BS EN 12697-7:2014

BSI Standards Publication

Bituminous mixtures — Test methods for hot mix asphalt

Part 7: Determination of bulk density of bituminous specimens by gamma rays

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National foreword

This British Standard is the UK implementation of EN 12697-7:2014. It supersedes BS EN 12697-7:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/510/1, Asphalt products.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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

Mélanges bitumineux - Méthodes d'essai pour mélange hydrocarboné à chaud - Partie 7: Détermination de la masse volumique apparente des éprouvettes bitumineuses par les rayons gamma

Asphalt - Prüfverfahren für Heißasphalt - Teil 7: Bestimmung der Raumdichte von Asphalt-Probekörpern mit Gamma-Strahlen

This European Standard was approved by CEN on 4 April 2014.

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Foreword

This document (EN 12697-7:2014) has been prepared by Technical Committee CEN/TC 227 “Road materials”, 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of an identical text or by endorsement, at the latest by November 2014, and conflicting national standards shall be withdrawn at the latest by November 2014.

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

This document supersedes EN 12697-7:2002.

The following is a list of significant technical changes since the previous edition:

— changed the consistency of the calibration coefficient *k* from “0,001” by “0,005”;

— corrected Formulae (4) and (5).

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: Bitumen recovery: Rotary Evaporator*

EN 12697-4, *Bituminous mixtures — Test methods for hot mix asphalt — Part 4: Bitumen 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 specimens*

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 12697-10, *Bituminous mixtures — Test methods for hot mix asphalt — Part 10: Compactability*

EN 12697-11, *Bituminous mixtures — Test methods for hot mix asphalt — Part 11: Determination of the affinity between aggregates 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*

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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*

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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 cylindrical specimens (CY)*

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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 a 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 slab 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*

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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*

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EN 12697-47, *Bituminous mixtures — Test methods for hot mix asphalt — Part 47: Determination of the ash content of natural asphalts*

prEN 12697-48, *Bituminous mixtures — Test methods for hot mix asphalt — Part 48: Interlayer Bonding (Torque bond test - TBT, Shear bond test - SBT, Tensile Adhesion Test (TAT)*[1)]

prEN 12697-49, *Bituminous mixtures — Test methods for hot mix asphalt — Part 49: Determination of friction after polishing*[1)]

prCEN/TS 12697-50, *Bituminous mixtures — Test methods for hot mix asphalt — Part 50: Scuffing resistance of surface course*[1)]

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1) In preparation

Introduction

Bulk density measurement in the laboratory using gamma rays is a method which does not affect the properties of the material. It can be included in a series of tests carried out on a given sample. It allows the plotting of a density chart or gradient.

1 Scope

This European Standard specifies a method for measuring the bulk density of pavement mixtures using a transmission-type gamma radiation test bench.

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

The safety regulations applicable to the use of gamma rays should be applied.

This European Standard applies to cylindrical specimens or blocks, prepared in a laboratory or cut from a pavement, the thickness and the mass absorption coefficient which is a function of the chemical composition are known. The thickness of the specimen body traversed by the radiation shall be between 30 mm and 300 mm. The method cannot be applied to materials containing slags, with variable metal content or chemical composition which may affect the absorption of gamma rays.

2 Normative references

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

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

3 Terms and definitions

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

3.1
precision
closeness of agreement between independent test results obtained under stipulated conditions

Note 1 to entry: Precision depends only on the distribution of random errors and does not relate to the true value or the specified value.

Note 2 to entry: The measure of precision is usually expressed in terms of imprecision and computed as a standard deviation of the test results. Less precision is indicated by a larger standard deviation.

Note 3 to entry: “Independent test results” means results obtained in a manner not influenced by any previous result on the same or similar test sample. Quantitative measures of precision depend critically on the stipulated conditions. Repeatability and reproducibility conditions are particular sets of extreme conditions.

3.2
repeatability
precision under repeatability conditions

3.3
repeatability conditions
conditions where independent tests results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time

3.4
reproducibility
precision under reproducibility conditions

3.5
reproducibility conditions
conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment

4 Principle

The method is based upon the absorption of gamma radiation by the material. Under the conditions of the test described in this European Standard and for materials such as bituminous mixtures, the method follows an exponential law of the following formula:

$$C = C_o \exp\left(-k\mu'\rho_{b\gamma}d\right) \quad (1)$$

where

- C is the count rate after going through the mixture (ratio of N to count time) in counts per second;
- N is the number of gamma photons of the incident radiation directly transmitted after having gone through the mixture;
- C_o is the count rate in the air;
- k is the calibration coefficient;
- μ' is the mass absorption coefficient (depending on composition of the mixture);
- $\rho_{b\gamma}$ is the bulk density, in megagrams per cubic metre (Mg/m^3);
- d is the thickness of the mixture traversed by the radiation, in millimetre (mm).

The bulk density of the material is given by the formula:

$$\rho_{b\gamma} = \frac{1}{k\mu'' d} \ln\left(\frac{C_o}{C}\right) \quad (2)$$

where

- $\rho_{b\gamma}$ is the bulk density, in megagrams per cubic metre (Mg/m^3);
- k is the calibration coefficient;
- μ' is the mass absorption coefficient (depending on composition of the mixture);
- d is the thickness of the mixture traversed by the radiation, in millimetres (mm);
- C_o is the count rate in the air;
- C is the count rate after going through the mixture (ratio of N to count time) in counts per second.

The specimen is placed in the path of a gamma ray beam coming from an emitting unit containing a radioactive source and having a collimation corridor. A photomultiplier in the receiving unit transforms the incident photons into pulses with amplitudes proportional to their energy. An electronic system performs the functions allowing the different applications.

5 Apparatus

5.1 Emitter-source unit[2)] and receiving unit, at a fixed distance in relation to each other during the measurement. The axis of the gamma radiation beam and that of the receiver shall coincide.

NOTE Two cases are possible:

— the emitter and receiver are fixed and the specimens move between them;

— the specimens are fixed and the emitter-receiver assembly moves in relation to them.

In both cases, during the measurement the apparatus allows the rotation of cylindrical specimens about themselves or the relative translation of the specimens having at least one flat side.

5.2 Several lead collimators, whose diameter is known to within 1 %.

5.3 Measurement chain including a count unit and a processing chain. The count unit and the processing chain shall be stabilized electronically against the effect of temperature variations.

5.4 Technical note, with nomograms allowing the determination of the measurement time yielding the requested precision.

The calibration coefficient (k) of the apparatus shall be checked periodically using a specimen with a known density according to the instructions given in the equipment user's manual: it shall be between 0,990 and 1,010 and shall remain constant to within 0,005, for a given diameter of the gamma radiation beam.

6 Preparation of specimens

Specimens shall have a known water content or be dry. If necessary, dry them at ambient temperature.

NOTE They are considered to be dry when the relative mass variation is less than 0,1 % per period of 6 h.

Specimens with one or more bituminous mix layers shall be placed on a flat and horizontal surface to avoid any deformation. The height of the part of each specimen on which density can be measured shall be noted on the test sheet.

In the case of specimens made in the laboratory, the top of the specimens shall be marked.

The surfaces analysed shall be rid of any foreign matter that may be clinging to them.

The thickness of material penetrated by the radiation shall be measured to within 0,1 mm[3)].

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2) A radioactive source of Cs 137 with an energy level of 0,662 MeV is suitable for this purpose.

3) The uncertainty on the measurement of density is larger than the uncertainty on the measurement of the thickness of the material.

7 Procedure

7.1 Prior adjustments

Before performing a bulk density measurement or a series of measurements on a specimen, the following adjustments shall be carried out in accordance with instructions given by the manufacturer and in particular:

— alignment of different elements (if required);

— adjustment of the measurement chain.

7.2 Choice of beam diameter

At the outlet of the source support, place, as required, a collimator with a diameter equal or slightly smaller than that of the source.

In front of the detection unit place a 10 mm collimator, or, if the apparatus is such that the collimator can be changed, place:

— a 5 mm collimator to measure the density of layers of thickness less than or equal to 40 mm in the direction perpendicular to the beam;

— a 10 mm collimator for thicknesses greater than 40 mm in the direction perpendicular to the beam with materials whose maximum size is less than or equal to 14 mm;

— a 20 mm collimator for layer thicknesses greater than 40 mm in the direction perpendicular to the beam, with materials whose maximum size is greater than 14 mm.

7.3 Measurement procedure

7.3.1 Measurement mode

Either of the following methods shall be used:

a) continuous measurements: During the measurement, the specimen to be analysed is moved along a direction perpendicular to the radiation;

b) localized or point measurements: There is no movement of the material during the measurement except for the axial rotation of cylindrical specimens explored radially.

7.3.2 Continuous measurements

— Measure the count rate in the absence of the material to be tested C_{01}.

— Calculate the integration time constant and the speed of the specimen in relation to the beam that yields the required accuracy, using the nomograms furnished in the test bench instructions.

— Set the sample on the specimen passer.

— Record the count rate (C) through the material during the movement of the specimen.

— Measure the count rate in the absence of the material to be tested C_{02} under the same conditions as the determination of C_{01}.

— The counts in the absence of the material to be tested shall be determined immediately before (C_{01}) and immediately after (C_{02}) passing the specimen.

— The count consistency test

$$\frac{|C_{01} - C_{02}|}{\sqrt{\frac{C_{01} + C_{02}}{t}}} \leq 1{,}96 \qquad (3)$$

where

C_{01}, C_{02} is the count rate (ratio of N_{01} or N_{02} to count time) in the absence of the material to be tested (in the air or in a reference specimen body, e.g. aluminium) before penetration into the material in counts per second, during the measurement number 1 or 2;

N_{01}, N_{02} is the number of gamma photons of the incident radiation measured in the absence of the material to be tested (in the air or in a reference specimen body, e.g. aluminium) before penetration into the material in counts per second, during the measurement number 1 or 2;

t is the measurement time, in seconds (s).

shall be verified.

7.3.3 Localized or point measurements

— Measure the count rate in the absence of the material to be tested C_{01}. Using the nomograms of the test bench instructions, in which the parameters are the count rate in the absence of material to be tested, the estimated density and the thickness of the specimen, determine the count time in absence of the material and through the material compatible with the required accuracy.

— In the case of a cylindrical specimen, ensure that the measurement is carried out during the rotation of the specimen. The specimen shall make at least one revolution, at constant speed, during the measurement.

— Carry out the measurement of (C) in the specimen making sure the edge of the gamma ray beam is at a distance of more than 3 mm from the sides of the specimen.

— Measure (C_{02}) in the absence of the material to be tested to check for drift.

— The count consistency test $\frac{|C_{01} - C_{02}|}{\sqrt{\frac{C_{01} + C_{02}}{t}}} \leq 1{,}96$ shall be verified.

8 Expression of results

Calculate the overall mass absorption coefficient (μ') by determining the weighted average of the coefficients as a function of the mass proportion of each element in the material including water. If the water content of the material is less than 4 % do not take into account the mass of water for the calculation of μ'. The factor $k\,\mu'\,d$ can also be determined by back calibration, for this purpose, the density of a sample of material of the same chemical composition shall be measured in accordance with EN 12697-6.

The bulk density of the material including water if the specimen is not dry shall be given by the formula

— if C_{01} and C_{02} are count rates in the air:

$$\rho_{b\gamma} = \frac{10}{k\ \mu''\ d} \times \ln\left(\frac{C_{01} + C_{02}}{2\ C}\right) \quad (4)$$

where

$\rho_{b\gamma}$ is the bulk density, in megagrams per cubic metre (Mg/m^3);

C is the calibration coefficient;

μ' is the mass absorption coefficient (depending on composition of the mixture);

d is the thickness of the mixture traversed by the radiation, in millimetre (mm);

C_{01}, C_{02} is the count rate (ratio of N_{01} or N_{02} to count time) in the absence of the material to be tested (in the air or in a reference specimen body, e.g. aluminium) before penetration into the material in counts per second, during the measurement number 1 or 2;

N_{01}, N_{02} is the number of gamma photons of the incident radiation measured in the absence of the material to be tested (in the air or in a reference specimen body, e.g. aluminium) before penetration into the material in counts per second, during the measurement number 1 or 2;

C is the count rate after going through the mixture (ratio of N to count time), in counts per second.

— if C_{01} and C_{02} are count rates in a reference body of thickness d_{ref}, absorption coefficient μ_{ref} and density ρ_{ref}

$$\rho_{b\gamma} = \rho_{ref} \times \frac{\mu'_{ref}\ d_{ref}}{\mu' d} + \frac{10}{k\ \mu' d} \times \ln\left(\frac{C_{01} + C_{02}}{2\ C}\right) \quad (5)$$

where

$\rho_{b\gamma}$ is the bulk density, in megagrams per cubic metre (Mg/m^3);

ρ_{ref} is the density of the reference body, in megagrams per cubic metre (Mg/m^3);

μ'_{ref} is the mass absorption coefficient of the reference body;

d_{ref} is the thickness of the reference body, in millimetres (mm);

μ' is the mass absorption coefficient (depending on composition of material);

d is the thickness of material traversed by the radiation, in millimetre (mm);

k is the calibration coefficient;

μ' is the mass absorption coefficient (depending on composition of the mixture);

C_{01}, C_{02} is the count rate (ratio of N_{01} or N_{02} to count time) in the absence of the material to be tested (in the air or in a reference specimen body, e.g. aluminium) before penetration into the material in counts per second, during the measurement number 1 or 2;

C is the count rate after going through the mixture (ratio of N to count time), in counts per second.

9 Test report

With reference to this European Standard, the test report shall include the following information:

a) nature of the specimen and its identification;

b) main parameters of the determination (beam diameter, type of apparatus and the measurement mode);

c) appearance, any irregularities, the dimensions of the specimen and the dimensions of the measured zone;

d) average bulk density, and if applicable, the density distribution chart.

10 Precision

The precision was determined to ISO 5725 on a 10 mm asphalt concrete core having a bulk density of 2,294 Mg/m^3 by 21 laboratories in France in March 2003 as being:

Repeatability: $r = 0{,}007\ Mg/m^3$

Reproducibility: $R = 0{,}02\ Mg/m^3$

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