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Mélanges bitumineux - Méthodes d'essai pour mélange hydrocarboné à chaud - Partie 5: Détermination de la densité maximale

Bituminous mixtures - Test methods for hot mix asphalt - Part 5: Determination of the maximum density

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Bureau voor Normalisatie Brabançonnelaan 29 B-1000 Brussel België
Tel: +32 2 738 01 12 - Fax: +32 2 733 42 64 - E-mail: info@nbn.be - NBN Online: www.nbn.be
Bank 000-3255621-10 IBAN BE41 0003 2556 2110 BIC BPOT BEB1 BTW: BE 0880.857.592

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Bureau de Normalisation - Avenue de la Brabançonne 29 - 1000 Bruxelles - Belgique
Tél: +32 2 738 01 12 - Fax: +32 2 733 42 64 - E-mail: info@nbn.be - NBN Online: www.nbn.be
Banque 000-3255621-10 IBAN BE41 0003 2556 2110 BIC BPOT BEB1 TVA: BE 0880.857.592

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Foreword

This document (EN 12697-5:2002+A1:2007) has been prepared by Technical Committee CEN/TC 227 "Road mixtures", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2008 and conflicting national standards shall be withdrawn at the latest by January 2008.

This document includes Amendment 1, approved by CEN on 2007-05-16.

This document supersedes EN 12697-5:2002.

The start and finish of text introduced or altered by amendment is indicated in the text by tags ▌A1⟩ ⟨A1▌.

This European Standard is one of a series of standards as listed below.

EN 12697-1, *Bituminous mixtures – Test methods for hot mix asphalt – Part 1: Soluble binder content*

EN 12697-2, *Bituminous mixtures – Test methods for hot mix asphalt – Part 2: Determination of particle size distribution*

EN 12697-3, *Bituminous mixtures – Test methods for hot mix asphalt – Part 3: Binder recovery: Rotary evaporator*

EN 12697-4, *Bituminous mixtures – Test methods for hot mix asphalt – Part 4: Binder recovery: Fractionating column*

EN 12697-5, *Bituminous mixtures - Test methods for hot mix asphalt - Part 5: Determination of the maximum density*

EN 12697-6, *Bituminous mixtures – Test methods for hot mix asphalt – Part 6: Determination of bulk density of bituminous specimen*

EN 12697-7, *Bituminous mixtures – Test methods for hot mix asphalt – Part 7: Determination of bulk density of bituminous specimens by gamma rays*

EN 12697-8, *Bituminous mixtures – Test methods for hot mix asphalt – Part 8: Determination of void characteristics of bituminous specimens*

EN 12697-9, *Bituminous mixtures – Test methods for hot mix asphalt – Part 9: Determination of the reference density*

EN 12697-10, *Bituminous mixtures – Test methods for hot mix asphalt – Part 10: Compactibility*

EN 12697-11, *Bituminous mixtures – Test methods for hot mix asphalt – Part 11: Determination of the affinity between aggregate and bitumen*

EN 12697-12, *Bituminous mixtures – Test methods for hot mix asphalt – Part 12: Determination of the water sensitivity of bituminous specimens*

EN 12697-13, *Bituminous mixtures – Test methods for hot mix asphalt – Part 13: Temperature measurement*

EN 12697-14, *Bituminous mixtures – Test methods for hot mix asphalt – Part 14: Water content*

EN 12697-15, *Bituminous mixtures – Test methods for hot mix asphalt – Part 15: Determination of the segregation sensitivity*

EN 12697-16, *Bituminous mixtures – Test methods for hot mix asphalt – Part 16: Abrasion by studded tyres*

EN 12697-17, *Bituminous mixtures – Test methods for hot mix asphalt – Part 17: Particles loss of porous asphalt specimen*

EN 12697-18, *Bituminous mixtures – Test methods for hot mix asphalt – Part 18: Binder drainage*

EN 12697-19, *Bituminous mixtures – Test methods for hot mix asphalt – Part 19: Permeability of specimen*

EN 12697-20, *Bituminous mixtures – Test methods for hot mix asphalt – Part 20: Indentation using cube or Marshall specimens*

EN 12697-21, *Bituminous mixtures – Test methods for hot mix asphalt – Part 21: Indentation using plate specimens*

EN 12697-22, *Bituminous mixtures – Test methods for hot mix asphalt – Part 22: Wheel tracking*

EN 12697-23, *Bituminous mixtures – Test methods for hot mix asphalt – Part 23: Determination of the indirect tensile strength of bituminous specimens*

EN 12697-24, *Bituminous mixtures – Test methods for hot mix asphalt – Part 24: Resistance to fatigue*

EN 12697-25, *Bituminous mixtures – Test methods for hot mix asphalt – Part 25: Cyclic compression test*

EN 12697-26, *Bituminous mixtures – Test methods for hot mix asphalt – Part 26: Stiffness*

EN 12697-27, *Bituminous mixtures – Test methods for hot mix asphalt – Part 27: Sampling*

EN 12697-28, *Bituminous mixtures – Test methods for hot mix asphalt – Part 28: Preparation of samples for determining binder content, water content and grading*

EN 12697-29, *Bituminous mixtures – Test methods for hot mix asphalt – Part 29: Determination of the dimensions of bituminous specimen*

EN 12697-30, *Bituminous mixtures – Test methods for hot mix asphalt – Part 30: Specimen preparation by impact compactor*

EN 12697-31, *Bituminous mixtures – Test methods for hot mix asphalt – Part 31: Specimen preparation by gyratory compactor*

EN 12697-32, *Bituminous mixtures – Test methods for hot mix asphalt – Part 32: Laboratory compaction of bituminous mixtures by a vibratory compactor*

EN 12697-33, *Bituminous mixtures – Test methods for hot mix asphalt – Part 33: Specimen preparation by roller compactor*

EN 12697-34, *Bituminous mixtures – Test methods for hot mix asphalt – Part 34: Marshall test*

EN 12697-35, *Bituminous mixtures – Test methods for hot mix asphalt – Part 35: Laboratory mixing*

EN 12697-36, *Bituminous mixtures – Test methods for hot mix asphalt – Part 36: Determination of the thickness of a bituminous pavement*

EN 12697-37, *Bituminous mixtures – Test methods for hot mix asphalt – Part 37: Hot sand test for the adhesivity of binder on precoated chippings for HRA*

EN 12697-38, *Bituminous mixtures – Test methods for hot mix asphalt – Part 38: Common equipment and calibration*

EN 12697-39, *Bituminous mixtures – Test methods for hot mix asphalt – Part 39: Binder content of by ignition*

EN 12697-40, *Bituminous mixtures – Test methods for hot mix asphalt – Part 40: In situ drainability*

EN 12697-41, *Bituminous mixtures – Test methods for hot mix asphalt – Part 41: Resistance to deicing fluids*

EN 12697-42, *Bituminous mixtures – Test methods for hot mix asphalt – Part 42: Amount of coarse foreign matters in reclaimed asphalt*

EN 12697-43, *Bituminous mixtures – Test methods for hot mix asphalt – Part 43: Resistance to fuel*

The applicability of this European Standard is described in the product standards for bituminous mixtures.

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WARNING — The method described in this European Standard can require the use of dichloromethane (methylene chloride), this solvent is hazardous to health and is subject to occupational exposure limits as described in relevant legislation and regulations.

Exposure levels are related to both handling procedures and ventilation provision and it is emphasised that adequate training should be given to staff employed in the use of this substances.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies test methods for determining the maximum density of a bituminous mixture (voidless mass). It specifies a volumetric procedure, a hydrostatic procedure and a mathematical procedure.

The test methods described are intended for use with loose bituminous mixtures containing paving grade bitumens, modified binders or other bituminous binders used for hot mix asphalt. The tests are suitable for both fresh or aged bituminous mixtures.

NOTE 1 Samples can be supplied as loose mixture or as compacted mixture.

NOTE 2 General guidance on selection of a test procedure to determine the maximum density of a bituminous mixture is given in annex A.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1097-6, *Test for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption.*

EN 12697-1, *Bituminous mixtures – Test methods for hot mix asphalt – Part 1: Soluble binder content.*

EN 12697-27, *Bituminous mixtures – Test methods for hot mix asphalt – Part 27: Sampling.*

EN 12697-28, *Bituminous mixtures – Test methods for hot mix asphalt – Part 28: Preparation of samples for determining binder content, water content and grading.*

EN ISO 3838, *Crude oil and liquid or solid petroleum products – Determination of density or relative density – Capillary-stoppered pyknometer and graduated bicappilary pyknometer methods (ISO 3838:1995).*

3 Terms and definitions

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

3.1
maximum density
mass per unit volume, without air voids, of a bituminous mixture at known test temperature

3.2
bulk density
mass per unit volume, including the air voids, of a specimen at known test temperature

3.3
apparent particle density
ratio of the oven dried mass of a sample of aggregate to the volume it occupies in water including any internal sealed voids but excluding water accessible voids

3.4
particle density on an oven dried basis of aggregate
ratio of the oven dried mass of a sample of aggregate to the volume it occupies in water including both internal sealed voids and water accessible voids

3.5
loose bulk density of aggregate
quotient obtained when the mass of dry aggregate filling a specified container without compaction is divided by the capacity of that container

4 Principle

The maximum density, together with the bulk density, is used to calculate the air voids content of a compacted sample and other volumetric-related properties of a compacted bituminous mixture.

In the volumetric and hydrostatic procedures the maximum density of bituminous mixtures is determined from the volume of the sample without voids and from its dry mass.

In the volumetric procedure the volume of the sample is measured as the displacement of water or solvent by the sample in a pyknometer.

In the hydrostatic procedure the volume of the sample is calculated from the dry mass of the sample and from its mass in water.

In the mathematical procedure the maximum density of a bituminous mixture is calculated from its composition (binder content and aggregate content) and the densities of the constituent mixtures.

5 Materials

5.1 De-aired water (freshly de-aired and cooled) or organic solvent, suitable to solve bituminous binders (for the volumetric and hydrostatic procedures).

5.2 Dispersion agent, [e.g. 7 % of Nonylphenolpolyglcolether (7 groups of Ethoxyl) in water].

5.3 Boiling water.

6 Apparatus

6.1 Tools to clean samples (if required).

6.2 Ventilated cabinet, capable of drying the sample and maintaining a uniform temperature within (110 ± 5) °C in the vicinity of the test sample(s).

6.3 Suitable tools to loosen and separate the sample, e.g. spatula.

6.4 Balance, accurate to at least 0,1 g.

6.5 Thermometer, accurate to at least 0,1 °C.

6.6 Water-bath, maintaining the water at a uniform temperature within ± 0,2 °C in the vicinity of the test sample(s). The water-bath shall contain a grid to permit submersion of the pyknometer or container to around 20 mm below the upper edge of pyknometer or container and to allow water to circulate. The volume of the bath shall be at least three times that of the pyknometer/container.

6.7 Vibrating table, or other means to shake the pyknometer or container during evacuation of air.

6.8 Pyknometer, (for the volumetric procedure), of suitable size, with an accurately fitting head piece. The volume of the pyknometer shall be such that the sample occupies up to 2/3 of its volume. The volume of the pyknometer shall be regularly calibrated in accordance with annex C.

6.9 Vacuum system, (for the volumetric procedure), with manometer or calibrated vacuum gauge, capable of evacuating air from the pyknometer to a residual pressure of 4 kPa or less.

6.10 Container, (for the hydrostatic procedure), capable of being suspended in water. The shape of the container shall be such that the sample can be immersed completely when filling the container with water; the sample shall occupy up to 2/3 of the container's volume which shall be not less than 3 000 cm^3.

6.11 Vacuum desiccator, (for the hydrostatic procedure), or other vacuum vessel capable of accommodating the pyknometer or container.

7 Sampling

Samples of bituminous mixture shall be obtained in accordance with EN 12697-27.

Samples shall have a mass expressed in grams of at least 50 times the numerical value of the nominal maximum particle size of the aggregates in millimetres, i.e. the largest specified sieve size of the mixture with a minimum of 250 g.

8 Preparation of sample

8.1 Bulk samples

Obtain a test sample from a bulk sample after homogenising by riffling or quartering in accordance with EN 12697-28.

8.2 Samples from finished mixture

Samples of compacted mixture shall be cleaned by brushing or washing before being placed in the ventilated cabinet, at a temperature of (110 ± 5) °C, dried to constant mass and then separated.

NOTE Constant mass is obtained when the change of mass between two determinations at an interval of at least 30 min is less than 0,1 % (m/m).

8.3 Sample separation

Samples shall be loosened and separated into coarse particles and agglomerations. Agglomerations shall not be larger than 6 mm. If the mixture is not sufficiently soft to separate manually, warm it on a tray in an oven at a temperature not exceeding 110 °C, but only until it can be properly handled.

9 Procedure

9.1 General

All masses shall be determined in grams to the nearest 0,1 g. The volume of the pyknometer shall be determined in cubic metres to the nearest 0,5 x 10^{-6} m^3.

9.2 Procedure A: Volumetric procedure

9.2.1 Weigh the empty pyknometer including the head piece (m_1) of known volume (V_p).

NOTE The volume of the pyknometer can be determined in accordance with ⟨A1⟩ Annex C ⟨A1⟩.

9.2.2 Place the dry test sample into the pyknometer and bring it to ambient temperature, then weigh again, together with the head piece (m_2).

9.2.3 Fill the pyknometer with de-aired water or solvent, up to a maximum of 30 mm below the head joint.

9.2.4 Evacuate entrapped air, by applying a partial vacuum [A1⟩ that results in a residual pressure ⟨A1] of 4 kPa or less for (15 ± 1) min.

NOTE The evacuation of air in accessible pores is important. Evacuation can be assisted by stirring, rotating or vibrating the pyknometer on a vibrating table. When using water, adding a small amount of a dispersion agent (two drops only) can facilitate air evacuation. When using solvent, stirring and vibrating without applying a vacuum should be used. The de-aired water can be replaced by boiling water.

9.2.5 [A1⟩ Fix the head piece or stopper after carefully filling the pyknometer ⟨A1] with de-aired water or solvent (ensuring no air is introduced) almost to the reference mark of the head piece or to the stopper.

9.2.6 [A1⟩ When using water, place the pyknometer in a water-bath at known uniform test temperature (± 1,0 °C) for at least 30 min, but no longer than 180 min, in order to bring the temperature of the sample and of the water in the pyknometer to the same level as that of the water in the water-bath.

When using solvent, place the pyknometer in a water-bath at known uniform test temperature (± 0,2 °C) for at least 60 min, but no longer than 180 min, in order to bring the temperature of the sample and of the solvent in the pyknometer to the same level as that of the water in the water-bath.

The water in the water-bath shall reach up to approximately 20 mm below the edge of the pyknometer. ⟨A1]

9.2.7 Fill the pyknometer up to the measuring mark with the water or solvent. The container with water or solvent shall be brought to the test temperature in a water-bath.

9.2.8 Take the pyknometer out of the water-bath, wipe the outside dry and weigh it immediately (m_3).

9.3 Procedure B: Hydrostatic procedure

9.3.1 Determine the mass of the empty container in air (m_1), and when submerged in water (m_2).

9.3.2 Place the test sample in the dried container and bring it to ambient temperature, then determine the mass of the container plus test sample in air (m_3).

9.3.3 Fill the container with de-aired water and evacuate entrapped air, by stirring and/or vibrating.

NOTE The evacuation of air in accessible pores is important. Adding a small amount of a dispersion agent (two drops only) can facilitate the air evacuation. Further facilitation can be obtained by applying a vacuum [A1⟩ that results in a residual pressure ⟨A1] of approximately 4 kPa or less during (15 ± 1) min and/or by using boiling water (see also 9.2.4, concerning vacuum period).

9.3.4 Place the container in the water-bath at a known uniform temperature (± 1,0 °C) within the range from 20 °C to 30 °C for at least 30 min, to bring the temperature of the sample and the water in the container to the same level as that of the water in the water-bath.

The level of water in the water-bath shall reach up to approximately 20 mm below the top edge of the container.

9.3.5 Determine the mass of the container plus the test sample when suspended in water (m_4); the water shall be of the same temperature as used in **9.3.4**.

9.4 Procedure C: Mathematical procedure

Express the mixture composition in percentages of the total mix [percentage aggregate + percentage binder = 100,0 % (m/m)].

When the mixture composition is not known the binder content shall be determined according to EN 12697-1.

The densities shall be determined in accordance with EN 1097-6 for aggregates and EN ISO 3838 for binders.

10 Calculation

10.1 General

All masses shall be expressed in grams to the nearest 0,1 g. The volume of a pyknometer shall be expressed in cubic metres to the nearest $0{,}5 \cdot 10^{-6}$ m^3. All percentages shall be expressed to the nearest 0,1 % (see Table 1).

NOTE The water density is 997,1 kg/m^3 at 25 °C. For other temperatures the water density is (997,1 × *K*) kg/m^3:

Table 1 — Water density

Water temperature °C	Correction factor *K*	Water density kg/m^3	Water temperature °C	Correction factor *K*	Water density kg/m^3
10	1,002 7	999,8	20	1,001 2	998,3
11	1,002 6	999,7	21	1,001 0	998,1
12	1,002 5	999,6	22	1,000 7	997,8
13	1,002 3	999,4	23	1,000 5	997,6
14	1,002 2	999,3	24	1,000 3	997,4
15	1,002 1	999,2	25	1,000 0	997,1
16	1,001 9	999,0	26	0,999 7	996,8
17	1,001 7	998,8	27	0,999 5	996,6
18	1,001 6	998,7	28	0,999 2	996,3
19	1,001 4	998,5	29	0,998 9	996,0
20	1,001 2	998,3	30	0,998 6	995,7

10.2 Procedure A: Volumetric procedure

The maximum density ρ_{mv} of the bituminous mixture determined by the volumetric procedure shall be calculated to the nearest 1 kg/m^3 as follows:

[A1]

$$\rho_{mv} = \frac{m_2 - m_1}{1000x\left(V_P - \frac{m_3 - m_2}{\rho_W}\right)} \qquad (1)$$

[A1]

where

ρ_{mv} is the maximum density of the bituminous mixture as determined by the volumetric procedure, in kilograms per cubic metre (kg/m^3) [A1] to the nearest 0,1 kg/m^3 [A1];

m_1 is the mass of the pyknometer plus head piece and spring, in grams (g);

m_2 is the mass of the pyknometer plus head piece, spring and test sample, in grams (g);

m_3 is the mass of the pyknometer plus head piece, spring, test sample and water or solvent, in grams (g);

V_P is the volume of the pyknometer, when filled up to the reference mark, in cubic metres (m^3);

ρ_W is the density of the water or solvent at test temperature, in 0,1 kilograms per cubic metre (kg/m^3) to the nearest 0,1 kg/m^3.

10.3 Procedure B: Hydrostatic procedure

The maximum density ρ_{mh} of the bituminous mixture determined by the hydrostatic procedure shall be calculated to the nearest 1 kg/m^3 as follows:

$$\rho_{mh} = \frac{m_3 - m_1}{(m_3 - m_1) - (m_4 - m_2)} \times \rho_W \qquad (2)$$

where

ρ_{mh} is the maximum density of the bituminous mixture by the hydrostatic procedure, in kilograms per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

m_1 is the mass of the container in air, in grams (g);

m_2 is the mass of the container suspended in water, in grams (g);

m_3 is the mass of the container plus test sample in air, in grams (g);

m_4 is the mass of the container plus test sample suspended in water, in grams (g);

ρ_W is the density of the water at test temperature, in kilograms per cubic metre (kg/m^3) to the nearest 0,1 kg/m^3.

10.4 Procedure C: Mathematical procedure

The maximum density ρ_{mc} of the bituminous mixture determined by the mathematical procedure shall be calculated to the nearest 1 kg/m^3 as follows:

$$\rho_{mc} = \frac{100}{(p_a / \rho_a) + (p_b / \rho_b)} \qquad (3)$$

where

ρ_{mc} is the maximum density of the mixture by calculation, in kilograms per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

p_a is the percentage of aggregate in the mixture to the nearest 0,1 % (m/m);

ρ_a is the apparent density of the aggregate, in kilogram per cubic metre (kg/m^3) to the nearest 1 kg/m^3);

p_b is the percentage of binder in the mixture to the nearest 0,1 % (m/m);

ρ_b is the density of the binder at 25 °C, in kilogram per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

$p_a + p_b$ = 100,0 % (m/m).

When aggregates with different densities are used, calculate the maximum density as follows:

$$\rho_{mc} = \frac{100}{(p_{a1} / \rho_{a1}) + (p_{a2} / \rho_{a2}) + ... + (p_b / \rho_b)} \qquad (4)$$

where

ρ_{mc} is the maximum density of the mixture by calculation, in kilograms per cubic metre (kg/m^3) to the nearest 0,1 kg/m^3;

p_{a1} is the percentage of aggregate 1 in the mixture (m/m);

ρ_{a1} is the apparent density of aggregate 1, in kilogram per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

p_{a2} is the percentage of aggregate 2 in the mixture (m/m);

ρ_{a2} is the apparent density of aggregate 2, in kilogram per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

p_b is the percentage of binder in the mixture (m/m);

ρ_b is the density of the binder, in kilogram per cubic metre (kg/m^3) to the nearest 1 kg/m^3;

$p_{a1} + p_{a2} + ... + p_b$ = 100,0 % (m/m).

11 Precision

NOTE 1 The precision data presented in this clause are of an informative nature only and should only be applied for procedure A of this European Standard – (volumetric procedure). The exact values for the other procedures are not available.

NOTE 2 The precision data when using de-aired water originate from Swedish experiments….

NOTE 3 The precision data when using organic solvent are in accordance with the DIN 1996-7:1983.

11.1 Repeatability (same observer, same apparatus)

Standard deviation: σ_r = 4 kg/m^3 (using water)

σ_r = 7 kg/m^3 (using solvent)

Repeatability: r = 2,77 × σ_r = 11 kg/m^3 (using water)

r = 2,77 × σ_r = 19 kg/m^3 (using solvent)

11.2 Reproducibility (different observers, different apparatus)

Standard deviation: σ_R = 8 kg/m^3 (using water)

σ_R = 15 kg/m^3 (using solvent)

Reproducibility: R = 2,77 × σ_R = 22 kg/m^3 (using water)

R = 2,77 × σ_R = 42 kg/m^3 (using solvent)

12 Report

With reference to this European Standard the test report shall include the following information for all three procedures:

a) Test method and procedure applied (in case of procedure A: if water or solvent was used);

b) test temperature, in degrees Celsius (°C);

c) maximum density of the bituminous mixture, in kilogram per cubic metre to the nearest 1 kg/m^3.

For the mathematical procedure the test report shall include the following additional information:

d) Material composition, in % (m/m) to the nearest 0,1 % (m/m);

e) apparent densities of the aggregate and the binder, in kilogram per cubic metre to the nearest 1 kg/m^3.

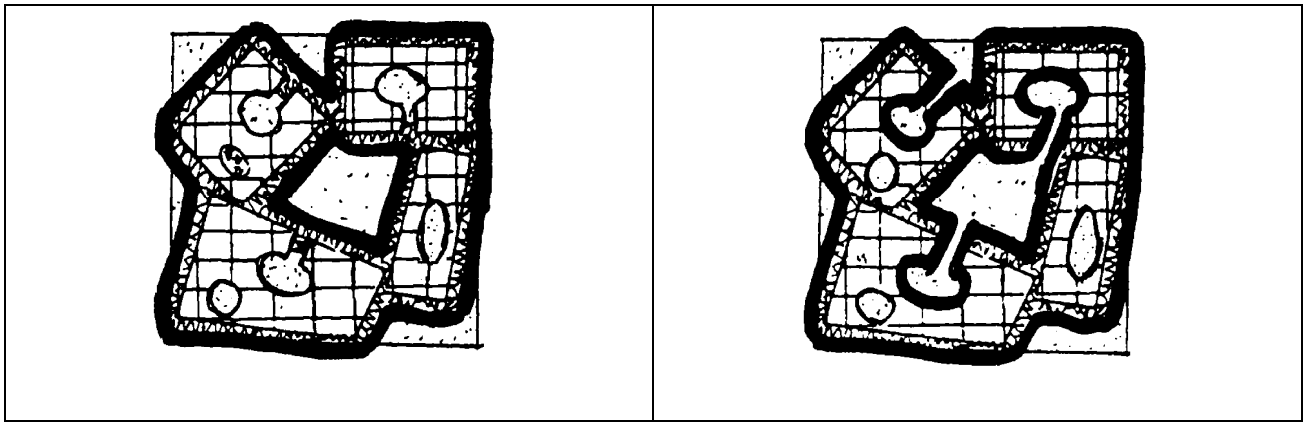
Annex A
(informative)

General guidance on selection of a test procedure to determine the maximum density of bituminous mixtures

A.1 General

This European Standard describes three procedures for determining the maximum density of a bituminous mixture (voidless mass): a volumetric procedure, a hydrostatic procedure and a mathematical procedure. The suitability of these procedures for a specific bituminous mixture is mixture-dependent.

When no specific procedure is required by the relevant product standard or when no product details are known, selecting a procedure can be simplified by the following the guidance given in this annex.



a) Water b) Solvent

Key

measured volume aggregate

Figure A.1 — Aggregate voids in a bituminous mixture

A.2 Using water and solvent

In the volumetric and hydrostatic procedures de-aired water at ambient temperature should be used. One advantage of using water is that no hazardous mixtures are used. A second advantage is that the density of water is less temperature susceptible than that of organic solvent, which means that the temperature control during the test execution requires less effort. A third advantage is that the accessible air voids in the aggregate beneath the binder film occurring when porous aggregates are used are determined as part of the volume of the aggregate, see Figure A.1.

NOTE 1 Figure A.1a): When using water the bitumen film on the particle surface remains intact, the accessible voids in the aggregate remain closed for the water.

The accessible voids are incorporated in the volume of the aggregate. Technologically this is preferable as from that point of view only the voids between particles are relevant.

NOTE 2 Figure A.1b): When using solvent the bitumen film on the particle surface is removed, the solvent will penetrate the accessible voids in the aggregate. These voids are now determined as being part of the voids between the particles, which results in unrealistic values for e.g. voids in the mixture, voids filled with binder etc.

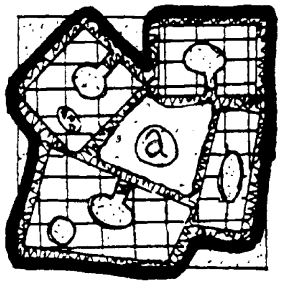


Figure A.2 — Voids between particles (a) to be accessed

One disadvantage of using water is that not all voids between coated particles can be accessed by the water and that voids that can occur beneath the binder film due to bad coating are also be included as part of the volume of the aggregate, see Figure A.2.

In particular, this can occur with mixtures which readily cohere in loose form. In that case the evacuation of entrapped air can be facilitated by either applying a partial vacuum, by using boiling (hot) water or by using an organic solvent. Additionally evacuation can be facilitated by stirring, vibrating and/or rotating. A small amount of dispersion agent can be applied.

It should be noted that when using an organic solvent the volume of voids consisting of accessible pores in the aggregate is included in the volume of voids between the particles. Another disadvantage of using such a solvent is that the test result might be less accurate because of the relatively large temperature susceptibility of such a mixture. Furthermore, hazardous mixtures are being introduced.

A.3 Using the mathematical procedure

The mathematical procedure is particularly suitable when the mix composition (percentage aggregate and percentage binder) and the densities of aggregates and binder are known. A disadvantage of this method is that the degree of binder absorption is to be assumed and so, can not accurately simulate the actual occurrence.

However, the procedure can also be used to determine the extreme limits of the expected maximum density of mixture by physical methods by applying respectively apparent particle density and dry particle density of the aggregates in the calculation.

NOTE 1 The accessibility of the voids between the coated particles depends predominantly on the percentage of fine aggregates in combination with the percentage of binder in the mixture and its stiffness. The absorption characteristics of the aggregate can be established using the procedure set out at annex B of this European Standard.

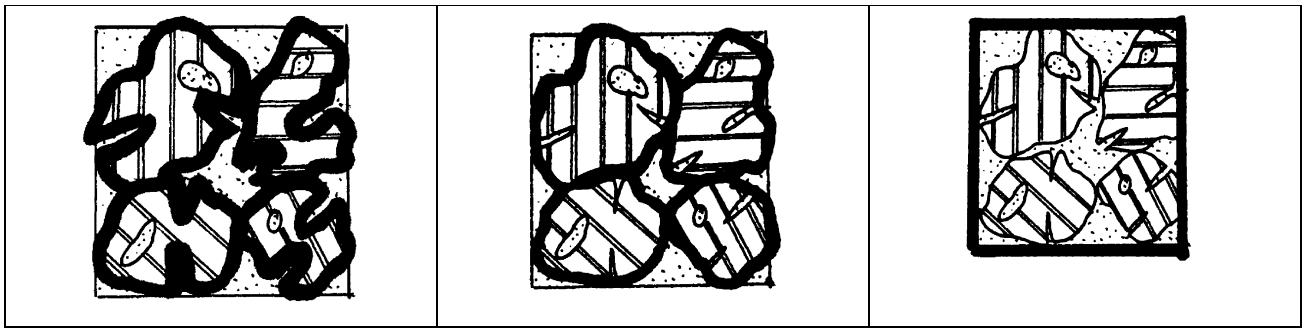
NOTE 2 As the suitability of a test procedure is product-specific, the procedure to be used will normally be indicated in the product standard.

Annex B
(informative)

Determination of the binder absorption characteristics of the mineral aggregates for bituminous mixtures

The maximum density of a bituminous mixture is affected by the existence of porous (permeable) voids in the mineral aggregate which are accessible for the binder. When applying such aggregates in a bituminous mix the binder might be absorbed into these voids. This will subsequently lead to a higher voids content of the specimen.

This annex describes how to determine whether an aggregate is absorptive or non-absorptive and how to deal with absorptive aggregate when determining the maximum density of bituminous mixtures.



a) Apparent density b) Particle dry density c) Loose bulk density

Key

---- Volume boarders

Figure B.1 — Aggregate densities (EN 1097-6)

If the aggregate is suspected to be absorptive the level of porosity can be determined from the apparent density and the particle dry density of the aggregate.

$$\text{Porosity} = \frac{\text{Apparent density} - \text{Particle dry density}}{\text{Particle dry density}} \times 100\ \%\ (v/v)$$

The apparent density of the aggregate can be determined from the masses of a known volume of aggregate under and above water. The mass under water should be established after applying a vacuum (according to the procedure described in **9.2**).

The particle dry density can be determined as follows:

— Take a portion of oven-dried aggregate and determine its mass in 0,1 g (m_1).

— Cover the aggregate with an impermeable film. As impermeable film bitumen can be used if during application its viscosity is sufficiently high to not penetrating the voids and sufficiently low to prevent inclusion of voids between particle and film. Alternatively paraffin can be used. Ensure that no aggregate particles get lost during coverage. The amount of covering material should be limited to prevent enclosure of voids between particles. An amount of approximately 1 % (m/m) bitumen mixed at approximately 120 °C with aggregate at ambient temperature size 8/11 has shown to be effective.

— ⟨A1⟩ Determine the mass of the covered aggregate (m_2) in grams (g) with an accuracy of 0,1 g by weighing.

— Determine the mass of the covered aggregate under water at ambient temperature (m_3) in grams (g) with an accuracy of 0,1 g by weighing.

— Determine the volume of the covered aggregate (V_1) in cubic metres (m³) with an accuracy of 0,1 x 10^{-6} m³ as:

$$V_1 = \frac{m_2 - m_3}{997{,}1} \times 10^{-3}$$

where 997,1 is the density of water at ambient temperature (kg/m³) (between 20 ºC and 30 ºC).

— Determine the volume of the covering bitumen (V_2) in cubic metres (m³) with an accuracy of 0,1 x 10^{-6} m³ as:

$$V_2 = \frac{m_2 - m_3}{1\,030} \times 10^{-3}$$

where 1 030 is the density of the binder (kg/m³).

— Determine the particle dry density (ρ_{pdd}) in kilograms per cubic meter (kg/m³) as:

$$\rho_{pdd} = \frac{1\,000 \times m_1}{V_1 - V_2}$$ ⟨A1⟩

The aggregate is considered to be non-porous (and thus non-absorptive) when the porosity is less than 0,5 % (*v*/*v*). The maximum density of the bituminous mixture then can be determined – depending on the mix type – by procedures A, B or C of this European Standard.

The aggregate is considered to be non-absorptive when the porosity is between 0,5 % (*v*/*v*) and 1,5 % (*v*/*v*). In this case the maximum density of the bituminous mixture can also be determined – depending on the mix type – by procedures A, B or C of this European Standard. For procedures A and B however organic solvent should not be used as test liquid.

NOTE Practical experience shows that the actual volume of the binder absorption is approximately 1/3 of the volume of the accessible pores. This means that at a porosity level of 1,5 % (*v*/*v*) the maximum binder absorption is approximately 0,5 % (*v*/*v*) or 0,2 % (m/m).

The aggregate is considered to be absorptive when the porosity exceeds 1,5 % (*v*/*v*). In this case the mathematical procedure to determine the maximum density of a bituminous mixture (procedure C) can only be used when the particle dry density of the aggregate is determined using e.g. bitumen as fluid. For procedures A and B organic solvent should not be used.

When determining volumetric characteristics of the mixture (as e.g. voids content, voids filled with binder) the volume of the absorbed binder should be subtracted from the applied binder volume.

NOTE The volume of bitumen absorption can be estimated from the difference of the volumes (V_1 - V_2) determined at conditions mentioned above and determined e.g. at actual plant mixing conditions (temperatures aggregate, binder).

Annex C
(normative)

Procedure for the calibration of a pyknometer

Weigh the pyknometer together with the head piece and spring holder to the nearest 0,1 g (mass m_1).

Fill the pyknometer with de-aired water which is approximately at calibration temperature.

Remove entrapped air in the water by applying a vacuum of a residual pressure less than 4 kPa during (15 ± 1) min.

Release the bubbles by stirring and rapping with a rubber mallet.

[A1] Fill the pyknometer completely to the reference mark with de-aired water and adjust the whole to the calibration temperature (expressed in 0,1 °C) ± 0,5 °C in a water-bath. Take care that, after adjustment, the pyknometer is filled completely to the reference mark. [A1]

Place the head piece into position and fix it with the spring holder. Take the pyknometer out of the water-bath, wipe the outside dry and weigh it immediately to the nearest 0,1 g (mass m_2).

[A1] Calculate the volume of the pyknometer to the nearest $0{,}5 \times 10^{-6}$ m³ as follows:

$$V_{Pt} = \frac{m_2 - m_1}{\rho_w} \times 10^{-3} \qquad \text{(C.1)}$$ [A1]

V_{Pt} is the volume of the pyknometer at temperature t (expressed in 0,1 °C), in cubic metres (m^3);

m_1 is the mass of the pyknometer plus head piece and spring, in grams (g);

m_2 is the mass of the pyknometer plus head piece, spring and water, in grams (g);

[A1] ρ_w is the density of water at calibration temperature in kilograms per cubic metre (kg/m³) with an accuracy of 0,1 kg/m³. [A1]

The calibration volume of the pyknometer shall be determined as the arithmetic mean of three measurements; the range of the three individual values shall be less than 0,1 % of the average volume.

NOTE 1 By repeating this procedure for a range of temperatures, a calibration curve can be developed.

NOTE 2 This procedure will be replaced by a European Standard.

Bibliography

[1] DIN 1996-7, *Testing of asphalt – Determination of bulk density, compacted density, void content and degree of compaction.*