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BSI Standards Publication

Tests for mechanical and physical properties of aggregates

Part 6: Determination of particle density and water absorption

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National foreword

This British Standard is the UK implementation of EN 1097-6:2013. It supersedes BS EN 1097-6:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/502/6, Test methods.

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

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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

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Contents

Page

Foreword

This document (EN 1097-6:2013) 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of an identical text or by endorsement, at the latest by January 2014, and conflicting national standards shall be withdrawn at the latest by January 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1097-6:2000.

Annex J provides details of significant changes between this European Standard and the previous edition.

This standard forms a part of a series of tests for mechanical and physical properties of aggregates. Test methods for other properties of aggregates are covered by the following European Standards:

— EN 932 (all parts), *Tests for general properties of aggregates*

— EN 933 (all parts), *Tests for geometrical properties of aggregates*

— EN 1367 (all parts), *Tests for thermal and weathering properties of aggregates*

— EN 1744 (all parts), *Tests for chemical properties of aggregates*

— EN 13179 (all parts), *Tests for filler aggregate used in bituminous mixtures*

The other parts of EN 1097 include:

— *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 the 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: Determination of water suction height*

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Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies the reference methods used for type testing and in case of dispute, for the determination of particle density and water absorption of normal weight and lightweight aggregates. Other methods may be used for other purposes, such as factory production control, provided that an appropriate working relationship with the reference method has been established. For convenience, some of these other methods are also described in this standard.

The reference methods for normal weight aggregates specified are:

— a wire basket method for aggregate particles retained on the 31,5 mm sieve (Clause 7, except for railway ballast which uses Annex B);

— a pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve (Clause 8);

— a pyknometer method for aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test sieve (Clause 9).

In Clauses 7, 8 and 9, three different particle density parameters (oven-dried particle density, saturated and surface dried particle density and apparent particle density) and water absorption are determined after a soaking period of 24 h. In Annex B, the oven-dried particle density parameter is determined after soaking in water to constant mass.

The wire basket method may be used as an alternative to the pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve. In case of dispute, the pyknometer method described in Clause 8 should be used as the reference method.

NOTE 1 The wire basket method can also be used for single aggregate particles retained on the 63 mm sieve.

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

The reference method for lightweight aggregates (Annex C) is a pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve. Three different particle density parameters and water absorption are determined after pre-drying and a soaking period of 24 h.

Three other methods for normal weight aggregates can be used to determine the pre-dried particle density:

— a wire basket method for aggregate particles passing the 63 mm test sieve and retained on the 31,5 mm test sieve (A.3);

— a pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 0,063 mm test sieve (A.4);

— a pyknometer method for aggregate particles passing the 31,5 mm test sieve, including the 0/0,063 mm size fraction (Annex G).

NOTE 3 If water absorption is less than about 1,5 %, the apparent particle density can be assessed using the pre-dried particle density method as defined in Annex A.

The quick method in Annex E can be used in factory production control to determine the apparent particle density of lightweight aggregates.

Guidance on the significance and use of the various density and water absorption parameters is given in Annex H.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

3 Terms and definitions

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

3.1
apparent particle density

ρ_a
ratio obtained by dividing the oven-dried mass of an aggregate sample by the volume it occupies in water including the volume of any internal sealed voids but excluding the volume of water in any water accessible voids

Note 1 to entry: For lightweight aggregates the symbol ρ_{La} is used.

3.2
constant mass
mass determined after successive weighings at least 1 h apart not differing by more than 0,1 %

Note 1 to entry: 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 ± 5) °C. Test laboratories can determine the time necessary to achieve constant mass for specific types and sizes of sample dependent upon the drying capacity of the oven used.

3.3
oven-dried particle density

ρ_{rd}
ratio obtained by dividing the oven-dried mass of an aggregate sample by the volume it occupies in water including the volume of any internal sealed voids and the volume of any water accessible voids

Note 1 to entry: For lightweight aggregates the symbol ρ_{Lrd} is used.

3.4
pre-dried particle density

ρ_p
ratio obtained by dividing the pre-dried mass of an aggregate sample by the volume it occupies in water including the volume of any internal sealed voids but excluding the volume of water in any water accessible voids

Note 1 to entry: Test conditions in terms of pre-drying of the test sample and the shorter immersion period differ from the ones for apparent particle density.

Note 2 to entry: Pre-dried particle density is a rapid test.

3.5
saturated and surface-dried particle density

ρ_{ssd}
ratio obtained by dividing the sum of the oven-dried mass of an aggregate sample and the mass of water in any water accessible voids by the volume it occupies in water including the volume of any internal sealed voids and the volume of any water accessible voids

Note 1 to entry: For lightweight aggregates the symbol ρ_{Lssd} is used.

3.6
test portion
sample used as a whole in a single test

3.7
test specimen
sample used in a single determination when a test method requires more than one determination of a property

3.8
water absorption
mass of absorbed water expressed as a percentage of the oven-dried mass of the aggregate sample

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 pyknometer method.

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 test report.

For porous aggregates, the values of absorption and density depend on the size fractions which are tested. For this reason, the size fractions tested should be stated in the test report.

If the aggregate consists of a number of different size fractions, it may be necessary to separate the various fractions before preparing the test portion. The percentage of each size fraction shall be stated in the test report.

5 Materials

Water, boiled and cooled before use.

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

6 Apparatus

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

6.1 Apparatus for general purposes.

6.1.1 Ventilated oven, thermostatically controlled to maintain a temperature of (110 ± 5) °C.

6.1.2 Balance, accurate to 0,1 % of the mass of the test portion and of sufficient capacity to enable the wire basket containing the sample to be suspended and weighed in water.

6.1.3 Water bath, thermostatically controlled, capable of being maintained at (22 ± 3) °C.

6.1.4 Thermometer, accurate to 0,1 °C.

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

6.1.6 Trays, which can be heated in a ventilated oven without change in mass.

6.1.7 Dry soft absorbent cloths.

6.1.8 Washing equipment.

6.1.9 Timer.

6.2 Special apparatus for the wire basket method (Clause 7, A.3 and Annex B).

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

6.2.2 Watertight tank, containing water at (22 ± 3) °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 6.1.3.

6.3 Special apparatus for pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve (Clause 8).

6.3.1 Pyknometer, 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.

The volume of the pyknometer should be chosen to suit the size of the test portion. It is recommended that the test portion occupies about half of the pyknometer volume. Two smaller pyknometers can be used instead of one large one, by summing the weighings before calculating the density of the aggregate.

6.4 Special apparatus for pyknometer method for aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test sieve (Clause 9).

6.4.1 Pyknometer, consisting of a glass flask or other suitable vessel with volume between 500 ml and 2 000 ml, constant to 0,5 ml for the duration of the test.

The volume of the pyknometer should be chosen to suit the size of the test portion. It is recommended that the test portion occupies about half of the pyknometer volume. Two smaller pyknometers can be used instead of one large one, by summing the weighings before calculating the density of the aggregate.

6.4.2 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.

6.4.3 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.

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

6.4.5 Shallow tray, of non-water absorbing material having a plane bottom of area not less than 0,1 m² and an edge of not less than 50 mm in height.

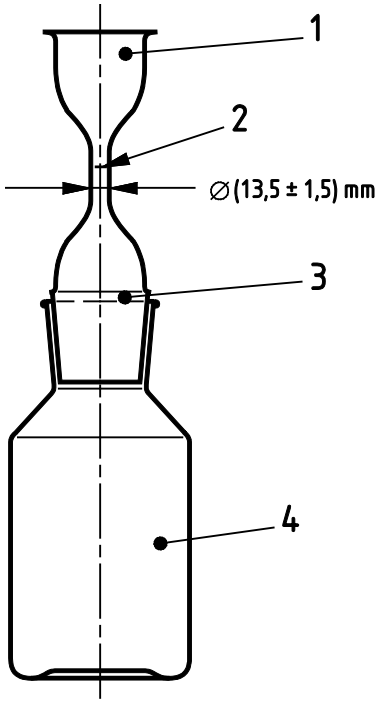
6.4.6 Warm air supply, such as a hair dryer.

6.5 Special apparatus for the pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 0,063 mm test sieve (A.4).

6.5.1 Pyknometer, consisting of a glass flask with a volume between 250 ml and 5000 ml, constant to 0,5 ml for the duration of the test, and a corresponding glass funnel.

Choose the pyknometer to suit the size of the test specimen. It is recommended that the test specimen occupies about half of the pyknometer volume.

NOTE An example of a suitable pyknometer is shown 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

6.6 Special apparatus for the determination of particle density and water absorption of coarse aggregates saturated to constant mass (Annex B).

6.6.1 Container, of similar capacity to the wire basket specified in 6.2.1 for storage of the sample in water.

6.7 Special apparatus for the determination of particle density and water absorption of lightweight aggregates (C.1).

6.7.1 Pyknometer, consisting of a glass flask with a volume between 1 000 ml and 2 000 ml and a corresponding funnel (Figure 1). If appropriate, the pyknometer shall contain a flexible grid to prevent aggregates from floating.

The size of the funnel should enable the release of any air bubbles.

The volume of the pyknometer should be chosen to suit the size of the test portion. It is recommended that the test portion occupies about half of the pyknometer volume.

6.8 Special apparatus for the determination of particle density of lightweight aggregates–with cylinder method (Annex E).

6.8.1 Glass graduated measuring cylinders, with a measuring volume of 1 000 ml.

6.8.2 Steel plunger (Figure 2), with a perforated base and vertical rod, to prevent aggregate particles from floating to the surface of the water. The difference between the internal diameter of the measuring cylinder and the diameter of the base shall be less than the smallest aggregate particles to be tested. The vertical rod of the plunger shall be marked so that volume it occupies in water is constant.

The dimensions of the holes in the perforated plate should be less than the smallest aggregate particles to be tested, but large enough to enable the release of entrapped air.

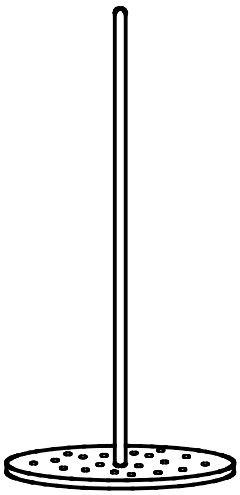


Figure 2 — Steel plunger with perforated plate

6.9 Special apparatus for the determination of the pre-dried particle density of aggregate passing the 31,5 mm test sieve (including the 0/0,063 mm size fraction) (Annex G).

6.9.1 Vacuum system, with a manometer or vacuum gauge, capable of evacuating air from the pyknometer to give a residual pressure of 4 kPa or less.

7 Wire basket method for aggregate particles passing the 63 mm test sieve and retained on the 31,5 mm test sieve

7.1 General

The wire basket method shall be used on aggregate particles passing the 63 mm test sieve and retained on the 31,5 mm test sieve. In the case of larger particles, reduce the particle 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. Wash the sample on the 63 mm sieve and the 31,5 mm sieve to remove finer particles. Discard any particles retained on the 63 mm sieve. Let the sample drain.

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)

Upper (D) aggregate size mm	**Minimum mass of test portions** kg
63	15
≤ 45	7
For other sizes, the minimum mass of the test portion may be interpolated from the masses specified in Table 1.	

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 ± 3) °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 letting it drop 25 times at about once per second.

Leave the basket and aggregate to remain completely immersed in the water at (22 ± 3) °C for a period of (24 ± 0,5) h.

Shake the basket and test portion and weigh them in water at a temperature of (22 ± 3) °C, M_2. Record the temperature of the water when M_2 was determined.

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 leave 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 ± 5) °C until it has reached constant mass. Let it cool to ambient temperature and weigh, M_4.

Record all masses 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 megagram per cubic metre in accordance with the following formulae:

apparent particle density $$\rho_a = \rho_w \frac{M_4}{M_4 - (M_2 - M_3)} \quad (1)$$

oven-dried particle density $$\rho_{rd} = \rho_w \frac{M_4}{M_1 - (M_2 - M_3)} \quad (2)$$

saturated and surface-dried particle density $$\rho_{ssd} = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)} \quad (3)$$

and the water absorption after immersion for 24 h, WA_{24}, in accordance with the following formula:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4} \quad (4)$$

where

ρ_w is the density of water at the temperature recorded when M_2 was determined, in megagrams per cubic metre (see Annex D);

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.

Express the values of particle density to the nearest 0,01 Mg/m^3 and the water absorption to the nearest 0,1 %.

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

$$\rho_{ssd} = \rho_{rd} + \rho_w (1 - \rho_{rd} / \rho_a) \quad (5)$$

NOTE 2 An indication of precision is given in Annex I.

8 Pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve

8.1 General

The pyknometer method specified in this clause shall be used on aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve.

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

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 (pyknometer method)

Upper (D) aggregate size mm	**Minimum mass of test portion** kg
31,5	5
16	2
8	1
For other sizes, the minimum mass of the test portion may be interpolated from the masses given in Table 2.	

8.3 Test procedure

Immerse the prepared test portion in water at (22 ± 3) °C in the pyknometer and remove entrapped air by gently rolling and jolting the pyknometer in a tipped position. Stand the pyknometer in the water bath and keep the test portion at a temperature of (22 ± 3) °C for (24 ± 0,5) h. At the end of the soaking period, take the pyknometer from the water bath and remove any remaining entrapped air by gentle rolling and jolting.

Entrapped air may also be removed by applying a vacuum.

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

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

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

Instead of measuring the pyknometer volume at each test it can be pre-calibrated. In that case the pyknometer should be tempered in a thermostatic bath to the calibration temperature ± 0,5 °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 aggregate particle 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-dried test portion to a tray and weigh the aggregate, M_1. Dry the aggregate in a ventilated oven at a temperature of (110 ± 5) °C until it has reached a constant mass. Let it cool to ambient temperature and weigh, 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 megagram per cubic metre in accordance with the following formulae:

apparent particle density $$\rho_a = \rho_w \frac{M_4}{M_4 - (M_2 - M_3)} \quad (6)$$

oven-dried particle density $$\rho_{rd} = \rho_w \frac{M_4}{M_1 - (M_2 - M_3)} \quad (7)$$

saturated and surface-dried particle density $$\rho_{ssd} = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)} \quad (8)$$

and the water absorption after immersion for 24 h, WA_{24}, from the following formula:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4} \quad (9)$$

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Annex D);

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 and water, 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/m^3 and the water absorption to the nearest 0,1 %.

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

$$\rho_{ssd} = \rho_{rd} + \rho_w \left(1 - \rho_{rd} / \rho_a\right) \quad (10)$$

NOTE 2 An indication of precision is given in Annex I.

9 Pyknometer method for aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test sieve

9.1 General

The pyknometer method specified in this clause shall be used on aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test 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. Wash the sample on a 4 mm and a 0,063 mm sieve to remove finer particles. Discard particles retained on the 4 mm sieve.

The mass of the 0,063/4 mm test portion of aggregate shall be not less than 300 g.

9.3 Test procedure

Immerse the prepared test portion in water at (22 ± 3) °C in the pyknometer and remove entrapped air by gently rolling and jolting the pyknometer in a tipped position. Stand the pyknometer in the water bath and keep the test portion at a temperature of (22 ± 3) °C for (24 ± 0,5) h. At the end of the soaking period, take the pyknometer from the water bath and remove any remaining entrapped air by gentle rolling and jolting.

Entrapped air may also be removed by applying a vacuum.

Overfill the pyknometer by adding water and place the cover on top without trapping air in the vessel. Then dry the pyknometer 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 pyknometer into a tray.

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

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

Instead of measuring the pyknometer volume at each test it can be pre-calibrated. In that case the pyknometer should be tempered in a thermostatic bath to the calibration temperature ± 0,5 °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. Let the sample 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. Through the hole at the top of the mould place the metal tamper on the surface of the sand. Tamp the surface 25 times by letting the tamper fall under its own weight. 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.

For crushed fine aggregates, the detection of the saturated surface dry state may be difficult. Further guidance is given in Annex F.

Weigh the saturated and surface-dried test portion, M_1. Dry the aggregate in a ventilated oven at a temperature of (110 ± 5) °C until it has reached a constant mass. Let it cool to ambient temperature and weigh, 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 megagram per cubic metre in accordance with the following formulae:

apparent particle density

$$\rho_a = \rho_w \frac{M_4}{M_4 - (M_2 - M_3)} \quad (11)$$

oven-dried particle density

$$\rho_{rd} = \rho_w \frac{M_4}{M_1 - (M_2 - M_3)} \quad (12)$$

saturated and surface-dried particle density $$\rho_{ssd} = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)} \quad (13)$$

and the water absorption after immersion for 24 h, WA_{24}, in accordance with the following formula:

$$WA_{24} = \frac{100 \times (M_1 - M_4)}{M_4} \quad (14)$$

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (see Annex D);

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 and water, 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/m^3 and the water absorption to the nearest 0,1 %.

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

$$\rho_{ssd} = \rho_{rd} + \rho_w \left(1 - \rho_{rd} / \rho_a\right) \quad (15)$$

NOTE 2 An indication of precision is given in Annex I.

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 test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each size fraction;

f) the method used to determine the particle density and absorption (Clauses 7, 8 or 9);

g) the test results with significant digits (four values for each test);

h) deviations from the reference method – if any.

10.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test portion;

e) petrographic description (EN 932-3);

f) other influencing parameters.

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 passing the 63 mm test sieve and retained on the 0,063 mm test sieve using the following methods:

a) Wire basket method (A.3) for aggregate particles passing the 63 mm test sieve and retained on the 31,5 mm test sieve.

b) Pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 0,063 mm test sieve.

The wire basket method can be used as an alternative to the pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve. In case of dispute, the pyknometer method should be used as the reference method.

NOTE This method generally applies to aggregates with water absorption less than about 1,5 %.

A.2 Principle

The purpose of this test is to determine the mass and volume of the test portion (or specimens) and calculate its particle density. The mass is obtained by weighing the test portion (or specimens) in an oven-dry condition. The volume is determined as the water displacement of the pre-dried particles either by mass reduction in a wire basket or in a pyknometer (see 6.5).

A.3 Wire basket method for aggregate particles passing the 63 mm test sieve and retained on the 31,5 mm test sieve

A.3.1 Preparation of test portion

The test portion shall be prepared as specified in 7.2. Dry the test portion in the oven at (110 ± 5) °C until constant mass is achieved. Let it cool to ambient temperature and weigh the test portion, M_1.

A.3.2 Test procedure

Place the test portion in the wire basket and immerse it in the tank containing water at a temperature of (22 ± 3) °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 letting it drop 25 times at about once per second.

Leave the basket and aggregate to remain completely immersed for no longer than 10 min. Shake the basket and test portion and weigh it in water at a temperature of (22 ± 3) °C, M_2. Record the temperature of the water when mass M_2 is determined.

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.

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

Record all masses 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 megagram per cubic metre in accordance with the following formula:

$$\rho_p = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)} \quad \text{(A.1)}$$

where

ρ_w is the density of the water at the test temperature, in megagrams per cubic metre (see Annex D);

M_1 is the mass of the pre-dried test portion, in grams;

M_2 is the mass in water of the basket containing the test portion under water, in grams;

M_3 is the mass in water of the empty basket, in grams.

Express the value of pre-dried particle density to the nearest 0,01 Mg/m^3.

A.4 Pyknometer method for aggregate particles passing the 31,5 mm test sieve and retained on the 0,063 mm test sieve

A.4.1 Preparation of test specimen

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)

Upper (D) aggregate size mm	**Minimum mass of test specimen** kg
31,5	1,5
16	1,0
8	0,5
4 (or less)	0,25
For other sizes, the minimum mass of the test specimen 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 ± 3) °C and placing it for at least 1 h in the water bath at (22 ± 3) °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 Test procedure

During the test the water bath shall be kept at a temperature of (22 ± 3) °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 ± 5) °C to constant mass. Let it 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 ± 3) °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 ± 3) °C for at least 1 h.

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 masses 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 megagram per cubic metre for each test specimen in accordance with the following formula:

Pre-dried particle density
$$\rho_p = \frac{(M_2 - M_1)}{V - (M_3 - M_2)/\rho_w} \qquad \text{(A.2)}$$

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 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 Mg/m^3.

NOTE An indication of precision is given in Annex I.

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 test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each fraction;

f) the method used to determine the pre-dried particle density (wire basket or pyknometer);

g) the test results with significant digits;

h) deviations from the method – if any.

A.5.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test portion/test specimen;

e) individual test results with significant digits, when required result is a mean value;

f) petrographic description (EN 932-3);

g) other influencing parameters.

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 particles of aggregate such as railway ballast.

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

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 particles of aggregate

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

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

NOTE The immersion in the container to reach constant mass as described in the test procedure (see B.3) can be carried out at the same time for several test portions, provided that each of them is clearly and indelibly marked.

Results of tests on a single particle of aggregate may not be representative. For homogeneous aggregates, at least ten particles should be tested. For non-homogeneous aggregates, at least five particles of each constituent petrographic type should be tested.

B.2.3 Railway ballast

The test portion shall consist of at least ten particles of aggregate for railway ballast with a size in the range 40 mm to 50 mm or 50 mm to 63 mm. Each particle 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. Let it cool to ambient temperature and weigh, M_3.

Record all masses 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 megagram per cubic metre in accordance with the following formula:

$$\rho_{cm} = \frac{M_3 \times \rho_w}{M_1 - M_2} \quad \text{(B.1)}$$

and the water absorption, WA_{cm}, in accordance with the following formula:

$$WA_{cm} = \frac{M_1 - M_3}{M_3} \times 100 \quad \text{(B.2)}$$

where

ρ_w is the density of water at the temperature recorded when M_2 was determined, in megagrams per cubic metre (Annex D);

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.

Express the values of the particle density to the nearest 0,01 Mg/m^3 and the water absorption to the nearest 0,1 %.

NOTE An indication of precision is given in Annex I.

B.5 Test report

B.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 test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) the nominal grading of the aggregate from which the sample was taken;

f) the test results with significant digits;

g) deviations from the reference method – if any.

B.5.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test portion;

e) petrographic description (EN 932-3);

f) other influencing parameters.

Annex C
(normative)

Determination of particle density and water absorption of lightweight aggregates

C.1 General

This annex specifies the reference method for determination of apparent, oven-dried, saturated and surface dried particle densities and water absorption of lightweight aggregates.

Particle densities of lightweight aggregates are always determined after pre-drying.

This method uses a pyknometer to determine the particle densities and water absorption of lightweight aggregates, using a soaking time of 24 h.

The wire basket method should not be used, as it doesn't enable correct elimination of air bubbles.

The method applies to aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve.

NOTE 1 This method can also be used on aggregate particles smaller than 4 mm if it is possible to surface-dry the aggregates without losing particles.

NOTE 2 Annex E also specifies a quick method for the determination of the apparent particle density of lightweight aggregates.

C.2 Preparation of test specimen

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

Prepare two test specimens. Each test specimen shall have a loose bulk volume between 0,5 l and 0,6 l. Dry the test specimens in the oven at (110 ± 5) °C to constant mass. Let them cool to ambient temperature. Sieve the test specimen on the 31,5 mm and the 4 mm sieves and discard any particle retained on the 31,5 mm sieve or passing the 4 mm sieve. Weigh the remaining test specimen, M_4.

C.3 Calibration of the pyknometer

If appropriate, insert a grid in the pyknometer. Fill the assembly with water at (22 ± 3) °C, and place it for at least 1 h in the water bath at (22 ± 3) °C. Then, top up with water to the funnel mark and remove from the water bath. Carefully dry the outside and weigh, M_3.

Some silicone grease may be added to the contact area before calibration to prevent the funnel from adhering to the pyknometer.

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

C.4 Test procedure

The test shall be carried out using two test specimens. During the test the water bath shall be kept at a temperature of (22 ± 3) °C.

Place the first test specimen carefully into the pyknometer. Insert the grid if necessary.

Fill the pyknometer with water at (22 ± 3) °C. Start the stop watch when most of the aggregates are soaked in water. Fit the funnel to the pyknometer and fill with water up to the mark on the funnel.

Stir the aggregate by gently rolling and tapping the pyknometer or gently apply vibration to remove entrapped air. Add water as necessary during the test to keep the water level close to the funnel mark. Weigh the pyknometer after (300 ± 15) s, M_2(5 min).

If shorter soaking times are necessary, the method for apparent particle density described in Annex E should be used.

Then place the assembly in the water bath at (22 ± 3) °C. Add water as necessary during the test to keep the water level close to the funnel mark.

After about 55 min, take the pyknometer out of the water bath. Stir the aggregate by gently rolling and tapping the pyknometer or gently apply vibration to remove entrapped air. Add water as necessary during the test to keep the water level close to the funnel mark. Dry the outside of the pyknometer and weigh it after (60 ± 2) min, M_2(1 h).

The variation of $M_2(t)$ is usually not linear. Hence, to determine the curve of $M_2(t)$ as a function of time, at least three different soaking times should be considered.

The operations mentioned in the previous paragraph may be repeated at other appropriate soaking times.

After (24 ± 0,5) h, take the pyknometer out of the water bath. Stir the aggregate by gently rolling and tapping the pyknometer or gently apply vibration to remove entrapped air. Add water as necessary during the test to keep the water level close to the funnel mark. Dry the outside of the pyknometer and weigh it, M_2(24 h).

Pour the water out of the pyknometer. 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_1(24h).

Repeat the procedure for the second test specimen.

If a soaking period longer than 24 h is necessary, determine $M_1(F)$ at final soaking time F and back calculate M_1(24 h) using the following formula:

$$M_1(24\text{h}) = M_1(\text{F}) - \left[M_2(\text{F}) - M_2(24\text{h})\right] \qquad \text{(C.1)}$$

C.5 Calculation and expression of results

For each test specimen, calculate the particle density (ρ_{La}, ρ_{Lrd} or ρ_{Lssd}, as appropriate) of the lightweight aggregate in megagram per cubic metre, in accordance with the following formula:

apparent particle density

$$\rho_{\text{La}} = \rho_{\text{w}} \frac{M_4}{M_4 - (M_2(24\text{h}) - M_3)} \qquad \text{(C.2)}$$

oven-dried particle density

$$\rho_{\text{Lrd}} = \rho_{\text{w}} \frac{M_4}{M_1(24\text{h}) - (M_2(24\text{h}) - M_3)} \qquad \text{(C.3)}$$

saturated and surface-dried particle density $$\rho_{Lssd} = \rho_w \frac{M_1(24h)}{M_1(24h) - (M_2(24h) - M_3)} \quad (C.4)$$

where

ρ_{La} is the apparent particle density, in megagrams per cubic metre;

ρ_{Lrd} is the oven-dried particle density, in megagrams per cubic metre;

ρ_{Lssd} is the saturated and surface-dried particle density, in megagrams per cubic metre;

ρ_w is the density of water at test temperature (see Annex D), in megagrams per cubic metre;

$M_1(24h)$ is the mass of saturated and surface-dried aggregates in the air after 24 h, in grams;

$M_2(24h)$ is the mass of the pyknometer, funnel, grid if used, water and saturated aggregates after 24 h, in grams;

M_3 is the mass of the pyknometer, funnel, grid if used and water as calibrated, in grams;

M_4 is the mass of dry aggregate, in grams.

Calculate the mean value of the two individual density values after 24 h. Express the mean value to the nearest 0,01 Mg/m^3.

Calculate the water absorption after 24 h,in accordance with the following formula:

$$WA_{L24} = 100 \frac{M_1(24h) - M_4}{M_4} \quad (C.5)$$

Calculate the water absorption at intermediate soaking times t = 5 min and t = 1 h (and, if necessary, at other appropriate soaking times) in accordance with the following formula:

$$WA_{Lt} = WA_{L24} - 100 \frac{(M_2(24h) - M_2(t))}{M_4} \quad (C.6)$$

where

$M_2(t)$ is the mass of the pyknometer, funnel, grid if used, water and saturated aggregates at the soaking time t, in grams;

WA_{Lt} is the water absorption at an intermediate soaking time t, in %;

WA_{L24} is the water absorption after 24 h, in %.

Calculate the mean value of the two individual water absorption values at the same soaking time. Express the mean value to the nearest 1 **%**.

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, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each fraction;

f) appropriate particle density after 24 h;

g) water absorptions after 5 min, 1 h and 24 h;

h) deviations from the reference method – if any.

C.6.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test specimens;

e) individual test results with significant digits;

f) water absorption at additional soaking times;

g) petrographic description (EN 932-3);

h) other influencing parameters.

Annex D
(normative)

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
(normative)

Quick method for the determination of the apparent particle density of lightweight aggregates using a graduated measuring cylinder and short soaking times

E.1 General

This annex specifies an alternative fast method, using a glass graduated measuring cylinder, for the determination of the **apparent** particle density of lightweight aggregates. This method is only suitable for measuring times shorter than 5 min. In case of dispute, Annex C shall be used.

The method applies to aggregate particles passing the 31,5 mm test sieve and retained on the 2 mm test sieve.

NOTE The method can be used for aggregate particles passing the 2 mm test sieve, if the particles do not float.

E.2 Preparation of test specimen

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

Prepare two test specimens. Each specimen shall have a loose bulk volume of approximately 0,5 l. Dry the test specimens in the oven at (110 ± 5) °C to constant mass. Let them cool to ambient temperature. Sieve the test specimen on the 31,5 mm and the 2 mm sieves to remove any particle retained on the 31,5 mm sieve or passing the 2 mm sieve. Weigh the specimen, M_4.

E.3 Procedure

The test is carried out using two test specimens. During the test the water used shall be kept at a temperature of (22 ± 3) °C.

Place one of the test specimens into the first measuring cylinder, marked as ‘A’. Fill the second measuring cylinder, marked as ‘B’, with water until the total volume of the water and the steel plunger immersed to the mark on the rod (6.8.2) is 400 ml, V_w. Pour the water from cylinder B to cylinder A. Quickly fit the steel plunger to cylinder A and start the stop watch. Remove entrapped air by gently agitating the steel plunger. Align the mark on the rod of the steel plunger with the level of the water surface and read the volume of the aggregate and water in cylinder A after 30 s.

Repeat the procedure for the second test specimen.

For some lightweight aggregates, 30 s may not be an appropriate time. If another time period is chosen, this should be stated in the test report.

E.4 Calculation and expression of results

For each test specimen, calculate the apparent particle density ρ_{La} of the lightweight aggregate in megagram per cubic metre, in accordance with the following formula:

apparent particle density $$\rho_{La} = \frac{M_4}{V(F) - V_w} \quad \text{(E.1)}$$

where

ρ_{La} is the apparent particle density, in megagrams per cubic metre;

M_4 is the mass of dry aggregate, in grams;

$V(F)$ is the volume of water, steel plunger if used, and saturated aggregates at final soaking time, in millilitres;

V_w is the volume occupied in cylinder A by the water and the steel plunger (if used) after aligning its mark with the water surface, in millilitres.

Calculate the mean value of the two individual density values at the actual soaking time. Express the mean value to the nearest 0,01 Mg/m^3. The soaking time shall always be expressed with the results.

E.5 Test report

E.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 test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) size fraction of the aggregate and, if tested as a number of fractions, the percentage of each fraction;

f) apparent particle density and the corresponding soaking time;

g) deviations from the method – if any.

E.5.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test specimens;

e) individual test results with significant digits;

f) petrographic description (EN 932-3);

g) other influencing parameters.

Annex F
(informative)

Guidance on the saturated and surface-dried condition of fine aggregates

Figure F.1 to Figure F.4 are examples of a typical fine aggregate.

The actual slope of the collapsed cone depends upon the material tested.

If the test portion contains fines (passing 0,063 mm) this may affect the shape of the collapsed state.

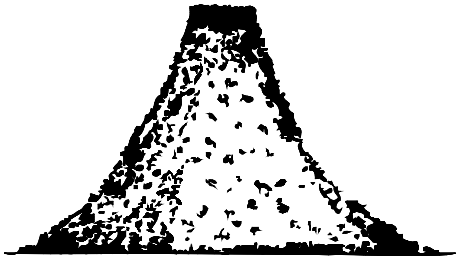


Figure F.1 — Aggregate moist; almost retains complete shape of metal mould

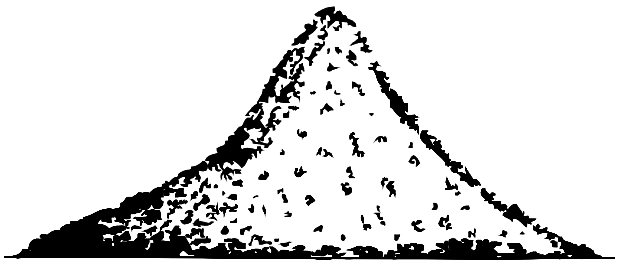


Figure F.2 — Aggregate slightly moist; appreciable slump observed

Figure F.3 — Aggregate saturated surface-dried; almost complete collapse but definite peak still visible and slopes are angular

Figure F.4 — 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.

To achieve the saturated and surface-dried condition for aggregate particles passing the 31,5 mm test sieve and retained on the 4 mm test sieve (8.3), an additional sample of roughly 500 g may be taken from the same source as the test portion, then oven-dried to constant mass. The appearance of this sample can be an indicator for the achievement of the surface-dried state, with the colour of the test portion becoming less dark when the saturated and surface-dried condition is reached.

Annex G
(normative)

Determination of the pre-dried particle density of aggregates passing the 31,5 mm test sieve (including the 0/0,063 mm size fraction)

G.1 General

This annex specifies a method for the determination of the pre-dried particle density of aggregates with a particle density greater than 1 Mg/m^3. This method applies to aggregate particles passing the 31,5 mm test sieve.

NOTE This method is based on the pyknometer method specified in Annex A.

G.2 Principle

The purpose of this test is to determine the mass and volume of the test portion and calculate its particle density. The mass is obtained by weighing the test portion in an oven-dry condition. The volume is determined as the water displacement of pre-dried particles in a pyknometer (6.5).

G.3 Preparation of the 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 shall be not less than the mass given in Table G.1.

Table G.1 — Minimum mass of the test portion

Upper (D) aggregate size mm	**Minimum mass of test portion** kg
31,5	1,5
16	1,0
8	0,5
4 (or less)	0,25
For other sizes, the minimum mass of the test portion may be interpolated from the masses given in Table G.1.	

G.4 Test procedure

Sieve the test portion and discard any particle retained on the 31,5 mm sieve. Dry in the oven at (110 ± 5) °C to constant mass. Let it cool to ambient temperature.

Clean, dry and weigh the pyknometer and its funnel, M_0. Fill the pyknometer with water at (22 ± 3) °C to about half of its volume. Tare the balance with the pyknometer and its content, then add carefully the test portion into the pyknometer. Read and record the mass of the test portion, M_1.

The volume of the pyknometer should be chosen to suit the size of the test portion. The test portion should not occupy more than one third of the volume of the pyknometer, to enable the release of entrapped air.

Next, fill the pyknometer with water at (22 ± 3) °C to about 30 mm below the ground section of the neck, so that the pyknometer can be tilted to 45° while keeping the test portion immersed under at least 5 mm of water. If necessary, add water.

To remove entrapped air and adherent air bubbles in the immersed test portion, use a glass rod to stir the test portion for 10 s. Then tilt the pyknometer to 45° and rotate it clockwise and anticlockwise for a total of 50 s. Quickly repeat this stir then rotate procedure, so that three cycles are completed in not more than 3 min.

Evacuate any remaining entrapped air from the immersed test portion by applying a partial vacuum that results in a residual pressure of 4 kPa or less. The partial vacuum shall be achieved within not more that 5 min and shall be maintained for at least 30 min. At the same time, agitate the pyknometer using a source of external vibration with sufficient amplitude to displace the whole of the test portion within the pyknometer.

After releasing the vacuum, fill the pyknometer with water. Place it without its funnel in the water bath at (22 ± 3) °C for at least 1 h. During the test the water bath shall be kept at a temperature of (22 ± 3) °C.

Insert the funnel on top of the pyknometer. Fill the pyknometer with water up to the graduation mark. Remove the pyknometer from the water bath, carefully dry the outside, then weigh and record the mass of the pyknometer with its content, M_2. Read and record the temperature of the water inside the pyknometer.

To determine its volume, clean and dry the pyknometer, then fill it with water and add the funnel. Fill the pyknometer with water up to the graduation mark. Next, dry the outside of the pyknometer and weigh it, M_3. Record the temperature of the water inside the pyknometer and make sure that it doesn't differ by more than 2 °C from the temperature recorded while weighing M_2.

Instead of measuring the pyknometer volume at each test it can be pre-calibrated. In that case, the temperature of the water bath shall not differ by more than 0,5 °C from the temperature of pre-calibration of the pyknometer.

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

G.5 Calculation and expression of results

Calculate the pre-dried particle density, ρ_p, in megagram per cubic metre in accordance with the following formula:

$$\rho_p = \frac{M_1}{V - \frac{(M_2 - M_1 - M_0)}{\rho_w}} \qquad \text{(G.1)}$$

where

ρ_w is the density of water at the temperature recorded when M_2 was determined, in megagrams per cubic metre (Annex D);

M_0 is the mass of the pyknometer and funnel, in grams;

M_1 is the mass of test portion, in grams;

M_2 is the mass of the pyknometer, funnel, test portion and water, in grams;

V is the volume of the pyknometer, in millilitres.

$$V = \frac{M_3}{\rho_W} \quad \text{(G.2)}$$

where

ρ_W is the density of water at test temperature, in megagrams per cubic metre (Annex D);

M_3 is the mass of water filling the pyknometer and its funnel to the graduation mark, in grams.

Express the value of the pre-dried particle density to the nearest 0,01 Mg/m^3.

G.6 Test report

G.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 test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) size fraction of the aggregate;

f) the test results with significant digits;

g) deviations from the method – if any.

G.6.2 Optional data

The test report can include the following information:

a) date of test;

b) reference to the chosen sampling procedure;

c) reference to the chosen sample reduction procedure;

d) mass of test portion;

e) petrographic description (EN 932-3);

f) other influencing parameters.

Annex H
(informative)

Guidance on the significance and use of various particle density parameters and water absorption

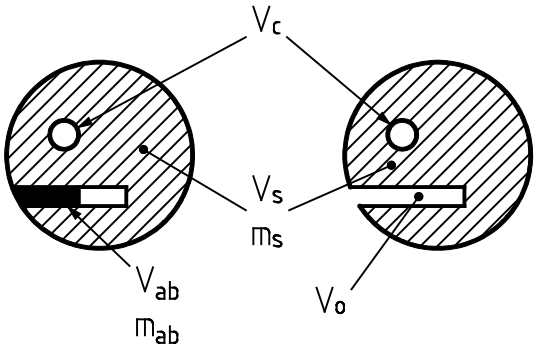
H.1 General

Particle density is a characteristic generally used to calculate the volume occupied by the aggregate in various mixtures proportioned on an absolute volume basis. The density and water absorption of an aggregate particle depends upon the density of the individual mineral particles that it contains and the size and structure of any void spaces between the mineral particles.

The size and structure of any void spaces in the aggregate particle is reflected in its water absorption value. This characteristic is often used in the design of concrete mixes and bituminous mixtures.

The methods in this standard determine particle density by calculating the ratio of mass to volume, where the volume is determined from the mass of water displaced after a specified period of immersion. Water is absorbed into accessible voids during the immersion stage but, sometimes, not all of the voids may be completely filled in the time specified in the appropriate test method. After immersion, the aggregate particles are surface dried and weighed.

For the purposes of this European Standard three basic particle density definitions apply. They can be expressed by the general formulas, given in Figure H.1.



Total particle volume	$V = V_0 + V_c + V_s$
Oven-dried particle density	$\rho_{rd} = m_s / V$
Saturated and surface-dried particle density	$\rho_{ssd} = \frac{(m_s + m_{ab})}{V}$
Apparent particle density	$\rho_a = \frac{m_s}{(V - V_{ab})}$
Water absorption	$WA = 100\, m_{ab} / m_s = 100 \rho_w V_{ab} / m_s$

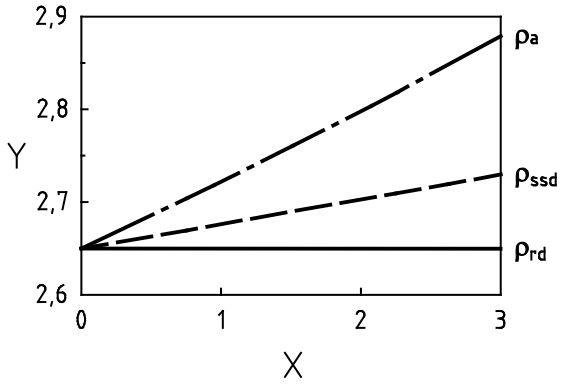
Figure H.1 — Definitions of particle voids, water absorption and the three basic particle density parameters for a surface-dried particle after finished immersion and for the same particle after drying to constant mass

H.2 Characteristics of the reference methods for normal weight aggregates according to Clauses 7, 8 and 9 and Annex B

The reference methods described in Clauses 7, 8 and 9 and Annex B are carried out using aggregate that is in a natural moisture state at the start of the immersion stage. The aggregate is not oven dried before testing.

The interrelationships between the three basic particle density parameters and water absorption, determined using the reference methods, are illustrated in Figure H.2. The figure assumes an oven-dried particle density of 2,65 Mg/m^3.

The interrelationship between the three particle density parameters and water absorption for three different values of oven-dried particle density are illustrated using the calculated values in Table H.1.



Key
X water absorption – %
Y particle density – Mg/m^3

Figure H.2 — Effect of increasing water absorption on the apparent particle density and the saturated and surface-dried particle density for an aggregate with an oven dried particle density of 2,65 Mg/m^3

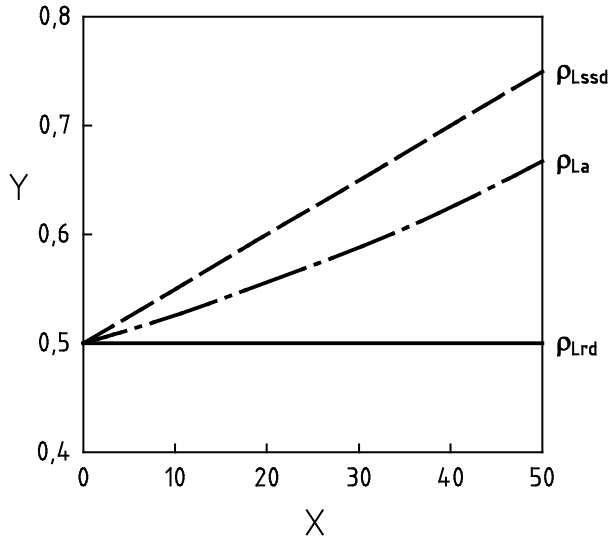
Table H.1 — Calculated particle density and water absorption values, derived from $\rho_{ssd} = \rho_{rd}\,[1 + WA/100]$ and $\rho_a = \rho_{rd} / [1 - \rho_{rd}\, WA/(100\rho_w)]$

WA (%)	**Oven-dried particle density** (= ρrd), Mg/m^3					
	2,00		2,65		3,00	
	ρ_{ssd}	ρ_a	ρ_{ssd}	ρ_a	ρ_{ssd}	ρ_a
0	2,00	2,00	2,65	2,65	3,00	3,00
0,5	2,01	2,02	2,66	2,69	3,02	3,05
1,0	2,02	2,04	2,68	2,72	3,03	3,09
1,5	2,03	2,06	2,69	2,76	3,05	3,14
2	2,04	2,08	2,70	2,80	3,06	3,19
3	2,06	2,13	2,73	2,88	3,09	3,30

H.3 Characteristics of the reference method for lightweight aggregates, specified in Annex C

The reference method according to Annex C is based on immersion for 24 h of the aggregate test sample in a pre-dried state (drying to constant mass). The three basic particle density parameters and water absorption are determined. Their notations have been supplemented with an L (Figure H.3).

The water absorption of lightweight aggregates is generally much greater than for natural aggregates. The open pores in lightweight aggregates may or may not become essentially filled after immersion for 24 h. Many lightweight aggregates can remain immersed in water for several days and weeks without completely filling the voids.



Key

X water absorption – %

Y particle density – Mg/m^3

Figure H.3 — Effect of increasing water absorption on the apparent particle density and the saturated and surface-dried particle density for a lightweight aggregate with an oven-dried particle density of 0,5 Mg/m^3

H.4 Characteristics of the methods for determination of the pre-dried particle density of normal weight aggregates, specified in Annex A and Annex G

The methods for determination of the pre-dried particle density, specified in Annex A and Annex G, can be used to estimate the apparent particle density. The formula for the calculation of the pre-dried particle density is identical to the formula for the apparent particle density, but the test conditions in terms of pre-drying of the test sample to constant mass and the shorter immersion periods differ. The water absorption is not determined by these methods.

For *WA* less than about 1,5 % and aggregate particles coarser than 4 mm, the pre-dried particle density is strongly correlated to the apparent particle density. Due to the shorter immersing time, the pre-dried particle density usually falls slightly below the apparent particle density.

For aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test sieve, the correlation between the pre-dried particle density and the apparent particle density is weaker.

The method in Annex G enables a swift determination of the pre-dried particle density of a test sample including the fines fraction. It is suitable for estimating the apparent particle density of the overall aggregate grading of asphalt mixes.

H.5 Selection of the appropriate particle density parameter

Guidance on the selection of the appropriate particle density parameter for various purposes is given in Table H.2. The two generally used particle density parameters are the saturated and surface-dried particle density and the oven-dried particle density.

Table H.2 — Selection of particle density parameter for various purposes

Purpose	Recommended particle density parameter
Declaration – general	ρ_a or ρ_{ssd} or ρ_{rd}
Declaration – railway ballast	ρ_{cm}
Declaration – LWA	ρ_{La} or ρ_{Lssd} or ρ_{Lrd}
Determination of aggregate class (normal weight or lightweight aggregates)	ρ_{rd}
Design of concrete mixes	ρ_{ssd}
Bituminous mixtures – binder content correction for aggregate density	ρ_a or ρ_p
Test methods for hot mix asphalt – correction of test portion mass for aggregate density	ρ_{rd} or ρ_p
Test method EN 1097-3 – calculation of voids in loosely filled aggregate	ρ_{rd} or ρ_p

H.6 Applicability of and test conditions for the various test methods in EN 1097-6

This European Standard includes several test methods, whose applicability and restrictions for use are specified in Table H.3 and whose special test conditions are specified in Table H.4.

Table H.3 — Applicability of various test methods in EN 1097-6

Aggregate class	Particle size fraction mm	Test procedure	*WA* determination	Restrictions for use
Normal weight aggregate	40/50	Annex B	Yes	Railway ballast only
	50/63	Annex B	Yes	
	31,5/63	Clause 7	Yes	
		A.3	No	*WA* less than about 1,5 %
	4/31,5	Clause 8	Yes	
		A.4	No	*WA* less than about 1,5 %
	0,063/4	Clause 9	Yes	
		A.4	No	*WA* less than about 1,5 %
	0,063/31,5	A.4	No	*WA* less than about 1,5 %
	0/31,5	Annex G	No	*WA* less than about 1,5 %
Lightweight aggregate (LWA)	4/31,5	Annex C	Yes	
	2/31,5	Annex E	No	Only the apparent particle density is determined

Table H.4 — Summary of test conditions for the various test methods in EN 1097-6

Method according to clause or annex	Type of test procedure	Pre-drying of test portion	Immersing time	Surface dry control
7	Wire Basket	No	24 ± 0,5 h	Cloth
8	Pyknometer	No	24 ± 0,5 h	Cloth
9	Pyknometer	No	24 ± 0,5 h	Cone test
A.3	Wire Basket	Yes	Max 10 min	No
A.4	Pyknometer	Yes	At least 1 h	No
B.3	Wire Basket	No	Until constant mass	Cloth
Annex C	Pyknometer	Yes	24 ± 0,5 h	Cloth
Annex E	Graduated measuring cylinder	Yes	Less than 5 min	No
Annex G	Pyknometer	Yes	> 1,5 h, including 30 min vacuum	No

H.7 Relationships between different particle density parameters (notations according to the main methods, specified in Clauses 7, 8 and 9)

Notations

ρ_{rd} = oven-dried particle density
ρ_{ssd} = saturated and surface-dried particle density
ρ_a = apparent particle density
ρ_w = density of water
WA = water absorption

Particle density parameters

$\rho_{ssd} = \rho_{rd} [1 + WA/100]$
$\rho_a = \rho_{rd} / [1 - \rho_{rd} WA/(100\rho_w)]$
$\rho_a = \rho_{ssd} / \{1 - [WA /100][(\rho_{ssd}/\rho_w) - 1]\}$

Water absorption

$WA = 100 [(\rho_{ssd} / \rho_{rd}) - 1]$
$WA = 100 \rho_w (1/\rho_{rd} - 1/\rho_a)$
$WA = 100 \rho_w (\rho_a - \rho_{ssd}) / [\rho_a (\rho_{ssd} - \rho_w)]$

Annex I
(informative)

Precision

I.1 Data from National Standards

The precision data given in Table I.1 to Table I.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 I.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 I.2 — Oven-dried 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	0,025	0,044
Pyknometer (coarse aggregate)	8	0,031	0,042
Pyknometer (fine aggregate)	9	0,043	0,085

Table I.3 — Saturated and surface-dried 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	0,022	0,034
Pyknometer (coarse aggregate)	8	0,031	0,049
Pyknometer (fine aggregate)	9	0,035	0,070

Table I.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 I.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

I.2 Data from cross testing experiments

The results of a cross testing experiment carried out by 19 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 I.6. The repeatability r_1 and reproducibility R_1 values have been determined for the three tested aggregates on the basis of duplicate tests carried out on different samples.

Table I.6 — Repeatability and reproducibility values for determinations of particle density (Mg/m^3) and water absorption (%) of coarse aggregates

			Level 1	Level 2	Level 3
Size fractions (mm):			**10/14**	**10/14**	**5/10**
Pre-dried particle density determined in accordance with Annex A (pyknometer method)	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 determined in accordance with Clause 8 (pyknometer method)	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 determined in accordance with Clause 8 (pyknometer method)	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	0,011 2	0,222
	Repeatability limit	r_1	0,17	0,13	0,24
	Reproducibility limit	R_1	0,28	0,31	0,62

NOTE Except for the number of laboratories included, data related to particle density is expressed in megagram per cubic metre and data related to water absorption is expressed in %.

Annex J
(informative)

List of main changes from the previous edition (EN 1097-6:2000)

a) Clause 1 (Scope) of revised EN 1097-6 has been updated to account for the changes described hereafter.

b) In Clause 3, several definitions have been clarified, namely to highlight the differences between apparent and pre-dried particle densities, or to distinguish between parameters relevant to lightweight or to normal weight aggregates (addition of an 'L' subscript to appropriate density symbols).

c) In Clause 6, pyknometer permitted volumes have been updated and recommendations have been appended in appropriate subclauses (namely subclauses 6.4, 6.5.1, 6.6 and 6.8) to select a pyknometer with appropriate volume, as it may impact the precision of densities and water absorption determinations.

d) In Clause 7, subclause 7.3, the note recommending to shake the basket in case the test portion is transferred to a different tank for weighing has become normative text.

e) Clause 9 has been renamed 'Pyknometer method for aggregate particles passing the 4 mm test sieve and retained on the 0,063 mm test sieve'. In subclause 9.2, the minimum test portion mass has been reduced to 300 g. In subclause 9.3, the tamping procedure has been clarified in an attempt to mitigate uncertainties, and the presence of crushed fines has been recognised as a potential difficulty justifying the guidance given in Annex F (see below). Lastly, due to the difficulties encountered by some laboratories to apply the cone test with aggregates passing the 4 mm sieve but retained on the 2 mm sieve, a new Note 2 to Clause 1 suggests using the surface drying procedure defined in Clause 8.

f) A Note has been added to Clause A.1 of normative Annex A, observing that this method generally applies to aggregates with water absorption less than about 1,5 %.

g) In Annex B, consistency considerations have led to change to WA_{cm} the designation W_{cm} for the water absorption to constant mass, and product SCs have been asked to take the opportunity of the five-year review of product standards to amend their texts accordingly.

h) Former normative Annex C has been subdivided into two new normative annexes:

   1) New Annex C describes the reference method applicable for determining the apparent, oven-dried, saturated and surface-dried densities as well as the water absorption of lightweight aggregates passing the 31,5 mm sieve and retained on the 4 mm sieve. Lightweight aggregates are first pre-dried, then the reference soaking time is 24 h and the method uses a pyknometer. Furthermore, the density and water absorption calculations shall now use the density of water at the test temperature. Lastly, a note mentions that the method can be used on aggregate particles smaller than 4 mm if it is possible to surface-dry the aggregates without losing particles.

   2) New Annex E describes an alternative method to Annex C, allowing a quick assessment of the apparent particle density of lightweight aggregates. The maximum soaking time is 5 min and the method uses a graduated cylinder.

i) Former Annex E on precision data has become Annex I.

j) Annex F dealing with guidance on the saturated and surface-dried condition of fine aggregates has been supplemented with an ultimate paragraph advising to prepare an additional dry sample for visual comparison with the one subject to drying in saturated and surface-dried condition.

k) A new Annex G (normative) has been designed to determine the pre-dried particle density of aggregates passing the 31,5 mm test sieve, inclusive of the 0/0,063 mm fines fraction. The procedure is based on the

pyknometer method described in Annex A, but further requires the implementation of a vacuum system to evacuate entrapped air from immersed test portion.

l) A new Annex H (informative) has been designed to give guidance on the significance and use of various particle density parameters and water absorption.

Bibliography

[1] EN 932-3, *Tests for general properties of aggregates — Part 3: Procedure and terminology for simplified petrographic description*

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