Standard Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)[1]

This standard is issued under the fixed designation D6648; 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 [2]

1.1 This test method covers the determination of the flexural-creep stiffness or compliance and m-value of asphalt binders by means of a bending beam rheometer. It is applicable to material having flexural-creep stiffness values in the range of 20 MPa to 1 GPa (creep compliance values in the range of 50 nPa^{-1} to 1 nPa^{-1}) and can be used with unaged material or with materials aged using aging procedures such as Test Method D2872 or Practice D6521. The test apparatus may be operated within the temperature range from –36°C to 0°C.

1.2 Test results are not valid for test specimens that deflect more than 4 mm or less than 0.08 mm when tested in accordance with this test method.

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

D140 Practice for Sampling Bituminous Materials

D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)

D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

D6373 Specification for Performance Graded Asphalt Binder

E77 Test Method for Inspection and Verification of Thermometers

2.2 *DIN Standard:*[4]

43760

3. Terminology

3.1 *Definitions:*

3.1.1 *asphalt binder, n*—an asphalt-based cement that is produced from petroleum residue either with or without the addition of modifiers.

3.1.2 *physical hardening, n*—a time-dependent, reversible stiffening of asphalt binder that typically occurs when the binder is stored below room temperature.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contact load, n*—the load, P_c, required to maintain positive contact between the test specimen, supports, and the loading shaft; 35 ± 10 mN.

3.2.2 *flexural creep compliance, D(t), n*—the ratio obtained by dividing the maximum bending strain (see Eq X1.5) in a beam by the maximum bending stress (Eq X1.4). The flexural creep stiffness is the inverse of the flexural creep compliance.

3.2.3 *flexural creep stiffness, $S_e(t)$, n*—the creep stiffness obtained by fitting a second order polynomial to the logarithm of the measured stiffness at 8.0, 15.0, 30.0 60.0, 120.0, and 240.0 s and the logarithm of time (see Eq 5, section 14.4).

3.2.4 *measured flexural creep stiffness, $S_m(t)$, n*—the ratio (see Eq 3, section 14.2) obtained by dividing the measured maximum bending stress (see X1.4) by the measured maximum bending strain (see Eq X1.5). Flexural creep stiffness has been used historically in asphalt technology while creep compliance is commonly used in studies of viscoelasticity.

3.2.5 *m-value, n*—the absolute value of the slope of the logarithm of the stiffness curve versus the logarithm of time (see Eq 6, section 14.5).

3.2.6 *test load, n*—the load, P_t, of 240-s duration used to determine the stiffness of the asphalt binder being tested; 980 ± 50 mN.

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.44 on Rheological Tests.

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[2] This standard is based on SHRP Product 1002.

[3] 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.

[4] Deutsches Institut fuer Normung (German Standards Institute), Beuth Verlag GmbH, Burggrafenstrasse 6, 1000 Berlin 30, Germany.

3.2.7 *zero load cell reading*—the load indicated by the data acquisition system when the shaft is free floating in the bath and at the position that occurs when first making contact with a test specimen.

4. Summary of Test Method

4.1 The bending beam rheometer is used to measure the mid-point deflection of a simply supported prismatic beam of asphalt binder subjected to a constant load applied to its mid-point. The device operates only in the loading mode; recovery measurements cannot be obtained with the bending beam rheometer.

4.2 A prismatic test specimen is placed in the controlled temperature fluid bath and loaded with a constant test load for 240.0 s. The test load (980 ± 50 mN) and the mid-point deflection of the test specimen are monitored versus time using a computerized data acquisition system.

4.3 The maximum bending stress at the midpoint of the test specimen is calculated from the dimensions of the test specimen, the distance between the supports, and the load applied to the test specimen for loading times of 8.0, 15.0, 30.0, 60.0, 120.0, and 240.0 s. The maximum bending strain in the test specimen is calculated from the dimensions of the test specimen and the deflection for the same loading times. The stiffness of the test specimen for the specific loading times is calculated by dividing the maximum bending stress by the maximum bending strain.

5. Significance and Use

5.1 The temperatures for this test are based upon the winter temperature experienced by the pavement in the geographical area for which the asphalt binder is intended.

5.2 The flexural creep stiffness or flexural creep compliance, determined from this test, describes the low-temperature stress-strain-time response of asphalt binder at the test temperature within the range of linear viscoelastic response.

5.3 The low-temperature thermal cracking performance of asphalt pavements is related to the creep stiffness and the m-value of the asphalt binder contained in the mix.

5.4 The creep stiffness and the m-value are used as performance-based specification criteria for asphalt binders in accordance with Specification D6373.

6. Interferences

6.1 Measurements for which the mid-point deflections of the test specimen is greater than 4.0 mm are suspect. Strains in excess of this value may exceed the linear response of asphalt binders.

6.2 Measurements for which the mid-point deflections of the test specimen are less than 0.08 mm are suspect. When the mid-point deflection is less than 0.08 mm, the test system resolution may not be sufficient to produce reliable test results.

7. Apparatus

7.1 A bending beam rheometer (BBR) test system consisting of the following: (*1*) a loading frame with test specimen supports, (*2*) a controlled temperature liquid bath which maintains the test specimen at the test temperature and provides a buoyant force to counterbalance the force resulting from the mass of the test specimen, (*3*) a computer-controlled data acquisition system, (*4*) test specimen molds, and (*5*) items for verifying and calibrating the system.

7.2 *Loading Frame*—A frame consisting of a set of sample supports, a blunt-nosed shaft to apply the load to the midpoint of the test specimen, a load cell mounted in line with the loading shaft, a means for zeroing the load applied to the test specimen, a means for applying a constant load to the test specimen and a deflection measuring transducer attached to the loading shaft. A schematic of the device is shown in Fig. 1.

7.3 *Loading System*—A loading system that is capable of applying a contact load of 35 ± 10 mN to the test specimen and maintaining a test load of 980 ± 50 mN within ± 10 mN.

7.3.1 *Loading System Requirements*—The rise time for the test load shall be less than 0.5 s. The rise time is the time required for the load to rise from the 35 ± 10 mN contact load to the 980 ± 50 mN test load. During the rise time the system shall dampen the test load to 980 ± 50 mN. Between 0.5 and 5.0 s, the test load shall be within ± 50 mN of the average test

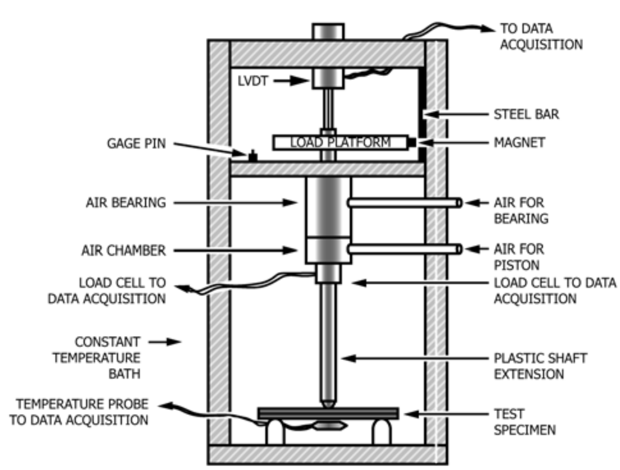

FIG. 1 Schematic of Test Device

load, and thereafter shall be within ± 10 mN of the average test load. Details of the loading pattern are shown in Fig. 2.

7.3.2 *Loading Shaft*—A loading shaft continuous and in line with the load cell and deflection measuring transducer with a spherically shaped end 6.3 ± 0.3 mm in radius.

7.3.3 *Load Cell*—A load cell to measure the contact load and the test load. It shall have a minimum capacity of no less than 2.00 N and a resolution of at least 2.5 mN. It shall be mounted in line with the loading shaft and above the fluid level in the controlled temperature bath.

7.3.4 *Linear Variable Differential Transducer (LVDT)*—A linear variable differential transducer or other suitable device to measure the deflection of the test specimen. It shall have a linear range of at least 6 mm, and be capable of resolving linear movement of 2.5 µm. It shall be mounted axially with and above the loading shaft.

7.3.5 *Sample Supports*—Two stainless steel or other non-corrosive metal supports with a 3.0 ± 0.3 mm contact radius and spaced 102 ± 1.0 mm apart. The spacing of the supports shall be measured to ± 0.3 mm and the measured value shall be used in the calculations in Section 14. The supports shall be dimensioned to ensure that the test specimen remains in contact with the radiused portion of the support during the entire test. See Fig. 3.

7.3.5.1 The width of the test specimen support that contacts the test specimen shall be 9.50 ± 0.25 mm. See Fig. 3.

7.3.5.2 A vertical alignment pin 2 to 4 mm in diameter shall be provided at the back of each support to align the test specimen on the supports. The front face of the pins shall be 6.75 ± 0.25 mm from the middle of the support. See Fig. 3.

7.4 *BBR Thermometric Device*—A calibrated thermometric device integral to the BBR and capable of measuring the temperature to 0.1°C over the range from –36°C to 0°C with its thermal sensor (probe) mounted within 50 mm of the geometric center of the test specimen.

NOTE 1—The required temperature measurement can be accomplished with an appropriately calibrated thermometric device (platinum resistance or thermistor based). Calibration of the thermometric device can be verified as per section 11.5. A platinum resistance thermometric device meeting DIN Standard 43760 (Class A) is recommended for this purpose.

7.5 *Controlled-Temperature Fluid Bath*—A controlled-temperature liquid bath capable of maintaining the temperature at all points in the bath to within ± 0.1°C of the test temperature in the range of –36°C to 0°C. Placing a test specimen in the bath may cause the bath temperature to fluctuate ± 0.2°C from the target test temperature. Consequently bath fluctuations of ± 0.2°C during iso-thermal conditioning shall be allowed.

7.5.1 *Bath Agitator*—A bath agitator for maintaining the required temperature homogeneity with agitation intensity such that the fluid currents do not disturb the testing process and mechanical noise caused by vibrations is less than the resolution specified in 7.3.3 and 7.3.4.

7.5.2 *Circulating Bath (Optional)*—A circulating bath separate from the test frame, which pumps the bath fluid through the test bath. If used, vibrations from the circulating system shall be isolated from the bath test chamber so that mechanical noise is less than the resolution specified in 7.3.3 and 7.3.4.

7.6 *Data Acquisition and Control Components*—A data acquisition system that resolves loads to the nearest 2.5 mN, test specimen deflection to the nearest 2.5 µm, and bath fluid temperature to the nearest 0.1°C. The data acquisition system shall sense the point in time when the signal to switch from the contact load to the test load is activated. This time shall be used as the zero loading time for the test load and deflection signals. Using this time as the reference for zero time, the data acquisition system shall provide a record of subsequent load and deflection measurements at 8.0, 15.0, 30.0, 60.0, 120.0, and 240.0 s.

7.6.1 *Filtering of Acquired Load and Deflection Signals*—The load and deflection signals shall be filtered with a low pass analog or digital (or both) filter that removes components with frequencies greater than 4 Hz from the load and deflection signals. Filtering may be accomplished by averaging five or more digital signals equally spaced in time about the time at which the signal is reported. The averaging shall be over a time

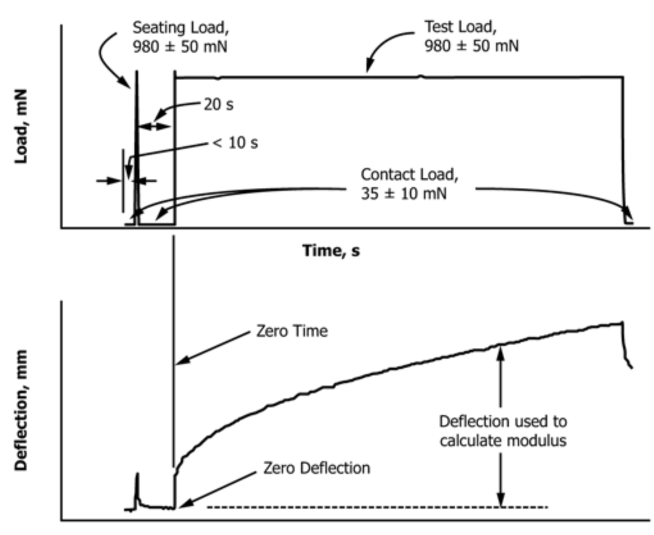

FIG. 2 Definition of Loading Pattern