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# **Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)**

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**AASHTO Designation: T 313-22<sup>1</sup>**

Technically Revised: 2022

Technical Subcommittee: 2b, Liquid Asphalt



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## Standard Method of Test for

# Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

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## 1. SCOPE

- 1.1. This test method covers the determination of the flexural creep stiffness or compliance of asphalt binders by means of a bending beam rheometer. It is applicable to material having a flexural stiffness value from 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 material aged using T 240 (RTFOT) or R 28 (PAV), or both. The test apparatus is designed for testing within the temperature range from –36 to 0°C.
- 1.2. Test results are not valid for beams of asphalt binder that deflect more than 4 mm, or less than 0.08 mm, when tested in accordance with this method.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*
- 1.4. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

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## 2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 320, Performance-Graded Asphalt Binder
  - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
  - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
  - R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
  - R 66, Sampling Asphalt Materials

- T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- T 314, Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)

2.2. *ASTM Standards:*

- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- E879, Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
- E1137/E1137M, Standard Specification for Industrial Platinum Resistance Thermometers
- E2877, Standard Guide for Digital Contact Thermometers

2.3. *International Electrotechnical Commission Standards:*

- IEC 60584-1:2013, Thermocouples - Part 1: EMF Specifications and Tolerances
- IEC 60751:2008, Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors

2.4. *NCHRP Document:*

- NCHRP Web-Only Document 71 (Project 09-26), Precision Estimates for AASHTO Test Method T 308 and the Test Methods for Performance-Graded Asphalt Binder in AASHTO Specification M 320

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### 3. TERMINOLOGY

3.1. *Definitions:*

- 3.1.1. *asphalt binder*—an asphalt-based cement that is produced from petroleum residue either with or without the addition of nonparticulate organic modifiers.
- 3.1.2. *physical hardening*—a time-dependent stiffening of asphalt binder that results from the time-delayed increase in stiffness when the asphalt binder is stored at low temperatures. The increase in stiffness due to physical hardening is reversible when the temperature is raised.

3.2. *Descriptions of Terms Specific to This Standard:*

- 3.2.1. *flexural creep*—a test in which a simply supported asphalt binder prismatic beam is loaded with a constant load at its midpoint and the deflection of the beam is measured with respect to loading time.
- 3.2.2. *measured flexural creep stiffness,  $S_m(t)$* —ratio obtained by dividing the maximum bending stress in the beam by the maximum bending strain.
- 3.2.3. *estimated creep stiffness,  $S(t)$* —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.
- 3.2.4. *flexural creep compliance,  $D(t)$* —ratio obtained by dividing the maximum bending strain in the beam by maximum bending stress.  $D(t)$  is the inverse of  $S(t)$ .  $S(t)$  has been used historically in asphalt technology, while  $D(t)$  is commonly used in studies of viscoelasticity.

- 3.2.5. *m-value*—absolute value of the slope of the logarithm of the stiffness curves versus the logarithm of the time.
- 3.2.6. *contact load*—load required to maintain positive contact between the beam and the loading shaft;  $35 \pm 10$  mN.
- 3.2.7. *seating load*—load of 1-s duration required to seat the beam;  $980 \pm 50$  mN.
- 3.2.8. *test load*—load of 240-s duration required to determine the stiffness of material being tested;  $980 \pm 50$  mN.
- 3.2.9. *testing zero time, s*—time at which the signal is sent to the solenoid valve to switch from zero load regulator (contact load) to the testing load regulator (test load).

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## 4. SUMMARY OF TEST METHOD

- 4.1. The bending beam rheometer measures the midpoint deflection of a simply supported beam of asphalt binder subjected to a constant load applied to the midpoint of the beam. The device operates only in the loading mode; recovery measurements are not obtained.
- 4.2. A test beam is placed in the controlled temperature fluid bath and loaded with a constant load for 240 s. The test load ( $980 \pm 50$  mN) and the midpoint of deflection of the beam are monitored versus time using a computerized data acquisition system.
- 4.3. The maximum bending stress at the midpoint of the beam is calculated from the dimensions of the beam, the span length, and the load applied to the beam for loading times of 8, 15, 30, 60, 120, and 240 s. The maximum bending strain in the beam is calculated for the same loading times from the dimensions of the beam and the deflection of the beam. The stiffness of the beam for the loading times specified above is calculated by dividing the maximum stress by the maximum strain.
- 4.4. The load and deflection at 0.0 and 0.5 s are reported to verify that the full-testing load ( $980 \pm 50$  mN) during the test is applied within the first 0.5 s. They are not used in the calculation of stiffness and *m-value* and should not be considered to represent material properties. The rise time of the load (time to apply full load) can be affected by improper operation of the pressure regulators, improper air bearing pressure, malfunctioning air bearing (friction), and other factors. By reporting the 0.0- and 0.5-s signals, the user of the test results can determine the conditions of the loading.

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## 5. SIGNIFICANCE AND USE

- 5.1. The test temperature for this test is related to the 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 linear viscoelastic response range.
- 5.3. The low-temperature thermal cracking performance of paving mixtures is related to the creep stiffness and the slope of the logarithm of the creep stiffness versus the logarithm of the time curve of the asphalt binder contained in the mix.

- 5.4. The creep stiffness and the slope of the logarithm of the stiffness versus the logarithm of the time curve are used as performance-based specification criteria for asphalt binders in accordance with M 320.

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## 6. APPARATUS

- 6.1. *Bending Beam Rheometer (BBR) Test System*—A bending beam rheometer (BBR) test system consisting of (1) a loading frame that permits the test beam, supports, and the lower part of the test frame to be submerged in a constant temperature fluid bath; (2) a controlled-temperature liquid bath that maintains the test beam at the test temperature and provides a buoyant force to counterbalance the force resulting from the mass of the beam; (3) a computer-controlled automated data acquisition component; (4) specimen molds; and (5) items needed to calibrate and/or verify the BBR.
- 6.1.1. *Loading Frame*—A frame consisting of a set of sample supports, a blunt-nosed shaft that applies the load to the midpoint of the test specimen, a load cell mounted on the loading shaft, a means for zeroing the load on the test specimen, a means for applying a constant load to the loading shaft, and a deflection measuring transducer attached to the loading shaft. A schematic of the device is shown in Figure 1.

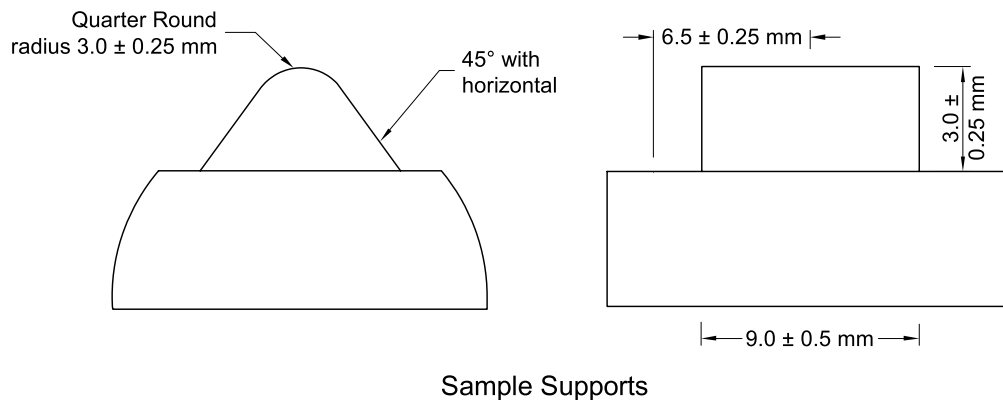
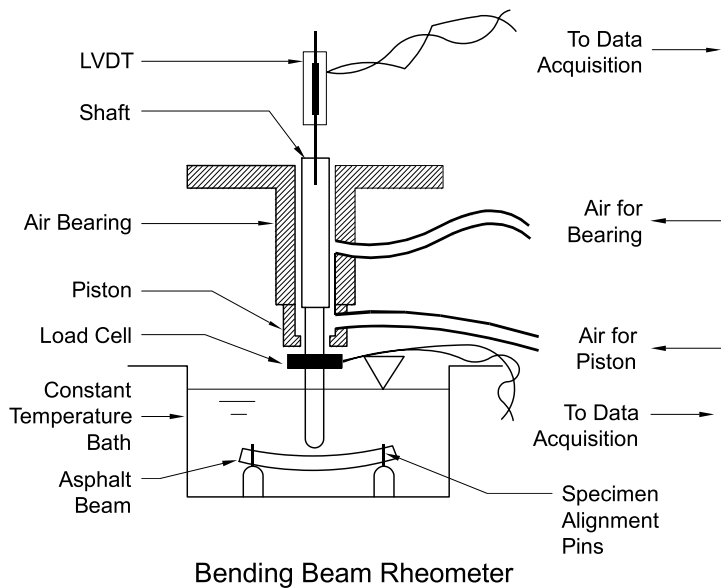


**Figure 1**—Schematic of the Bending Beam Rheometer

- 6.1.1.1. *Loading System*—A loading system that is capable of applying a contact load of  $35 \pm 10$  mN to the test specimen and maintaining a test load of  $980 \pm 50$  mN.
- 6.1.1.2. *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  $35 \pm 10$  mN contact load to the  $980 \pm 50$  mN test load. During the rise time, the system shall dampen the test load to  $980 \pm 50$  mN. Between 0.5 and 5.0 s, the test load shall be within  $\pm 50$  mN of the average test load, and thereafter shall be within  $\pm 10$  mN of the average test load.
- 6.1.1.3. *Sample Supports*—Sample supports with specimen support strips  $3.0 \pm 0.30$  mm in top radius and inclined at an angle of 45 degrees with the horizontal (see Figure 1). The supports, made of stainless steel (or other corrosion-resistant metal), are spaced  $102.0 \pm 1.0$  mm apart. The width of the supporting area of the supporting strips shall be  $9.5 \pm 0.25$  mm. This is required to ensure that the edges of the specimen, resulting from the molding procedure, do not interfere with the mid-span deflection of the specimen measured during testing. The supports shall also include

vertical alignment pins 2 to 4 mm in diameter placed at the back of each sample supports at  $6.75 \pm 0.25$  mm from the center of the supports. These pins should be placed on the back side of the support to align the specimen on the center of the supports. See Figure 1 for details.

- 6.1.1.4. *Loading Shaft*—A blunt-nosed loading shaft (with a spherical contact point  $6.25 (\pm 0.30)$  mm in radius) continuous with a load cell and a deflection measuring transducer that is capable of applying a contact load of  $35 \pm 10$  mN and maintaining a test load of  $980 \pm 50$  mN. The rise time for the test load shall be less than 0.5 s where the rise time is the time required for the load to rise from the  $35 \pm 10$  mN preload to the  $980 \pm 50$  mN test load. During the rise time, the system shall dampen the test load after the first 5 s to a constant  $\pm 10$ -mN value.
- 6.1.1.5. *Load Cell*—A load cell with a minimum capacity of 2000 mN, having a minimum resolution of 2.5 mN mounted in-line with the loading shaft and above the fluid to measure the contact load and the test load.
- 6.1.1.6. *Linear Variable Differential Transducer (LVDT)*—A linear variable differential transducer or other suitable mounted device mounted axially above the loading shaft capable of resolving a linear movement  $\leq 2.5$   $\mu$ m with a range of at least 6 mm to measure the deflection of the test beam.
- 6.1.2. *Controlled-Temperature Fluid Bath*—A controlled-temperature liquid bath capable of maintaining the temperature at all points within the bath between  $-36$  and  $0^\circ\text{C}$  within  $\pm 0.1^\circ\text{C}$ . Placing a cold specimen in the bath may cause the bath temperature to fluctuate  $\pm 0.2^\circ\text{C}$  from the target test temperature; consequently, bath fluctuations of  $\pm 0.2^\circ\text{C}$  during isothermal conditioning shall be allowed.
  - 6.1.2.1. *Bath Agitator*—A bath agitator for maintaining the required temperature homogeneity with agitator intensity such that the fluid current does not disturb the testing process, and mechanical noise caused by vibrations is less than the resolution specified in Sections 6.1.3 and 6.1.3.1.
  - 6.1.2.2. *Circulating Bath (Optional)*—A circulating bath unit separate from the test frame that 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 Sections 6.1.3 and 6.1.3.1.
- 6.1.3. *Data Acquisition System*—A data acquisition system that resolves loads to the nearest 2.5 mN, beam deflection to the nearest 2.5  $\mu$ m, and bath fluid temperature to the nearest  $0.1^\circ\text{C}$ . The system shall sense the point in time when the signal is sent to the solenoid valve(s) to switch from zero load regulator (contact load) to the testing load regulator (test load). This is zero time. Using this time as a reference, the system shall provide a record of load and deflection measurements relative to this time. The system shall record the load and deflection at the loading times of 0.0, 0.5, 8.0, 15.0, 30.0, 60.0, 120.0, and 240.0 s. All readings shall be an average of three or more points within  $\pm 0.2$  s from the loading time, e.g., for a loading time of 7.8, 7.9, 8.0, 8.1, and 8.2 s.
  - 6.1.3.1. *Signal Filtering*—Digital or analog smoothing of the load and the deflection data may be required to eliminate electronic noise that could otherwise affect the ability of the second-order polynomial to fit the data with sufficient accuracy to provide a reliable estimate of  $m$ -value. The load and deflection signals may be filtered with a low-pass analog or digital filter that removes signals of greater than 4-Hz frequency. The averaging shall be over a time period less than or equal to  $\pm 0.2$  s of the reporting time.
- 6.2. *Temperature Measuring Equipment*—A calibrated temperature transducer capable of measuring the temperature to  $0.1^\circ\text{C}$  over the range of  $-36$  to  $0^\circ\text{C}$  mounted within 50 mm of the midpoint of the test specimen supports. The thermometer for measuring the temperature shall meet the