place the test portion in the wire basket and immerse it in the tank containing water at a temperature of $(22 \pm 3)^\circ\text{C}$, 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 test specimen by lifting the basket about 25 mm above the base of the tank and allowing it to drop 25 times at about once per second.

Allow the basket and aggregate to remain completely immersed for no longer than 10 min. Shake the basket and test specimen and weigh them in water at a temperature of $(22 \pm 3)^\circ\text{C}$ (M_2). Record the temperature of the water when mass (M_2) was determined.

NOTE If it is necessary for the test specimen to be transferred to a different tank for weighing, shake the basket and test specimen 25 times as before in the new tank before weighing (M_2).

Empty the basket and return it to the water. Shake it 25 times and weigh it in water (M_3).

Record all weighing to an accuracy of 0,1 % of the mass of the test portion (M_1) or better.

A.3.3 Calculation and expression of results

Calculate the pre-dried particle density (ρ_p), in megagrams per cubic metre, for each test specimen in accordance with the following equation:

$$\rho_p = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)}$$

where

- M_1 is the mass of the oven-dry test specimen, in grams;
 M_2 is the mass in water of the basket containing the test sample, under water in grams;
 M_3 is the mass in water of the empty basket, in grams;
 ρ_w is the density of the water at the test temperature, in megagrams, per cubic metre (see annex D).

Express the value of pre-dried particle density to the nearest 0,01 Mg/m³.

NOTE An indication of precision is given in annex E.

A.4 Pyknometer method for aggregate particles between 0,063 mm and 31,5 mm**A.4.1 Preparation of test specimens**

Sampling of the aggregate shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2.

Two test specimens shall be prepared. The mass of the test specimens shall be not less than the mass given in Table A.1.

Table A.1 — Minimum mass of test specimens (pyknometer method)

Maximum size of aggregates mm	Minimum mass of test specimen kg
31,5	1,5
16	1,0
8	0,5
4 (or less)	0,25
NOTE For other sizes the minimum mass of the test portion may be interpolated from the masses given in Table A.1.	

A.4.2 Calibration of the pyknometer

Determine the volume of the pyknometer by filling it with water at $(22 \pm 3)^\circ\text{C}$ and placing it for at least 1 h in the water bath at $(22 \pm 3)^\circ\text{C}$. Calculate its volume (V), in millilitres, as the mean of three measurements, the range of the three individual values not exceeding 0,1 % of the mean value. When calculating the volume, make a correction for the density of the water by dividing the mass of the water filling the pyknometer by the density of the water at the measured calibration temperature (see annex D).

NOTE Instead of measuring the pyknometer volume at each test it can be pre-calibrated.

A.4.3 Procedure

During the test the water-bath shall be kept at a temperature of $(22 \pm 3) ^\circ\text{C}$.

Wash the test specimen to remove adherent particles and discard any particles retained on the 31,5 mm sieve and passing the 0,063 mm sieve. Dry in the oven at $(110 \pm 5) ^\circ\text{C}$ to constant mass. Allow to cool to ambient temperature.

Weigh the pyknometer and its funnel (M_1). Place the test specimen carefully into the pyknometer. Insert the funnel on the top of pyknometer and weigh the assembly (M_2).

NOTE 1 To prevent the funnel adhering to the pyknometer, some silicone grease can be added to the contact area before weighing.

Fill the pyknometer with water at $(22 \pm 3) ^\circ\text{C}$, to about 30 mm below the ground section of the neck. Carefully stir the aggregate with a glass rod to remove entrapped air and adherent air bubbles.

NOTE 2 Gentle rolling and tapping the pyknometer or vibrating the pyknometer on a vibrating table can serve the same purpose.

When the air is removed, refill the pyknometer (with the funnel in place) with water up to about 20 mm below the graduation mark on the funnel and place in the water-bath at $(22 \pm 3) ^\circ\text{C}$ for at least 1 h.

NOTE 3 The level of the water in the water-bath should be about 20 mm lower than the neck of the pyknometer.

Fill the pyknometer with water up to the graduation mark. Remove the pyknometer from the water bath, carefully dry the outside and weigh (M_3). Repeat the procedure using the second test specimen.

Record all weighing to an accuracy of 0,1 % of the mass of the test specimen ($M_2 - M_1$) or better.

A.4.4 Calculation and expression of results

Calculate the pre-dried particle density (ρ_p), in megagrams per cubic metre, for each test specimen in accordance with the following equation:

$$\text{Pre-dried particle density} \quad \rho_p = \rho_w \frac{(M_2 - M_1)}{V - (M_3 - M_2)}$$

where

M_1	is the mass of the pyknometer and funnel, in grams;
M_2	is the mass of the pyknometer, funnel and test specimen, in grams;
M_3	is the mass of the pyknometer, funnel, test specimen and water, in grams;
V	is the volume of the pyknometer, in millilitres;
ρ_w	is the density of the water at the test temperature, in megagrams per cubic metre.

Express the value of particle density for each test specimen to the nearest $0,001 \text{ Mg/m}^3$. The pre-dried particle density is the mean of the results for the two test specimens rounded to the nearest $0,01 \text{ Mg/m}^3$.

NOTE An indication of precision is given in annex E.

A.5 Test report

A.5.1 Required data

The test report shall include the following information:

- a) reference to this European Standard and this annex;
- b) identification of the sample;
- c) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each fraction;
- d) mass of dry sample tested;
- e) the method (wire basket or pycnometer) used to determine the pre-dried particle density;
- f) the test results;
- g) date of test.

A.5.2 Optional data

The test report can include the following information:

- a) name and location of the sample source;
- b) description of the sampling procedure;
- c) petrographic description (see EN 932-3).

Annex B (normative)

Determination of particle density and water absorption of coarse aggregates saturated to constant mass

B.1 General

This annex specifies a method for the determination of particle density and water absorption of coarse aggregate saturated to constant mass. The method may be used with a test portion consisting of a number of pieces of aggregate such as rail ballast.

NOTE 1 This method is based on the wire basket method specified in clause 7.

NOTE 2 The particle density of aggregate saturated to constant mass is equivalent to the particle density on a saturated and surface dried basis defined in 3.4 but absorption is allowed to continue until a constant mass is achieved.

B.2 Preparation of test portion

B.2.1 Sampling and sample reduction

Sampling of the aggregate shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2.

B.2.2 Single pieces of aggregate

The test portion shall consist of a single piece of aggregate with a mass of at least 150 g. If water absorption is to be determined, the mass of the test piece shall not exceed 350 g.

Remove any loose fragments and wash the test portion under running water to remove adhering fine particles.

NOTE A number of tests can be carried out at the same time, if each piece is clearly marked. For homogeneous aggregates at least 10 pieces should be tested. For non-homogeneous aggregates at least five pieces should be tested.

B.2.3 Rail ballast

The test portion shall consist of at least 10 pieces of aggregate for rail ballast with a size in the range 40 mm to 50 mm or 50 mm to 63 mm. Each piece shall have a mass of at least 150 g but not more than 350 g.

Remove any loose fragments and wash the test portion under running water to remove adhering fine particles.

B.3 Test procedure

Place the prepared test portion in the container and completely immerse it in water until its mass is constant. Place the test portion in the wire-basket suspended from the balance and immerse them in the tank containing water with a cover of at least 50 mm of water above the top of the basket.

Determine the apparent mass of the test portion in water (M_2) and measure the temperature of the water in the container to the nearest 1 °C.

Remove the test portion from the water and immediately remove the water from its surface using the absorbent cloths, until the surface is dull and no longer wet and shiny. Weigh the test portion (M_1).

Dry the test portion in the oven at a temperature of (110 ± 5) °C until it has reached constant mass (M_3).

Record all weighing to an accuracy of 0,05 % of the mass of the test portion (M_3) or better.

B.4 Calculation and expression of results

Calculate the particle density of coarse aggregate saturated to constant mass (ρ_{cm}), in megagrams per cubic metre, in accordance with the following equation:

$$\rho_{cm} = \frac{M_3 \times \rho_w}{M_1 - M_2}$$

Calculate the water absorption W_{cm} (as a percentage of the dry mass) in accordance with the following equation:

$$W_{cm} = \frac{M_1 - M_3}{M_3} \times 100$$

where

- | | |
|----------|--|
| M_1 | is the mass of the saturated and surface dried test portion, in grams; |
| M_2 | is the apparent mass in water of the saturated test portion, in grams; |
| M_3 | is the mass of the oven-dried test portion, in grams; |
| ρ_w | is the density of water at the temperature recorded when M_2 was determined, in megagrams per cubic metre (see annex D). |

Express the values of particle density to the nearest 0,01 Mg/m³ and the water absorption to the nearest 0,1 %.

NOTE An indication of precision is given in annex E.

B.5 Test report

B.5.1 Required data

The test report shall include the following information:

- reference to this European Standard and this annex;
- identification of the sample;
- the nominal grading of the aggregate from which the sample was taken;
- mass of dry sample tested;
- the test results;
- date of test.

B.5.2 Optional data

The test report can include the following information:

- name and location of the sample source;
- description of the sampling procedure.
- petrographic description (see EN 932-3).

Annex C (normative)**Determination of particle density and water absorption of lightweight aggregates****C.1 General**

This annex specifies a method, using a pycnometer, for the determination of pre-dried particle density and water absorption with time of lightweight aggregates. It applies to aggregate particles between 4 mm and 31,5 mm.

C.2 Preparation of test portion

Sampling of the aggregate shall be in accordance with EN 932-1 and reduction shall be in accordance with EN 932-2.

The test shall be carried out using two test specimens. Prepare each specimen to have a volume between 0,5 l and 0,6 l. Wash each one on a 4 mm sieve to remove finer particles and allow to drain. Discard any particles retained on the 31,5 mm sieve.

C.3 Calibration of the pycnometer

Weigh (M_p) the dry pycnometer and funnel and grid (if used).

Determine the volume of the pycnometer by filling it with water at $(22 \pm 3)^\circ\text{C}$ and placing it for at least 1 h in the water bath at $(22 \pm 1)^\circ\text{C}$. Top up with water to the funnel mark, and remove from the water bath. Carefully dry the outside and weigh (M). Calculate $(M - M_p)$.

Correct for the density of the water by dividing the mass of the water filling the pycnometer by the density of the water at the measured calibration temperature, to give a calculated volume (V_p).

NOTE Instead of measuring the pycnometer volume at each test it can be pre-calibrated.

C.4 Procedure

The test is carried out in duplicate using two test specimens. During the test the water-bath shall be kept at temperature of $(22 \pm 1)^\circ\text{C}$.

Weigh the pycnometer and its funnel or, in the case of floating lightweight aggregates, weigh the pycnometer, the grid and its funnel (m_1).

Dry the test specimens in the oven at $(110 \pm 5)^\circ\text{C}$ to constant mass. Allow to cool to ambient temperature and place the first test specimen carefully into the pycnometer. Weigh the pycnometer containing the first test specimen or, in the case of floating lightweight aggregates, insert the grid into the pycnometer, place the funnel on top of the pycnometer and weigh the assembly (m_2).

NOTE 1 To prevent the funnel adhering to the pycnometer, some silicone grease may be added to the contact area before weighing.

Fill the pycnometer with water at $(22 \pm 1)^\circ\text{C}$ up to the mark on the funnel and start the stopwatch. Place the assembly in the water bath at $(22 \pm 1)^\circ\text{C}$. Add water as necessary during the test, to keep the water level close to the funnel mark.

After a period of 5 min, remove the assembly from the water-bath. Stir the aggregate by gently rolling and tapping the pycnometer or apply gently vibration to remove entrapped air. Refill the pycnometer with water up to the funnel mark, carefully dry the outside and weigh (M_5). Return the pycnometer to the water-bath.

Repeat the operation described above after 24 h (M_{24}).

NOTE 2 The operation can also be carried out at other times (2 h and 7 days are examples to

suit the end uses for the aggregate).

After the final measurement, pour the water from the pycnometer. Transfer the aggregate to a dry cloth and remove the surface water by gentle rolling in the cloth for not more than 15 s. Weigh the aggregate (M_w). Repeat the procedure for the second test specimen.

NOTE 3 For most tests M_w will be determined after 24 h.

C.5 Calculation and expression of results

For each test specimen, calculate the apparent particle density (ρ_a) of lightweight aggregate, in megagrams per cubic metre, in accordance with the following equation:

$$\rho_a = \frac{(m_2 - m_1)\rho_w}{M_p + (V_p \times \rho_w) + M_w - M_F}$$

where

m_1	is the mass of the pycnometer, funnel and grid (if used), in grams;
m_2	is the mass of the pycnometer, funnel, dry test specimen and grid (if used), in grams;
ρ_w	is the density of water at 22 °C;
M_p	is the mass of the pycnometer and grid (if used) at calibration, in grams;
V_p	is the volume of the pycnometer at calibration, in millilitres;
M_w	is the mass of the surface dried aggregate at the end of the test, in grams;
M_F	is the mass of the pycnometer, funnel, test specimen, water and grid (if used) at the final measuring time, in grams.

Calculate the value of particle density to the nearest 0,001 Mg/m³.

The average of the two test specimen values, expressed to the nearest 0,01 Mg/m³, is the pre-dried particle density of lightweight aggregate.

Calculate the water absorption (as a percentage of the dry mass) at the final measuring time (W_F) in accordance with the following equation:

$$W_F = \frac{M_w - (m_2 - m_1)}{(m_2 - m_1)} \times 100$$

Calculate the water absorption (as a percentage of the dry mass) at the intermediate measuring times (W_i) in accordance with the following equation:

$$W_i = W_F - \frac{(M_F - M_i)}{(m_2 - m_1)} \times 100$$

where

m_1	is the mass of the pycnometer, funnel and grid (if used), in grams;
m_2	is the mass of the pycnometer, funnel, dry test specimen and grid (if used), in grams;
M_F	is the mass of the pycnometer, funnel, test specimen, water and grid (if used) at the final measuring time, in grams;
M_i	is the mass of the pycnometer, funnel, test specimen, water and grid (if used) at the intermediate measuring time, in grams.

Calculate each value of water absorption to the nearest 0,1 %. Use the average value for the two test specimens, expressed to the nearest 0,1 %, as the water absorption at each measuring time.

C.6 Test report

C.6.1 Required data

The test report shall include the following information:

- a) reference to this European Standard and this annex;
- b) identification of the sample;
- c) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each fraction;
- d) mass of dry sample tested;
- e) the test results;
- f) date of test.

C.6.2 Optional data

The test report can include the following information:

- a) name and location of the sample source;
- b) description of the sampling procedure;
- c) petrographic description (see EN 932-3).

Annex D (informative)

Density of water

Table D.1 – Density of water

Temperature °C	Density Mg/m ³
5	1,000 0
6	0,999 9
7	0,999 9
8	0,999 8
9	0,999 8
10	0,999 7
11	0,999 6
12	0,999 5
13	0,999 4
14	0,999 2
15	0,999 1
16	0,998 9
17	0,998 8
18	0,998 6
19	0,998 4
20	0,998 2
21	0,998 0
22	0,997 8
23	0,997 5
24	0,997 3
25	0,997 0
26	0,996 8
27	0,996 5
28	0,996 2
29	0,995 9
30	0,995 6

Annex E (informative)**Precision****E.1 Data from national standards**

The precision data given in Tables E.1 to E.5 has been extracted from national standards and may deviate slightly from precision data obtained using the test methods specified in this European Standard. The data may not be appropriate for lightweight aggregates.

Table E.1 — Apparent particle density - repeatability r and reproducibility R

Method of test	Clause no.	Repeatability r Mg/m ³	Reproducibility R Mg/m ³
Wire Basket	7	0,023	0,031
Pyknometer (coarse aggregate)	8	0,031 (UK) 0,025 (F)	0,044 (UK) 0,028 (F)
Pyknometer (fine aggregate)	9	0,038	0,067

Table E.2 — Particle density on an oven-dried basis - repeatability r and reproducibility R

Method of test	Clause no.	Repeatability r Mg/m ³	Reproducibility R Mg/m ³
Wire Basket	7	0,025	0,044
Pyknometer (coarse aggregate)	8	0,031	0,042
Pyknometer (fine aggregate)	9	0,043	0,085

Table E.3 — Particle density on saturated and surface-dried basis - repeatability r and reproducibility R

Method of test	Clause no.	Repeatability r Mg/m ³	Reproducibility R Mg/m ³
Wire Basket	7	0,022	0,034
Pyknometer (coarse aggregate)	8	0,031	0,049
Pyknometer (fine aggregate)	9	0,035	0,070

Table E.4 — Water absorption - repeatability r and reproducibility R

Method of test	Clause no.	Repeatability r %	Reproducibility R %
Wire Basket	7	0,2	0,3
Pyknometer (coarse aggregate)	8	0,3	0,4
Pyknometer (fine aggregate)	9	0,5	1,2

Table E.5 — Pyknometer test for pre-dried particle density of non-porous aggregates (see A.4) - repeatability r_1 and reproducibility R_1

Critical range W_c Mg/m ³	Repeatability r_1 Mg/m ³	Reproducibility R_1 Mg/m ³
0,025	0,019	0,042

E.2 Data from cross testing experiments

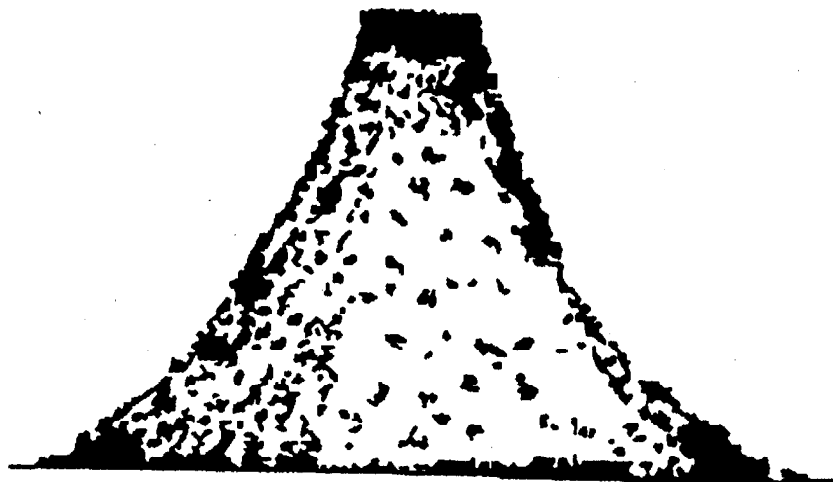
The results of a cross testing experiment carried out by nineteen laboratories in 1996, as part of a project (Project 134) funded by the European Community under the Measurements and Testing Programme, are given in Table E.6.

Table E.6 — Repeatability and reproducibility values for determinations of particle density (Mg/m³) and water absorption (%) of coarse aggregates

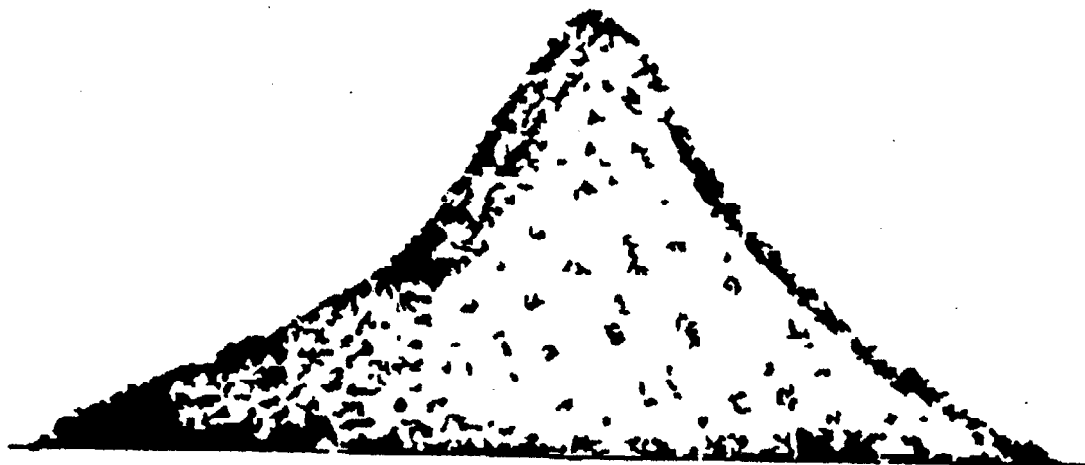
			Level 1	Level 2	Level 3
Pre-dried particle density	Number of laboratories included	N	18	19	18
	Average	X	2,70	3,06	2,60
	Repeatability standard deviation	S_{r1}	0,002 8	0,005 6	0,003 0
	Reproducibility standard deviation	S_{R1}	0,006 7	0,009 4	0,013 4
	Critical range	W_c	0,010	0,021	0,012
	Repeatability limit	r_1	0,008	0,016	0,009
	Reproducibility limit	R_1	0,019	0,026	0,037
Saturated and surface-dried particle density	Number of laboratories included	N	19	19	19
	Average	X	2,67	3,05	2,51
	Repeatability standard deviation	S_{r1}	0,002 7	0,005 8	0,005 9
	Reproducibility standard deviation	S_{R1}	0,004 1	0,008 9	0,009 2
	Repeatability limit	r_1	0,008	0,016	0,017
	Reproducibility limit	R_1	0,012	0,025	0,026
Water absorption	Number of laboratories included	N	19	19	16
	Average	X	1,0	0,5	3,1
	Repeatability standard deviation	S_{r1}	0,061	0,047	0,084
	Reproducibility standard deviation	S_{R1}	0,101	0,0112	0,222
	Repeatability limit	r_1	0,17	0,13	0,24
	Reproducibility limit	R_1	0,28	0,31	0,62

Annex F (informative)

Guidance on the saturated and surface dry condition of fine aggregates



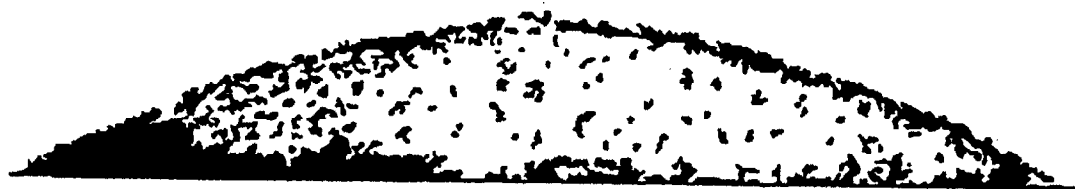
a) Aggregate moist, almost retains complete shape of metal mould



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 guidance only.

Bibliography

- EN 932-3 *Tests for general properties of aggregates -
Part 3: Procedure and terminology for simplified petrographic description.*

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