BS EN 1097-6:2022

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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 1097-6:2022. It supersedes BS EN 1097-6:2013, which is withdrawn.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 committee manager.

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

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

This European Standard was approved by CEN on 12 December 2021.

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European foreword

This document (EN 1097-6:2022) has been prepared by Technical Committee CEN/TC 154 "Aggregates", the secretariat of which is held by BSI.

This document shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2022, and conflicting national standards shall be withdrawn at the latest by August 2022.

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

This document supersedes EN 1097-6:2013.

In comparison with the previous edition, the following technical modifications have been made:

a) Normative references has been extended with EN 1097-5 (used in Annex D). EN 932-1 has been deleted from the clause since sampling is out of the scope, as for other standards;

b) the definitions of laboratory sample and subsample have been added in Clause 3;

c) the glass funnel in 6.4.4 has been deleted since it is part of the pyknometer in 6.5.1. The minimum volume of the pyknometer in 6.5.1 has been changed from 250 ml to 500 ml. New 6.8 and 6.10 have been added and describe special apparatus referenced in new Annexes D and F;

d) Clause 9 has been extended with an illustration of the surface-dry state assessment using the cone test;

e) the possibility to remove air from the pyknometer by applying a vacuum has been added in A.4.3;

f) in Annex B, the test portion mass for single aggregates (B.2.2) and the temperature requirement in B.3 have been clarified. In addition, the time needed for achieving constant mass during suction has been clarified;

g) the Note in C.1 has been revised to say that the method can also be used for aggregate particles passing the 4 mm sieve and retained on the 1 mm sieve. Soaking times for the water absorption determination have been added in C.1. A new paragraph has been added in C.1, saying that for concrete applications the water absorption of coarse lightweight aggregate shall be determined in the as-used moisture state instead of the oven-dry state. In C.4, a Note about using vibrating table as a vibration means has been added. Precision of individual values has been defined in C.5;

h) a new normative Annex D has been designed to determine the particle density and water absorption of fine lightweight aggregates. Consequently, Annex C has been retitled to only apply to coarse lightweight aggregates;

i) the title of Annex E has been shorted. The Note in E.1 has been revised to say that the method can also be used for aggregate particles passing the 2 mm sieve and retained on the 1 mm sieve. Precision of individual values has been defined in E.4;

j) Annex F has been replaced by a new informative annex designed to determine the particle density and water absorption of aggregates passing the 4 mm sieve;

k) the procedure in Annex H has been extended to specify double determination. In addition, the recommended volume which the test portion should occupy to enable the release of entrapped air, has been changed from one third to one half of the pyknometer volume, in consistency with other clauses;

l) all annexes have been reordered to collect the annexes about lightweight aggregates. Annex D Density of water has been moved to Annex G and Annex J List of main changes has been deleted.

Furthermore, the whole standard has been updated according to the current rules and to reflect the changes. The text has been clarified and the Bibliography has been supplemented.

This document 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*

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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1 Scope

This document 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 can 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 document.

The reference methods for normal weight aggregates 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 sieve and retained on the 4 mm sieve (Clause 8);

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

In Clauses 7, 8 and 9, three different particle densities (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 is determined after soaking in water to constant mass.

For aggregate particles passing the 31,5 mm sieve and retained on the 4 mm sieve, the wire basket method in Clause 7 can be used as an alternative to the pyknometer method in Clause 8.

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 and retained on the 2 mm sieve.

The reference methods for lightweight aggregates are:

— a pyknometer method for aggregate particles passing the 31,5 mm sieve and retained on the 4 mm sieve (Annex C). Three different particle densities (oven-dried; saturated and surface-dried; apparent) and water absorption are determined after pre-drying and a soaking period of 24 h;

— a method, using a Büchner funnel, for aggregate particles passing the 4 mm sieve (Annex D). The three particle densities and water absorption are determined using a vacuum in the range of 50 mbar to 100 mbar for at least five minutes.

Three other methods for normal weight aggregates can be used to determine the pre-dried particle density, as specified in normative Annexes A and H:

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

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

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

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.

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

The method in informative Annex F can be used to determine the particle density and water absorption of aggregate particles passing the 4 mm sieve.

Data on the density of water at various temperatures is specified in normative Annex G.

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

Precision data are presented in informative Annex J.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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*

EN 1097-5, *Tests for mechanical and physical properties of aggregates — Part 5: Determination of the water content by drying in a ventilated oven*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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.

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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 volumes of any internal sealed voids and 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 volumes 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 volumes of any internal sealed voids and water accessible voids

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

3.6
laboratory sample
sample intended for laboratory testing

3.7
subsample
sample obtained by means of a sample reduction procedure

3.8
test portion
sample used as a whole in a single test

3.9
test specimen
sample used in a single determination when a test method requires more than one determination of a property

3.10
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-dry condition and again in the oven-dry 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 shall be stated in the test report.

If the aggregate consists of a number of different size fractions, it can 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

5.1 Water, which shall be free from any impurity (e.g. dissolved air or soluble substances) that could significantly affect its density. Dissolved air can be removed by applying a vacuum.

Distilled water which is boiled and cooled before use, or demineralized water, are preferred.

Fresh tap water is also suitable.

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, capable of maintaining a temperature of (110 ± 5) °C.

6.1.2 Balance, accurate to 0,1 % of the mass of the test portion and capable of weighing the wire basket containing the sample while immersed in water.

6.1.3 Water bath, capable of maintaining a temperature of (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 Soft absorbent cloths.

6.1.8 Washing equipment.

6.1.9 Timer.

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

6.2.1 Wire basket or perforated container of sufficient capacity for samples according to the clause, and equipped 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 completely immersed and 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 the water bath specified in 6.1.3.

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

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

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

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

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.

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

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

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 Tray, of non-water absorbing material having a plane bottom of area not less than 0,1 m^2 and an edge of not less than 50 mm in height.

6.4.5 Warm air supply, such as a hair dryer.

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

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

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.

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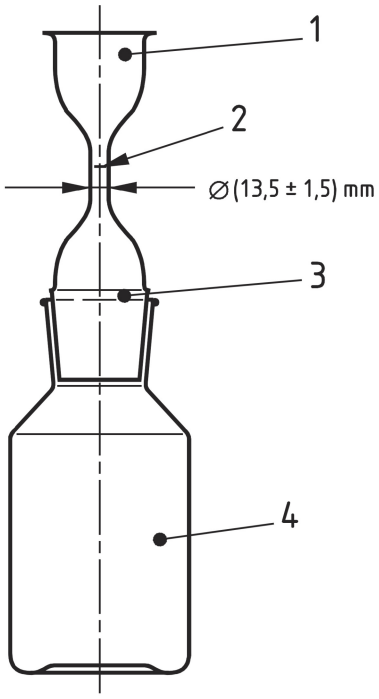

Key

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 coarse lightweight aggregates (Annex C)

6.7.1 Pyknometer, consisting of a glass flask with a volume of 1 000 ml, constant to 0,5 ml for the duration of the test, 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 shall enable the release of any air bubbles.

It is recommended that the test portion occupies about half of the pyknometer volume.

6.8 Special apparatus for the determination of particle density and water absorption of fine lightweight aggregates (Annex D)

6.8.1 Balance, accurate to 0,1 g.

6.8.2 Glass graduated measuring cylinder, with a measuring volume of 1 000 ml, accurate to 5 ml.

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6.8.3 Funnel, of suitable size to transfer the test specimen into the glass measuring cylinder.

6.8.4 Cylinder, for transferring surface-dried material from the Büchner funnel to the glass measuring cylinder.

6.8.5 Büchner funnel, with a diameter of 150 mm and minimum 60 mm height.

6.8.6 Erlenmeyer flask, with tap for the Büchner funnel.

6.8.7 Filter paper, of type Ø 150 mm-range for filtration speed from 10 s to 25 s (e.g. Herzberg).

6.8.8 Glass rod or spatula, for stirring in the Büchner funnel. The length shall be greater than the depth of the Büchner funnel.

6.8.9 Vacuum system, with a manometer or vacuum gauge, capable of maintaining a vacuum of 50 mbar to 100 mbar with wet filter only (without sample) and the same range of vacuum at the end of the test (with wet sample).

6.9 Special apparatus for the determination of the apparent particle density of coarse lightweight aggregates with cylinder method (Annex E)

6.9.1 Glass graduated measuring cylinders, with a measuring volume of 1 000 ml, accurate to 5 ml.

6.9.2 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 steel plunger base shall be less than the smallest aggregate particles to be tested. The vertical rod of the plunger shall be marked so that the volume it occupies in water is constant.

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

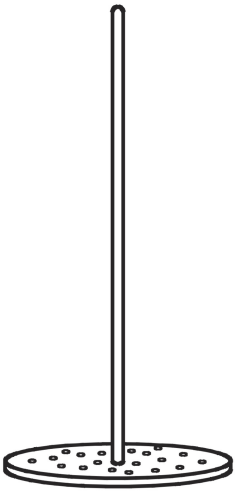

Figure 2 — Example of steel plunger with perforated base

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6.10 Special apparatus for the determination of the particle density and water absorption for aggregate particles passing the 4 mm sieve (including the 0/0,063 mm size fraction) (Annex F)

6.10.1 Warm air supply with two speeds, such as a two-speed hair dryer.

NOTE A hair dryer with a power of 1 700 W to 2 200 W, fixed on a bracket with a height of 60 cm to 80 cm is a possible solution.

6.11 Special apparatus for the determination of the pre-dried particle density of aggregate particles passing the 31,5 mm sieve (including the 0/0,063 mm size fraction) (Annex H)

6.11.1 Vacuum system, with a manometer or vacuum gauge, capable of evacuating air from the pyknometer to give a residual pressure of 40 mbar or less.

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

7.1 General

The wire basket method shall be used on aggregate particles passing the 63 mm sieve and retained on the 31,5 mm 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 specified in Annex B.

7.2 Preparation of test portion

Reduce the laboratory sample according to EN 932-2.

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

The mass of the test portion shall be not less than the mass specified in Table 1.

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

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

7.3 Test procedure

Place the prepared test portion d_0/D_0 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.

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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 vigorously, until no air bubble is visible, and weigh them in water at a temperature of (22 ± 3) °C, M_2. Record the temperature of the water.

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 onto one of the absorbent 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 absorbent cloth when the first will remove no further moisture. Spread the aggregate out not more than one stone deep on the second cloth, and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed, but the aggregate still has a damp appearance. Weigh the aggregate, M_1.

Transfer the aggregate to a tray and dry it in the oven at (110 ± 5) °C to constant mass. Let it cool to room 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 megagrams per cubic metre in accordance with Formulae (1) to (3):

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 Formula (4):

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

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where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Mg/m³) (see Annex G);

M_1 is the mass of the saturated and surface-dried aggregate in the air, in grams (g);

M_2 is the apparent mass in water of the basket containing the sample of saturated aggregate, in grams (g);

M_3 is the apparent mass in water of the empty basket, in grams (g);

M_4 is the mass of the oven-dried test portion in air, in grams (g).

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

NOTE 1 The calculations can be checked using Formula (5):

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

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

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

8.1 General

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

8.2 Preparation of test portion

Reduce the laboratory sample according to EN 932-2.

Wash the subsample 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 and let the sample drain.

The mass of the test portion shall be not less than the mass specified in Table 2.

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

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

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8.3 Test procedure

Immerse the prepared test portion d_0/D_0 in water at (22 ± 3) °C in the pyknometer. Remove entrapped air by gently rolling and jolting the pyknometer in a tipped position. Stand the pyknometer with the test portion in the water bath and keep it at a temperature of (22 ± 3) °C for (24 ± 0,5) h.

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. Wipe off 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. Wipe off 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, the volume can be predetermined. In that case, the pyknometer shall be tempered in a thermostatic bath to the temperature measured when the volume was determined ± 0,5 °C.

Transfer the drained test portion onto one of the absorbent 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 cloth, and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed, but the aggregate still has a damp appearance.

Transfer the saturated and surface-dried test portion to a tray and weigh the aggregate, M_1. Dry the aggregate in the oven at (110 ± 5) °C to constant mass. Let it cool to room temperature and weigh it, 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 Formulae (6) to (8):

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

$$\rho_{ssd} = \rho_w \frac{M_1}{M_1 - (M_2 - M_3)} \quad (8)$$

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and the water absorption after immersion for 24 h, WA_{24}, from Formula (9):

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

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Mg/m³) (see Annex G);

M_1 is the mass of the saturated and surface-dried aggregate in the air, in grams (g);

M_2 is the mass of the pyknometer containing the sample of saturated aggregate and water, in grams (g);

M_3 is the mass of the pyknometer filled with water only, in grams (g);

M_4 is the mass of the oven-dried test portion in air, in grams (g).

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

NOTE 1 The calculations can be checked using Formula (10):

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

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

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

9.1 General

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

9.2 Preparation of test portion

Reduce the laboratory sample according to EN 932-2.

Wash the subsample 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 sufficient to fill the cone.

NOTE A test portion of 400 g is usually sufficient to fill the cone.

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 with the test portion in the water bath and keep it at a temperature of (22 ± 3) °C for (24 ± 0,5) h.

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.

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Overfill the pyknometer by adding water and place the cover on top without trapping air in the vessel. Wipe off 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. Wipe off 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, the volume can be predetermined. In that case, the pyknometer shall be tempered in a thermostatic bath to the temperature measured when the volume was determined ± 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 aggregate. Tamp the surface 25 times by letting the tamper fall under its own weight. Be sure to move the tamper so the entire surface of the aggregate is packed in the same way. 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 cone collapses into a pyramid shape at mould removal (see Figure 3).

Figure 3 — Examples of surface-dry state (the cone collapses over its entire periphery)

Weigh the saturated and surface-dried test portion, M_1. Dry the aggregate in the oven at (110 ± 5) °C to constant mass. Let it cool to room 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 megagrams per cubic metre in accordance with Formulae (11) to (13):

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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 Formula (14):

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

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Mg/m^3) (see Annex G);

M_1 is the mass of the saturated and surface-dried aggregate in the air, in grams (g);

M_2 is the mass of the pyknometer containing the sample of saturated aggregate and water, in grams (g);

M_3 is the mass of the pyknometer filled with water only, in grams (g);

M_4 is the mass of the oven-dried test portion in air, in grams (g).

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 Formula (15):

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

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

10 Test report

10.1 Required data

The test report shall include the following information:

a) reference to this European standard, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of test;

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

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

g) test results with significant digits;

h) any deviations from the reference method;

i) any unusual features observed.

10.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) masses of test portions;

f) water temperature;

g) petrographic description (according to EN 932-3);

h) other influencing parameters.

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Annex A
(normative)

Determination of pre-dried particle density of aggregates passing the 63 mm sieve (excluding the 0/0,063 mm size fraction)

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

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

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

The wire basket method may be used as an alternative to the pyknometer method for aggregate particles passing the 31,5 mm sieve and retained on the 4 mm sieve. In case of dispute, the pyknometer method shall 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 (6.2.1) or in a pyknometer (6.5.1).

A.3 Wire basket method for aggregate particles passing the 63 mm sieve and retained on the 31,5 mm 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 to constant mass. Let it cool to room 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 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.

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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.

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 megagrams per cubic metre in accordance with Formula (A.1):

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

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Mg/m³) (see Annex G);

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

M_2 is the mass in water of the basket containing the test portion, in grams (g);

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

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

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

A.4.1 Preparation of test specimens

Reduce the laboratory sample according to EN 932-2 to produce two subsamples.

Wash the subsamples 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. Allow to cool to room temperature.

Prepare two test specimens. The mass of each test specimen shall be not less than the mass specified in Table A.1.

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

Upper aggregate size (*D*) mm	**Minimum mass of test specimen** kg
31,5	1,5
16	1,0
8	0,5
4 (or less)	0,25
For other *D* values, the minimum mass of the test specimen may be interpolated from the masses specified.	

A.4.2 Determination of the pyknometer volume

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 G).

NOTE Instead of measuring the pyknometer volume at each test, the volume can be predetermined.

A.4.3 Test procedure

During the test, the water bath shall be kept at a temperature of (22 ± 3) °C.

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

NOTE 1 To prevent the funnel from 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.

Entrapped air may also be removed by applying a vacuum.

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 shall 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 wipe off 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.

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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 Formula (A.2):

pre-dried particle density

$$\rho_p = \frac{M_2 - M_1}{V - \frac{(M_3 - M_2)}{\rho_w}} \quad \text{(A.2)}$$

where

M_1 is the mass of the pyknometer and funnel, in grams (g);

M_2 is the mass of the pyknometer, funnel and test specimen, in grams (g);

M_3 is the mass of the pyknometer, funnel, test specimen and water, in grams (g);

V is the volume of the pyknometer, in millilitres (ml);

ρ_w is the density of the water at the test temperature, in megagrams per cubic metre (Mg/m^3) (see Annex G).

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 J.

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, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of the test;

e) number of test portions and their size fractions d_0/D_0;

f) method used to determine the pre-dried particle density (A.3 or A.4);

g) test results with significant digits;

h) deviations from the method – if any;

i) unusual features observed – if any.

A.5.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date, if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) mass of test portion/test specimens;

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

g) petrographic description (according to EN 932-3);

h) other influencing parameters.

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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 Sample reduction

Reduce the laboratory sample according to 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 150 g to 350 g.

Remove any loose fragments 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 might not be representative. For homogeneous aggregates, at least ten particles shall be tested. For non-homogeneous aggregates, at least five particles of each constituent petrographic type shall 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 of 40 mm to 50 mm or 50 mm to 63 mm. Each particle shall have a mass of 150 g to 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 (6.6.1) and completely immerse it in water for 24 hours at the minimum until constant mass is achieved. 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.

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Determine the apparent mass of the test portion in water at a temperature of (22 ± 3) °C, M_2, and record 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 (110 ± 5) °C to constant mass. Let it cool to room 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 megagrams per cubic metre in accordance with Formula (B.1):

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

and the water absorption, WA_{cm}, in accordance with Formula (B.2):

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

where

ρ_w is the density of water at the test temperature, in megagrams per cubic metre (Mg/m³) (see Annex G);

M_1 is the mass of the saturated and surface-dried test portion, in grams (g);

M_2 is the apparent mass in water of the saturated test portion, in grams (g);

M_3 is the mass of the oven-dried test portion, in grams (g).

Express the values of the 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 J.

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, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of test;

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

f) the test results with significant digits;

g) any deviations from the reference method;

h) any unusual features observed.

B.5.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) mass of test portion;

f) petrographic description (according to EN 932-3);

g) other influencing parameters.

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Annex C
(normative)

Determination of particle density and water absorption of coarse lightweight aggregates

C.1 General

This annex specifies the reference method for the determination of apparent, oven-dried, saturated and surface-dried particle densities and water absorption of coarse lightweight aggregates. It applies to aggregate particles passing the 31,5 mm sieve and retained on the 4 mm sieve.

NOTE 1 This method can also be used for aggregate particles passing the 4 mm sieve and retained on the 1 mm sieve.

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

This method uses a pyknometer to determine the particle densities after a soaking time of 24 h.

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

The water absorption is determined using a soaking time of 5 min, 1 h, 24 h and other appropriate times.

NOTE 3 This method can also be used to determine the curve of water absorption as a function of time.

For concrete applications, the water absorption of coarse lightweight aggregate shall be determined in the as-used moisture state instead of the oven-dry state.

C.2 Preparation of test specimens

Prepare two test specimens where each shall have a loose bulk volume of 500 ml to 600 ml:

Reduce the laboratory sample according to EN 932-2 to produce two subsamples.

Dry the subsamples in the oven at (110 ± 5) °C to constant mass. Allow to cool to room temperature.

Sieve the subsamples 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 obtained test specimen, M_4.

C.3 Determination of the pyknometer volume

If appropriate, insert a grid in the pyknometer (6.7.1).

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. Top up with water to the funnel mark and remove from the water bath. Carefully wipe off the outside of the pyknometer and weigh it, M_3.

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

NOTE Instead of measuring the pyknometer volume at each test, the volume can be predetermined.

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C.4 Test procedure

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 (6.7.1) if necessary.

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

NOTE Gentle vibrating the pyknometer on a vibrating table can help removing entrapped air.

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

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. Wipe off the outside of the pyknometer and weigh it after (60 ± 2) min, M_2(1 h).

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

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. Wipe off 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 absorbent cloth and remove the surface water by gentle rolling in the cloth for not more than 15 s. Weigh the aggregate, M_1(24 h).

Repeat the procedure using the second test specimen.

If a soaking period longer than 24 h is necessary, determine $M_1(F)$ at the final soaking time F and calculate M_1(24 h) using Formula (C.1):

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

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 coarse lightweight aggregate in megagrams per cubic metre, in accordance with Formulae (C.2) to (C.4):

apparent particle density

$$\rho_{\text{La}} = \rho_{\text{w}} \frac{M_4}{M_4 - \left[M_2\left(24\text{h}\right) - M_3\right]} \tag{C.2}$$

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oven-dried particle density

$$\rho_{\mathrm{Lrd}} = \rho_{\mathrm{w}} \frac{M_4}{M_1\left(24\mathrm{h}\right) - \left[M_2\left(24\mathrm{h}\right) - M_3\right]} \tag{C.3}$$

saturated and surface-dried particle density

$$\rho_{\mathrm{Lssd}} = \rho_{\mathrm{w}} \frac{M_1\left(24\mathrm{h}\right)}{M_1\left(24\mathrm{h}\right) - \left[M_2\left(24\mathrm{h}\right) - M_3\right]} \tag{C.4}$$

where

ρ_{w} is the density of water at the test temperature, in megagrams per cubic metre ($\mathrm{Mg/m^3}$) (see Annex G);

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

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

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

M_4 is the mass of dry aggregate, in grams (g).

Calculate the mean value of the two individual density values after 24 h. Express the individual results to the nearest 0,001 $\mathrm{Mg/m^3}$ and the mean value to the nearest 0,01 $\mathrm{Mg/m^3}$.

Calculate the water absorption after 24 h, WA_{L24}, in accordance with Formula (C.5):

$$WA_{\mathrm{L24}} = \frac{M_1\left(24\mathrm{h}\right) - M_4}{M_4} \times 100 \tag{C.5}$$

Calculate the water absorption, $WA_{\mathrm{L}t}$, at intermediate soaking times t = 5 min and t = 1 h (and, if necessary, at other appropriate soaking times) in %, in accordance with Formula (C.6):

$$WA_{\mathrm{L}t} = WA_{\mathrm{L24}} - \frac{M_2\left(24\mathrm{h}\right) - M_2\left(t\right)}{M_4} \times 100 \tag{C.6}$$

where

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

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

M_4 is the mass of dry aggregate, in grams (g).

Calculate the mean value of the two individual water absorption values at the same soaking time. Express the individual results to the nearest 0,1 % and 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, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of the test;

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) any deviations from the reference method;

i) any unusual features observed.

C.6.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) masses of test specimens;

f) individual test results with significant digits;

g) water absorption at additional soaking times;

h) petrographic description (according to EN 932-3);

i) other influencing parameters.

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Annex D
(normative)

Determination of particle density and water absorption of fine lightweight aggregates

D.1 General

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

NOTE This method is based on the German method DIN V 18004:2004.

D.2 Principle

The test specimen is dried, mixed with water and filtered in a Büchner funnel. A vacuum pump is used to give a surface-dry product. The water absorbed is expressed as a percentage of the dry mass.

This test procedure requires the creation of a vacuum in the range of 50 mbar to 100 mbar.

NOTE Experience shows that normally more than 50 % of the aggregates have to pass the 1 mm sieve to achieve the necessary vacuum.

If the vacuum cannot be maintained, the coarse fraction (d/D with $d > 1$ mm) shall be tested according to Annex C or Annex E and the fine fraction ($0/d$) shall be tested according to Annex D.

D.3 Preparation of test specimens

Reduce the laboratory sample according to EN 932-2 to produce two subsamples.

Dry the subsamples in accordance with EN 1097-5 and allow to cool to room temperature.

Prepare two test specimens where each shall have a volume of 400 ml to 600 ml. When specified, allow the test specimens to condition to moisture equilibrium at (22 ± 3) °C and (50 ± 10) % relative humidity.

D.4 Test procedure

D.4.1 Water absorption

Place a filter paper (6.8.7) in the Büchner funnel (6.8.5) and soak with water. Allow to drain with the pump. Weigh the funnel and wet filter paper to the nearest 0,1 g and record as M_1.

Transfer a test specimen into the funnel and reweigh as M_2.

Assemble the Büchner funnel with test specimen to the flask (6.8.6) and connect to the hose, pump and vacuum gauge (6.8.9).

Fill the Büchner funnel quickly and carefully with water, while stirring the test specimen. Take care not to damage or lift the filter paper and continue stirring until the entire test specimen is wet.

Allow the test specimen to soak in water for 5 min, adding more water if required.

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Drain the water away for 5 min using the vacuum pump, maintaining the vacuum in the range of 50 mbar to 100 mbar minimum. The sample should appear surface-dry after 5 min.

The water absorption can be measured for other soaking times if required. Record the soaking time as t.

Reweigh the Büchner funnel, wet filter paper and surface-dry test specimen to the nearest 0,1 g and record as $M_3(t)$.

Carry out the particle density measurement immediately after this procedure.

D.4.2 Particle density

This method can only be used to determine the particle density of lightweight aggregates which are non-floating when fully immersed in water.

Fill up 500 ml of water in the glass measuring cylinder (6.8.2). Weigh the cylinder with water to the nearest 0,1 g and record as M_4.

Transfer the test specimen from the Büchner funnel to the cylinder (6.8.4) with the funnel (6.8.3), then into the glass measuring cylinder and read the total volume V_G immediately. Weigh the cylinder filled with water and the test specimen to the nearest 0,1 g and record as $M_5(t)$.

Repeat the procedure using the second test specimen.

D.5 Calculation and expression of results

D.5.1 Water absorption

Calculate the water absorption at the given soaking time $WA(t)$ as a percentage of dry test specimen mass, in accordance with Formula (D.1):

$$WA(t) = \frac{M_3(t) - M_2}{M_2 - M_1} \times 100 \qquad \text{(D.1)}$$

where

M_1 is the mass of the Büchner funnel with wet filter paper, in grams (g);

M_2 is the mass of the Büchner funnel with wet filter paper and dry test specimen, in grams (g);

$M_3(t)$ is the mass of the Büchner funnel with wet filter paper and surface-dry test specimen at the time t, in grams (g).

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

D.5.2 Particle density

For each test specimen, calculate the particle density (ρ_{La}, ρ_{Lrd} or ρ_{Lssd}, as appropriate) in megagrams per cubic metre, in accordance with Formulae (D.2) to (D.4):

apparent particle density

$$\rho_{La} = \frac{A}{(V_G - 500) - \left(\frac{A \times WA(t)/100}{\rho_w}\right)} \quad (D.2)$$

oven-dried particle density

$$\rho_{Lrd} = \frac{A}{V_G - 500} \quad (D.3)$$

saturated and surface-dried particle density

$$\rho_{Lssd} = \frac{M_5(t) - M_4}{V_G - 500} \quad (D.4)$$

where

A is $\frac{(M_5(t) - M_4)}{1 + WA(t)/100}$;

V_G is the total volume of the saturated aggregates and the 500 ml of water in the graduated cylinder, in millilitres (ml) or cubic centimetres (cm^3);

$WA(t)$ is the water absorption at the soaking time t, in %;

ρ_w is the density of water at room temperature, in megagrams per cubic metre (Mg/m^3) (see Annex G);

$M_5(t)$ is the mass of the glass graduated cylinder filled with water and the sample, in grams (g);

M_4 is the mass of the glass graduated cylinder prefilled with 500 ml of water, in grams (g).

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

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D.6 Test report

D.6.1 Required data

The test report shall include the following information:

a) reference to this European standard and this annex, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) sample reception date if different from sampling date;

e) identification of the test laboratory;

f) date of the test;

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

h) mass of dry sample tested;

i) water absorption of fraction tested and the corresponding soaking time;

j) appropriate particle density and the corresponding soaking time;

k) any deviations from the reference method;

l) any unusual features observed.

D.6.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) masses of test specimens;

f) individual test results with significant digits;

g) petrographic description (according to EN 932-3);

h) other influencing parameters.

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Annex E
(normative)

Quick method for determination of apparent particle density of coarse lightweight aggregates

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 coarse 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 sieve and retained on the 2 mm sieve.

NOTE This method can also be used for aggregate particles passing the 2 mm sieve and retained on the 1 mm sieve.

E.2 Preparation of test specimens

Prepare two test specimens where each shall have a loose bulk volume of approximately 500 ml:

Reduce the laboratory sample according to EN 932-2 to produce two subsamples.

Dry the subsamples in the oven at (110 ± 5) °C to constant mass. Allow to cool to room temperature.

Sieve the subsamples on the 31,5 mm and the 2 mm sieves and discard any particle retained on the 31,5 mm sieve or passing the 2 mm sieve.

Weigh the obtained test specimen, M_4.

E.3 Procedure

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 (6.9.1), 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 (6.9.2), 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 timer. 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 using the second test specimen.

For some lightweight aggregates, 30 s may not be an appropriate time. If a longer time period is necessary to remove air bubbles, this shall be stated in the test report.

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E.4 Calculation and expression of results

For each test specimen, calculate the apparent particle density ρ_{La} of the lightweight aggregate in megagrams per cubic metre, in accordance with Formula (E.1):

apparent particle density

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

where

M_4 is the mass of dry aggregate, in grams (g);

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

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 (ml).

Calculate the mean value of the two individual density values at the actual soaking time. Express the individual results to the nearest 0,001 Mg/m^3 and 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 document and this annex, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of the test;

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) any deviations from the method;

h) any unusual features observed.

E.5.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) masses of test specimens;

f) individual test results with significant digits;

g) petrographic description (according to EN 932-3);

h) other influencing parameters.

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Annex F
(informative)

Determination of the particle density and water absorption of aggregates passing the 4 mm sieve

F.1 General

This annex describes the pyknometer method for the determination of particle density and water absorption for aggregate particles passing the 4 mm sieve (including the 0/0,063 mm size fraction). It applies to normal weight aggregates, including crushed fine aggregates.

NOTE 1 The test method is mostly used for concrete applications.

NOTE 2 Experience with this method on fine recycled aggregates is limited.

NOTE 3 The water absorption of size fraction 0/4 mm of a natural crushed fine aggregate can also be derived from the water absorption determined on a coarser size fraction (e.g. 8/16 mm or 10/14 mm), provided that the aggregate product is of the same petrographic source and production process. In that case, the water absorption is calculated in accordance with Formula (F.1):

$$WA = 100 \times \rho_w \times \left[\frac{1}{\rho_{rd}\left(0/4\right)} + \frac{1}{\rho_a\left(8/16 \text{ or } 10/14\right)} \right] \quad \text{(F.1)}$$

where

ρ_w is the density of water at room temperature, in megagrams per cubic metre (Mg/m^3) (see Annex G);

ρ_{rd} is the oven-dried particle density determined on a second test portion of size fraction 8/16 mm, in megagrams per cubic metre (Mg/m^3);

ρ_a is the apparent particle density of the test portion determined after 24 h immersion in water, in megagrams per cubic metre (Mg/m^3).

F.2 Preparation of test portion

Reduce the laboratory sample according to EN 932-2.

Sieve the test sample on a 4 mm sieve and discard any particles retained on the 4 mm sieve.

The mass of the 0/4 mm test portion of aggregate shall be enough to fill the cone.

NOTE A test portion of 800 g is usually enough to fill the cone.

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F.3Procedure

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. Place the pyknometer with the test portion in the water bath and keep it at a temperature of (22 ± 3) °C for (24 ± 0,5) h.

Take the pyknometer from the water bath and remove any remaining entrapped air by gently rolling and jolting the pyknometer. 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. Wipe off the pyknometer on the outside and weigh it, M_2. Record the water temperature.

Leave to stand for the time necessary for the fines to settle.

Remove most of the water covering the test portion and empty the sample on a tray.

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

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 predetermined. In that case, the pyknometer should be tempered in a thermostatic bath to the temperature measured when the volume was determined ± 0,5 °C.

Spread the soaked test sample to get a uniform layer over the bottom of the tray. Expose the aggregate to a gentle current of warm air (6.10.1) to evaporate surface moisture. Stir the aggregate 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. To avoid the loss of fines, the slowest speed of the dryer shall be used at the end of the drying procedure.

NOTE The colour difference between wet and dry fine aggregates is a good indicator for determining the absence of traces of moisture.

Assess whether the surface-dry state has been achieved, by performing the cone test as follows. Hold the metal cone mould (6.4.2) 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 aggregate. Tamp the surface 25 times by letting the tamper fall under its own weight. Be sure to move the tamper so the entire surface of the aggregate is packed in the same way. Do not refill the mould after tamping. Gently lift the mould clear of the aggregate.

If the aggregate cone does not collapse (see Figure F.1a), continue drying and repeat the cone test just until the cone collapses into a pyramid shape at mould removal. This state is illustrated for crushed aggregates in Figure F.1b and F.1c and for rounded aggregates in Figure F.1c.

If the cone collapses totally on the first attempt (see Figure F.1d), the fine aggregate shall be slightly moistened again, and the cone test shall be repeated.

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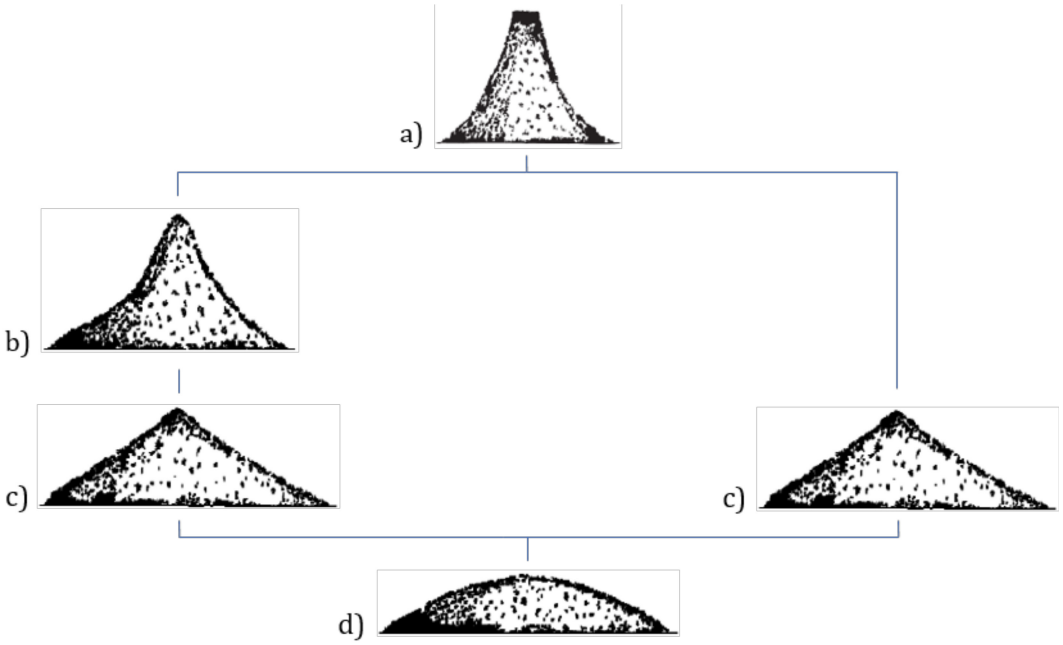

Key

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

b) aggregate slightly moist; appreciable slump observed

c) aggregate saturated and 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 Sketches a, b, c and d are applicable for crushed aggregates. Sketches a, c and d are applicable for rounded aggregates.

Figure F.1 — Examples of cone test result

Weigh the saturated and surface-dried test portion, M_1.

Dry the aggregate in the oven at (110 ± 5) °C to constant mass. Let it cool to room 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.

F.4Calculation and expression of results

Use the formulae in 9.4.

F.5Test report

F.5.1 Required data

The test report shall include the following information:

a) reference to this European standard and this annex, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of the test;

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

f) the test results with significant digits (four parameters);

g) any deviations from the method;

h) any unusual features observed.

F.5.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) laboratory sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) mass of test portion;

f) petrographic description (according to EN 932-3);

g) other influencing parameters.

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Annex G
(normative)

Density of water

Table G.1 — Density of water

Temperature °C	Density Mg/m³
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

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Annex H
(normative)

Determination of the pre-dried particle density of aggregates passing the 31,5 mm sieve

H.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. It applies to aggregate particles passing the 31,5 mm sieve (including the 0/0,063 mm size fraction).

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

H.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 (6.5.1).

H.3 Preparation of test specimens

Reduce the laboratory sample according to EN 932-2 to produce two subsamples.

Sieve the subsamples and discard any particles retained on the 31,5 mm sieve. Dry in the oven at (110 ± 5) °C to constant mass. Allow to cool to room temperature.

Prepare two test specimens. The mass of each test specimen shall be not less than the mass specified in Table H.1.

Table H.1 — Minimum mass of test specimens

Upper aggregate size (*D*) mm	**Minimum mass of test specimens** kg
31,5	1,5
16	1,0
8	0,5
4 (or less)	0,25
For other *D* values, the minimum mass of the test specimen may be interpolated from the masses specified.	

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H.4 Test procedure

During the test, the water bath shall be kept at a temperature of (22 ± 3) °C.

Clean, wipe off and weigh the pyknometer and its funnel, M_0. Fill the pyknometer with water at (22 ± 3) °C to about half of its volume. Add carefully one of the test specimens into the pyknometer. It is recommended that the test specimen occupies not more than one half of the pyknometer volume, to enable the release of entrapped air. Record the mass of the test specimen, M_1.

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 specimen immersed under at least 5 mm of water. If necessary, add water.

Stir the aggregate with a glass rod for 10 s to remove entrapped air and adherent air bubbles. Then tilt the pyknometer to 45° and rotate it clockwise and anticlockwise for a total of 50 s. Repeat this "stir and rotate" procedure, so that three cycles are completed in not more than 3 min.

Agitate the pyknometer using a source of external vibration with sufficient amplitude to displace the whole of the test specimen within the pyknometer.

Evacuate any remaining entrapped air from the immersed test specimen by applying a partial vacuum that results in a residual pressure of 40 mbar or less. The partial vacuum shall be achieved within not more than 5 min and shall be maintained for at least 30 min.

After releasing the vacuum, refill the pyknometer with water and place it without its funnel in the water bath at (22 ± 3) °C for at least 1 h.

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 wipe off the outside, then weigh and record the mass of the pyknometer with its content, M_2. Record the temperature of the water inside the pyknometer.

Repeat the procedure using the second test specimen.

H.5 Determination of the pyknometer volume

Clean and wipe off the pyknometer. Fill it with water and add the funnel.

Fill the pyknometer with water up to the graduation mark. Wipe off the outside of the pyknometer and weigh it, M_3.

Record the temperature of the water inside the pyknometer and make sure that it does not 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 predetermined. In that case, the pyknometer should be tempered in a thermostatic bath to the temperature measured when the volume was determined ± 0,5 °C.

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

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H.6 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 Formulae (H.1) and (H.2):

pre-dried particle density

$$\rho_p = \frac{M_1}{V - \frac{\left(M_2 - M_1 - M_0\right)}{\rho_w}} \quad \text{(H.1)}$$

where

M_1 is the mass of test specimen, in grams (g);

M_2 is the mass of the pyknometer, funnel, test specimen and water, in grams (g);

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

ρ_w is the density of water at the temperature recorded when M_2 was determined, in megagrams per cubic metre (Mg/m^3) (see Annex G);

V is the volume of the pyknometer, in millilitres (ml).

$$V = \frac{M_3}{\rho_w} \quad \text{(H.2)}$$

where

M_3 is the mass of water filling the pyknometer and its funnel to the graduation mark, in grams (g);

ρ_W is the density of water at test temperature, in megagrams per cubic metre (Mg/m^3) (see Annex G).

Express the value of the pre-dried 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.

H.7 Test report

H.7.1 Required data

The test report shall include the following information:

a) reference to this European standard and this annex, including its year of publication;

b) identification of the laboratory sample, including the origin;

c) identification of the laboratory;

d) date of the test;

e) size fraction of the aggregate;

f) the test results with significant digits;

g) any deviations from the method;

h) any unusual features observed.

H.7.2 Optional data

The test report can include the following information:

a) reference to the chosen sampling procedure;

b) sampling certificate, if available;

c) sample reception date if different from sampling date;

d) reference to the chosen sample reduction procedure;

e) mass of test portion;

f) individual test results with significant digits;

g) petrographic description (according to EN 932-3);

h) other influencing parameters.

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Annex I
(informative)

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

I.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 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 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 document, three basic particle density definitions apply. They can be expressed by the general formulae, given in Figure I.1.

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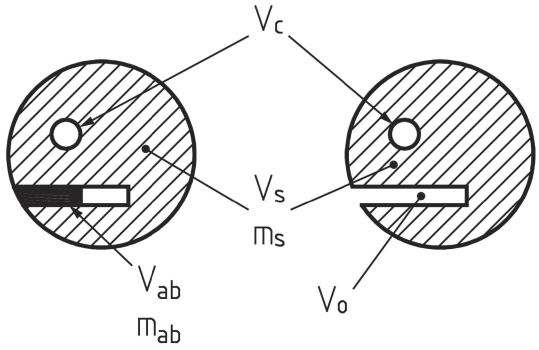

Key

Total particle volume	$V = V_0 + V_c + V_s$
Oven-dried particle density	$\rho_{\mathrm{rd}} = \frac{m_s}{V}$
Saturated and surface-dried particle density	$\rho_{\mathrm{ssd}} = \frac{m_s + m_{ab}}{V}$
Apparent particle density	$\rho_{\mathrm{a}} = \frac{m_s}{V - V_{ab}}$
Water absorption	$WA = \frac{m_{ab}}{m_s} \times 100 = \frac{\rho_{\mathrm{w}} \times V_{ab}}{m_s} \times 100$

Figure I.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

I.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 I.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 I.1.

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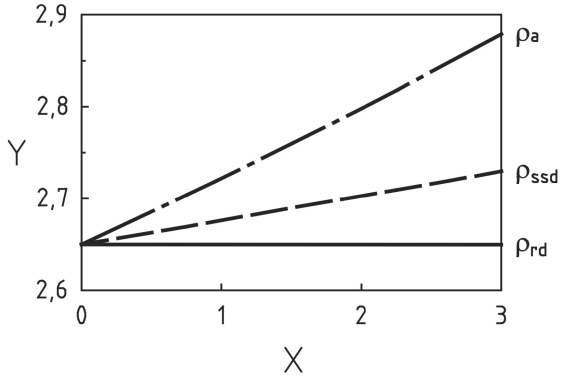

Key

X water absorption – %

Y particle density – Mg/m³

Figure I.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/m³

Table I.1 — The interrelationship between the three particle density parameters and water absorption, for three different values of oven-dried particle density

Water absorption, WA	ρ_{rd} = 2,00		ρ_{rd} = 2,65		ρ_{rd} = 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
Calculated particle density, in Mg/m³, and water absorption values in %, derived from $\rho_{ssd} = \rho_{rd}\,[1 + WA/100]$ and $\rho_a = \rho_{rd} / [1 - \rho_{rd}\, WA/(100\rho_w)]$						

I.3 Characteristics of the reference method for coarse 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 I.3).

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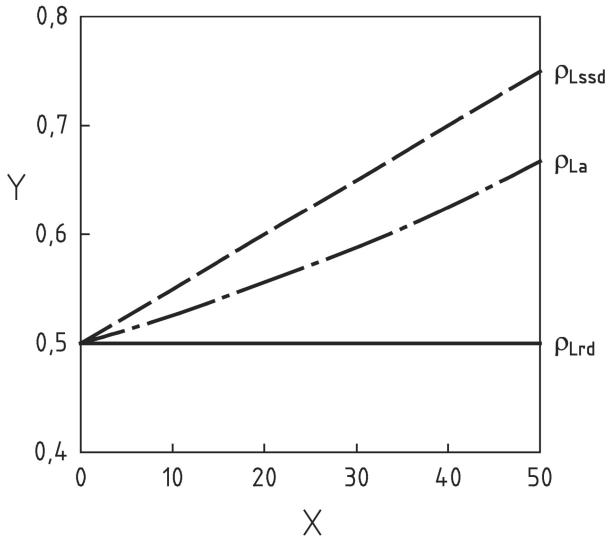
The water absorption of lightweight aggregates is generally much greater than for normal weight aggregates. The open pores in lightweight aggregates may or may not become essentially filled after immersion for 24 h. Many lightweight aggregates can remain immersed in water for several days and weeks without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



Key

X water absorption – %

Y particle density – Mg/m^3

Figure I.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

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

The methods for determination of the pre-dried particle density, specified in Annex A and Annex H, 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 water absorption 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 sieve and retained on the 0,063 mm sieve, the correlation between the pre-dried particle density and the apparent particle density is weaker.

The method in Annex H 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.

I.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 I.2. The two generally used particle density parameters are the saturated and surface-dried particle density and the oven-dried particle density.

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

Purpose	Recommended particle density parameter
Declaration – aggregates others than railway ballast and lightweight aggregates	ρ_a or ρ_{ssd} or ρ_{rd}
Declaration – railway ballast	ρ_{cm}
Declaration – lightweight aggregates	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

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

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

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Table I.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 %
	0/4	Annex F	Yes	–
	0,063/31,5	A.4	No	*WA* less than about 1,5 %
	0/31,5	Annex H	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
	0/4	Annex D	Yes	–

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Table I.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	Assessment of surface-dry state of test portion
7	Wire basket	No	24,0 ± 0,5 h	Using a cloth
8	Pyknometer	No	24,0 ± 0,5 h	Using a cloth
9	Pyknometer	No	24,0 ± 0,5 h	Using the cone test
A.3	Wire basket	Yes	Max 10 min	No
A.4	Pyknometer	Yes	At least 1 h	No
Annex B	Wire basket	No	Until constant mass	Using a cloth
Annex C	Pyknometer	Yes	24,0 ± 0,5 h	Using a cloth
Annex D	Büchner funnel	Yes	5 min or more	No
Annex E	Graduated measuring cylinder	Yes	Less than 5 min	No
Annex F	Pyknometer	No	24,0 ± 0,5 h	Using the cone test
Annex H	Pyknometer	Yes	> 1,5 h, including 30 min vacuum	No

I.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 J
(informative)

Precision

J.1 Data from National Standards

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

Table J.1 — Apparent particle density — repeatability *r* and reproducibility *R*

Method of test	Clause No	Repeatability *r* Mg/m³	Reproducibility *R* Mg/m³
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 J.2 — Oven-dried particle density — repeatability *r* and reproducibility *R*

Method of test	Clause No	Repeatability *r* Mg/m³	Reproducibility *R* Mg/m³
Wire basket	7	0,025	0,044
Pyknometer (coarse aggregate)	8	0,031	0,042
Pyknometer (fine aggregate)	9	0,043	0,085

Table J.3 — Saturated and surface-dried particle density — repeatability *r* and reproducibility *R*

Method of test	Clause No	Repeatability *r* Mg/m³	Reproducibility *R* Mg/m³
Wire basket	7	0,022	0,034
Pyknometer (coarse aggregate)	8	0,031	0,049
Pyknometer (fine aggregate)	9	0,035	0,070

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Table J.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 J.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/m³	Repeatability r_1 Mg/m³	Reproducibility R_1 Mg/m³
0,025	0,019	0,042

J.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 J.6. The repeatability r_1 and reproducibility R_1 values have been determined for the three tested aggregates based on duplicate tests carried out on different samples.

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Table J.6 — Repeatability and reproducibility values for determinations of particle density 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
Except for the number of laboratories included, data related to particle density is expressed in megagrams per cubic metre, and data related to water absorption is expressed in %.					

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

[2] EN 1097-3, *Tests for mechanical and physical properties of aggregates — Part 3: Determination of loose bulk density and voids*

[3] DIN V 18004:2004, *Anwendungen von Bauprodukten in Bauwerken – Prüfverfahren für Gesteinskörnungen nach DIN V 20000-103 und DIN V 20000-104.* (Use of building products in construction works – Test methods for aggregates according to DIN V 20000-103 and DIN V 20000-104).

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