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Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods[1]

This standard is issued under the fixed designation D2950/D2950M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes a test procedure for determining the density of bituminous concrete by the attenuation of gamma radiation, where the source and detector(s) remain on the surface (Backscatter Method) or the source or detector is placed at a known depth up to 300 mm [12 in.] while the detector or source remains on the surface (Direct Transmission Method).

1.2 The density, in mass per unit volume of the material under test, is determined by comparing the detected rate of gamma emissions with previously established calibration data.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific warning statements see Section 6 and Note 5.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D1188 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Coated Samples

D1559 Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (Withdrawn 1998)[3]

D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

D2726 Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures

D3665 Practice for Random Sampling of Construction Materials

D6752 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method

D7013 Guide for Nuclear Surface Moisture and Density Gauge Calibration Facility Setup

D7759 Guide for Nuclear Surface Moisture and Density Gauge Calibration

3. Significance and Use

3.1 The test method described is useful as a rapid, nondestructive technique for determining the in-place density of compacted bituminous mixtures.

3.2 With proper calibration and confirmation testing, the test method is suitable for quality control and acceptance testing of compacted bituminous concrete.

3.3 The test method can be used to establish the proper rolling effort and pattern to achieve the required density.

3.4 The non-destructive nature of the test allows repetitive measurements to be made at a single test location between roller passes and to monitor changes in density.

3.5 The density results obtained by this test method are relative. Correlation with other test methods such as D1188 or D2726 are required to convert the results obtained using this method to actual density. It is recommended that at least seven core densities and seven nuclear densities be used to establish a conversion factor. A new factor must be established at any time a change is made in the paving mixture or in the construction process.

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.21 on Specific Gravity and Density of Asphalt Mixtures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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4. Interferences

4.1 The chemical composition of the material being tested may significantly affect the measurement and adjustments may be necessary. Certain elements with atomic numbers greater than 20 may cause erroneously high test values.

4.2 The test method exhibits spatial bias in that the instrument is most sensitive to the density of the material in closest proximity to the nuclear source.

4.2.1 When measuring the density of an overlay, it may be necessary to employ a correction factor if the underlying material varies in thickness, mineral composition or degree of consolidation at different points within the project. (See Annex A1.)

4.2.2 The surface roughness of the material being tested may cause lower than actual density determination.

4.3 Oversize aggregate particles in the source-detector path may cause higher than actual density determination.

4.4 The sample volume being tested is approximately 0.0028 m^3 [0.0989 ft^3] for the Backscatter Method and 0.0056 m^3 [0.198 ft^3] for the Direct Transmission Method. The actual sample volume varies with the apparatus and the density of the material. In general, the higher the density the smaller the volume (Note 1).

NOTE 1—The volume of field compacted material represented by a test can be effectively increased by repeating the test at adjacent locations and averaging the results.

4.5 If samples of the measured material are to be taken for purposes of correlation with other test methods such as D1188 or D2726, the volume measured can be approximated by a 200 mm [8 in.] diameter cylinder located directly under the center line of the radioactive source and detector(s). The height of the cylinder to be excavated will be the depth setting of the source rod when using the Direct Transmission Method or approximately 75 mm [3 in.] when using the Backscatter Method (Note 2).

NOTE 2—If the layer of bituminous concrete to be measured is less than the depth of measurement of the instrument, corrections must be made to the measurements to obtain accurate results due to the influence of the density of the underlying material. (See Annex A1. for the method used.)

5. Apparatus

5.1 *Nuclear Device*—An electronic counting instrument, capable of being seated on the surface of the material under test, and which contains:

5.1.1 *Gamma Source*—A sealed high energy gamma source such as cesium or radium, and

5.1.2 *Gamma Detector*—Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 *Reference Standard*—A block of dense material used for checking instrument operation and to establish conditions for a reproducible reference-count rate.

5.3 *Site Preparation Device*—A metal plate, straightedge, or other suitable leveling tool which may be used to level the test site to the required smoothness using fine sand or similar material.

5.4 *Drive Pin*—A steel rod of slightly larger diameter than the rod in the Direct Transmission Instrument, to prepare a perpendicular hole in the material under test for inserting the rod. A drill may also be used.

6. Hazards

6.1 This equipment utilizes radioactive materials which may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, etc. are a recommended part of the operational guidelines for the use of this instrument.

6.3 A regulatory agency radioactive materials license may be required to possess this equipment.

7. Calibration

7.1 Calibrate the instrument in accordance to Guide D7759 and Guide D7013.

7.2 *Calibration Adjustments*—The calibration response shall be checked by the user prior to performing tests on materials that are distinctly different from the material types used in establishing the calibration. The calibration response shall also be checked on newly acquired or repaired apparatus. Take a sufficient number of measurements and compare them to other accepted methods (such as Test Method D2726 or Test Method D6752) to establish a correlation.

8. Standardization and Reference Check

8.1 Nuclear test devices are subject to long-term aging of the radioactive source, detectors, and electronic systems, which may change the relationship between count rate and material density. To offset this aging, the apparatus may be standardized as the ratio of the measured count rate to a count rate made on a reference standard. The reference count rate should be of the same order of magnitude as the measured count rate over the useful density range of the apparatus.

8.2 Standardization of equipment should be performed at the start of each day's work, and a permanent record of this data retained.

8.2.1 Perform the standardization with the apparatus located at least 10 m [33 ft] away from other sources of radioactivity and clear of large masses or other items which may affect the reference count rate.

NOTE 3—The user is advised that the value given in section 8.2.1 is intended as a minimum distance for nuclear sources typical in surface moisture/density gauges. The user should consider requiring a greater distance if other nuclear sources of greater activity are present.

8.2.2 Turn on the apparatus prior to standardization and allow it to stabilize. Follow the manufacturer's recommendations in order to provide the most stable and consistent results.

8.2.3 Using the reference standard, take at least four repetitive readings at the normal measurement period and determine the mean. If available on the apparatus, one measurement period of four or more times the normal period is acceptable. This constitutes one standardization check.

8.2.4 If the value obtained in 8.2.3 is within the following stated limits, the apparatus is considered to be in satisfactory operating condition and the value may be used to determine the count ratios for the day of use. If the value is outside these limits, allow additional time for the apparatus to stabilize, make sure the area is clear of sources of interference and then conduct another standardization check. If the second standardization check is within the limits, the apparatus may be used, but if it also fails the test, the apparatus shall be adjusted or repaired as recommended by the manufacturer. The limits are as follows:

$$\left| N_s - N_o \right| \leq 2.0 \sqrt{N_o/F} \quad (1)$$

where:

N_s = value of current standardization count,
N_o = average of the past four values of N_s taken previously, and
F = value of any prescale.

NOTE 4—The count per measurement periods shall be the total number of gammas detected during the timed period. The displayed value must be corrected for any prescaling which is built into the instrument. The prescale value (F) is a divisor which reduces the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.

8.3 Use the value of N_s to determine the count ratios for the current day's use of the instrument. If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

9. Procedure

9.1 In order to provide more stable and consistent results: (*1*) Turn the instrument on prior to use to allow it to stabilize, and (*2*) Leave the power on druing the day's testing.

9.2 Standardize the apparatus.

9.3 Select a test location in accordance wtih the project specifications, or, if not otherwise specified, in accordance with Practice D3665. If the instrument will be closer than 250 mm [10 in.] to any vertical mass that may influence the result, follow the instrument manufacturer's correction procedure.

9.4 Maximum contact between the base of the instrument and the surface of the material under test is critical. The maximum void shall not exceed 6 mm [¼ in.]. Use native fines or fine sand to fill the voids and level with the guide/scraper plate.

9.5 For the Direct Transmission Method use the guide/scraper plate and drive the steel rod to a depth of at least 25 mm [1 in.] deeper than the desired measurement depth.

NOTE 5—**Caution:** Extreme care must be taken when driving the rod into compacted bituminous concrete as it may cause a disturbance of the material which could cause errors in the measurement. Drilling may be more suitable.

9.6 Place the source in the proper position. For the Direct Transmission Method measurements move the instrument so that the rod is firmly against the side of the hole in the gamma measurement path.

9.7 Take a count for the normal measurement period. If the Backscatter Method using the Air Gap Technique is used take an additional measurement in the air-gap position as recommended by the manufacturer. (See Note 2)

9.8 Determine the ratio of the reading to the standard count or the air-gap count. From this ratio and the calibration and adjustment data, determine the in-place density. (See Note 6 and Note 7)

NOTE 6—Some instruments have built-in provisions to compute the ratio, bulk (or wet) density, and allow an adjustment bias.

NOTE 7—If the depth of the bituminous concrete layer under test is less than the depth of measurement of the instrument, the value obtained in 9.8 must be adjusted. (See Annex A1.)

NOTE 8—Do not leave the gauge on a hot surface for an extended period of time. Prolonged high temperatures may adversely affect the instrument's electronics. The gauge should be allowed to cool between measurements.

10. Calculation of Results

10.1 Using the calibration chart, calibration tables, or equation, and coefficients, or instrument direct readout feature, with appropriate calibration adjustments, determine the in-place density. This is the bulk (or wet) density.

10.1.1 An adjustment bias can be calculated by comparing the results from a number of instrument measurements to the results obtained using Test Method D2726.

10.2 Compare the results obtained to samples compacted by Test Method D1559 or with the results of test methods such as D2041 to determine acceptability (percentage of compaction).

11. Report

11.1 Report the following information:

11.1.1 Make, model, and serial number of the test apparatus,

11.1.2 Date and source of calibration data,

11.1.3 Date of test,

11.1.4 Standard count for the day of the test,

11.1.5 Test site description including project identification number, location and mixture type(s),

11.1.6 Thickness of layer tested and any adjustment bias,

11.1.7 Method of measurement (backscatter or direct transmission), depth, count rate, calculated density of each measurement and any adjustment data, and

11.1.8 Percentage of compaction, if required.

12. Precision and Bias[4]

12.1 *Precision:*

12.1.1 Precision is based on a field experiment in 2008 that used six gauges from five manufacturers. Materials included Superpave 9.5, 12.5, 19.0, and 37.5 HMA used on a construction project sponsored by the New York DOT. Density varied from 127.8 to 149.1 pounds per cubic foot with mean of 138.07 and standard deviation 3.900. Each test with a single gauge was conducted by the same operator, therefore, single-operator precision for this statement is also considered to be single-gauge precision if conducted by the same operator.

12.1.2 *Single Operator Precision*—The single-operator standard deviation has been found to be 25.15 kgm^3 [1.57

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D04-1032.

lb/ft^3].[5] Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 70.48 kgm^3 [4.4 lb/ft^3].[5]

12.1.3 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 1.75 pounds per cubic foot [20.03 kgm^3].[5] Therefore, results of two properly conducted tests from two different laboratories on the same material should not differ by more than 78.49 kgm^3 [4.9 lb/ft^3].[5]

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670, for Preparing Precision Statements for Test Methods for Construction Materials.

12.2 *Bias:*

12.2.1 There is no consensus on the most accurate method to determine the values of density against which this test can be compared. Accordingly, a statement of method bias cannot be made.

NOTE 9—With regards to the Bias statement above, any user may elect to conduct a comparison of these gauges related to the laboratory measured value from core samples. Gauge measurements should be taken directly on the location of the pavement where cores will be cut.

13. Keywords

13.1 bituminous-concrete density; density; in-place density; nuclear test method

ANNEX

A1. DETERMINATION OF DEPTH OF MEASUREMENT

A1.1 The depth of measurement is characteristic of a particular instrument design and may be defined as that depth, measured from the surface, at which a significant change in density will not result in change in the measurement.

A1.1.1 Determine the depth by measuring the apparent density of top layers of uniform density but varying thicknesses placed over a base layer having a highly different density. Vary the thickness of the top layer until a constant density as determined by the instrument is reached (Note A1.2).

NOTE A1.1—For lift thicknesses of 51 mm [2 in.] or less, the backscatter mode is suggested; for lift thicknesses greater than 51 mm [2 in.] the direct transmission mode is suggested. Thin lift gauges can be used for lift thicknesses up to 102 mm [4 in.].

NOTE A1.2—Materials such as magnesium and aluminum in sheet form have proven to be satisfactory for the top layer. Blocks of magnesium and aluminum used as calibration standards are useful as the base material.

A1.1.2 Plot the results on graph paper and determine the depth at which the apparent measured density is equal to the calculated density. This determination should be made for both a lower density material and a higher density material as the top layer. The depth of measurement is the average of the two results.

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