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Bituminous mixtures — Test methods

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

bsi.

National foreword

This British Standard is the UK implementation of EN 12697-7:2022. It supersedes BS EN 12697-7:2014, which is withdrawn.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 committee manager.

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Bituminous mixtures - Test methods - Part 7: Determination of the bulk density of bituminous specimens by gamma rays

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

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

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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (EN 12697-7:2022) has been prepared by Technical Committee CEN/TC 227 "Road materials", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2022, and conflicting national standards shall be withdrawn at the latest by August 2022.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 12697-7:2014.

The main changes compared to the previous edition are listed below:

— the title no longer refers to hot mix asphalt;

— [ge] editorial update according to current standard template;

— Clause 1, scope clarified according the CEN/CENELEC Internal Regulations Part 3:2019, 14.5;

— Clause 4, deletion of the exponential law including equation. Added reference to Clause 8;

— (5.1), footnote [1)] amended to NOTE. Existing NOTE amended to normal text;

— Clause 6, NOTE 1: The period for when specimens are considered to be dry amended to 4 h in line with other parts;

— Clause 6, Footnote [2)] amended to NOTE 2. Existing NOTE amended to NOTE 1;

— Clause 6, measurement of the thickness of specimen replaced by "shall be known";

— (7.3.3), formula for consistency test deleted and replaced with reference to Formula (1);

— Clause 8, editorial adjustments, renumbered formulas and addition of references to formulas;

— Clause 9, revision of data to be reported;

— Clause 10, completion of standard edition to read ISO 5725-2;

— [ge] bibliography added.

A list of all parts in the EN 12697 series can be found on the CEN website.

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

This method applies to cylindrical specimens or parallelepipedal 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 is between 30 mm and 300 mm.

The method cannot be applied to materials containing slags, with variable metal content or chemical composition.

NOTE Material containing metal or chemical compositions can affect the absorption of gamma rays.

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 12697-6, *Bituminous mixtures - Test methods - 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.

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

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

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

4 Principle

The method is based upon the absorption of gamma radiation by the material under the conditions of the test described in this document and for materials such as bituminous mixtures. The method follows an exponential law according to Clause 8, Formulae (2) and (3).

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

The safety regulations applicable to the use of gamma rays apply.

5.1 Emitter-source unit 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 A radioactive source of Cs 137 with an energy level of 0,662 MeV is suitable for this purpose.

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 1 Specimens are considered to be dry when the relative mass variation is less than 0,1 % per period of 4 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 known to the nearest 0,1 mm.

NOTE 2 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 for thickness less than or equal to 40 mm in the direction perpendicular to the beam;

— a 10 mm collimator to measure the density of layers 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 to measure the density of layers for 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 is given by Formula (1):

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

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 according to Formula (1) 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 %, the mass of water for the calculation of μ' may be ignored. The factor k 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 (2) if C_{01} and C_{02} are count rates in the air:

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

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_{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}, the bulk density shall be given by Formula (3).

$$\rho_{b\gamma} = \rho_{ref} \frac{\mu'_{ref} d_{ref}}{\mu' d} + \frac{10}{k\mu' d} \times ln\left(\frac{C_{01} + C_{02}}{2C}\right) \quad (3)$$

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);

d is the thickness of material traversed by the radiation, in millimetres (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

The test report shall include at least the following information:

a) nature of the specimen and its identification;

b) reference to this document;

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

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

e) average bulk density, and if applicable, the density distribution chart;

f) any deviations from the procedure;

g) the date of the test.

10 Precision

The precision was determined according to ISO 5725-2 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

Bibliography

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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