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

AASHTO Designation: T 419-24¹

Adopted without Revisions: 2024

**Technical Subcommittee: 2d, Proportioning
of Asphalt–Aggregate Mixtures**



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1. SCOPE

- 1.1. This test method covers the determination of the flexural creep stiffness or compliance of asphalt mixtures by means of a bending beam rheometer. It is applicable to material having a flexural stiffness value from 2 GPa to 20 GPa (creep compliance values in the range of 0.5 nPa⁻¹ to 0.05 nPa⁻¹). The test apparatus is designed for testing within the temperature range from –36 to 0°C.
- 1.2. Test results are valid for beams of asphalt mixtures that deflect at least 15 µm and less than 150 µm (550 microstrains) during the entire duration of the test, when tested in accordance with this method.
- 1.3. This method has been verified with asphalt mixtures having a nominal maximum aggregate size of 12.5 mm.
- 1.4. *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.*
- 1.5. *The quality of the results produced by this standard is 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.*

2. REFERENCED DOCUMENTS

- 2.1. AASHTO Documents:
 - Mechanistic-Empirical Pavement Design Guide, 3rd ed. with 2021 Supplement. MEPDG-3-M. Available from <https://store.transportation.org/search?q=mepdg&categoryCode=&index=storeitem&type=storeitem&pageNum=1&pageSize=10&sortBy=Relevance&itemType=All>
 - 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
- T 313, Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

2.2. *ASTM Standards:*

- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E879, Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
- E1137/E1137M, Standard Specification for Industrial Platinum Resistance Thermometers

2.3. *International Electrotechnical Commission Standard:*

- IEC 60751: 2008 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors

3. TERMINOLOGY

3.1. *Definition:*

- 3.1.1. *asphalt mixture*—an asphalt-based composite material that consists of asphalt binder, coarse and fine aggregates, filler, and air voids.

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

- 3.2.1. *contact load*—load required to maintain positive contact between the beam and the loading shaft, and equal to 35 ± 10 mN.
- 3.2.2. *estimated flexural creep stiffness, $S(t)$* —the creep stiffness obtained by fitting a second-order polynomial to the logarithm of the measured stiffness, from 8.0 to 1000 seconds, as a function of the logarithm of time.
- 3.2.3. *flexural creep*—a test in which a simply supported asphalt mixture prismatic beam is loaded with a constant load at its midpoint and the deflection of the beam is measured with respect to loading time.
- 3.2.4. *flexural creep compliance, $D(t)$* —ratio obtained by dividing the time-dependent maximum bending strain in the beam by the time-independent maximum bending stress.
- 3.2.5. *measured flexural creep stiffness, $S_m(t)$* —ratio obtained by dividing the maximum bending stress in the beam by the maximum bending strain. $S(t)$ is the inverse of $D(t)$. $S(t)$ has been used historically in asphalt technology while $D(t)$ is commonly used in studies of viscoelasticity.
- 3.2.6. *m -value*—absolute value of the slope of the logarithm of the estimated stiffness curves versus the logarithm of the time. Note that m -value estimation for any time during the test is based on the creep test results for the entire duration of the test.
- 3.2.7. *seating load*—load of one-second duration required to seat the beam, and equal to 4000 ± 100 mN.
- 3.2.8. *test load*—load of 1000-seconds duration required to determine the stiffness of the material being tested, and equal to 4000 ± 100 mN.
- 3.2.9. *testing zero time, seconds*—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).

4. SUMMARY OF TEST METHOD

- 4.1. The bending beam rheometer measures the midpoint deflection of a simply supported beam of asphalt mixtures 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 1000-seconds. The test load (4000 ± 100 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. 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 is calculated by dividing the maximum stress by the maximum strain.
- 4.4. The load and deflection at 0.0 and 0.5 second are reported to verify that the full-testing load (4000 ± 100 mN) during the test is applied within the first 0.5 second. 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 the 0.5 second signals, the user of the test results can determine the conditions of the loading.

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. For quality control purposes the single test temperature shall be 10°C above the specified binder grade required for the mixture. For performance prediction at least 3 temperatures shall be used at 6°C intervals. The test temperatures of 4°C, 10°C, and 16°C above the specified binder grade used in the mixtures have been successfully used. Other temperatures can also be used depending on the project requirements.
- 5.2. The flexural creep stiffness or flexural creep compliance, determined from this test, describes the low-temperature, stress-strain-time response of asphalt mixtures 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 mixture.
- 5.4. The creep compliance is used in the low temperature algorithm of the AASHTO *Mechanistic-Empirical Pavement Design Guide* to calculate thermal stresses used in predicting pavement performance.

6. APPARATUS

- 6.1. *Bending Beam Rheometer (BBR) Test System*—A bending beam rheometer (BBR) test system consisting of (1) a loading frame which 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 which maintains the test beam at the test temperature, and (3) a computer-controlled automated data acquisition component, and (4) items needed to standardize the BBR, verify it, or both.

Note 1—The buoyant force in the liquid of the bath provides partial counterbalance of the weight of the mixture beam. The remainder of the weight is approximately equal to 90 mN, which can be neglected for a testing load of 4000 mN.

- 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.

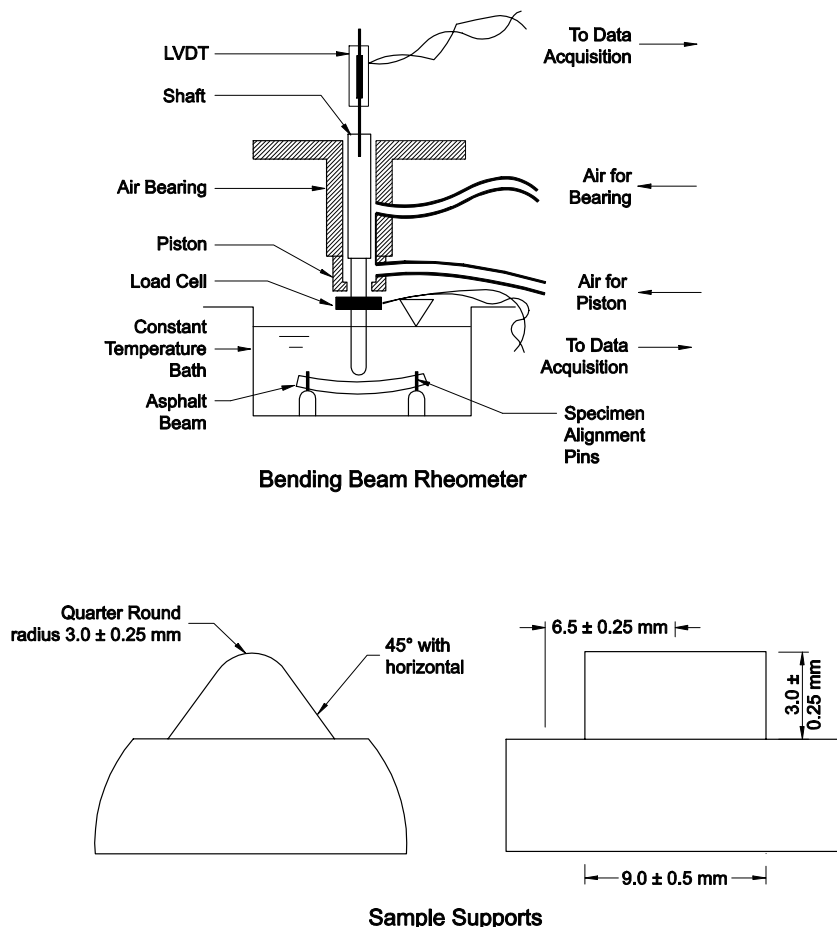


Figure 1—Schematic of the Bending Beam Rheometer (T 313)

- 6.1.1.1. *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 4000 ± 100 mN.
- 6.1.1.2. *Loading System Requirements*—The rise time for the test load shall be less than 0.5 second. The rise time is the time required for the load to rise from the 35 ± 10 mN contact load to the 4000 ± 100 mN test load. During the rise time, the system shall dampen the test load to 4000 ± 100 mN. Between 0.5 and 5.0 second, the test load shall be within ± 100 mN of the average test load, and thereafter shall be within ± 50 mN of the average test load.
- 6.1.1.3. *Sample Supports*—Sample supports with specimen support strips 3.0 ± 0.25 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 ± 1.0 mm apart. The width of the supporting area of the supporting strips shall be 9.5 ± 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 ± 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 which is capable of applying a contact load of 35 ± 10 mN and maintaining a test load of 4000 ± 100 mN. The rise time for the test load shall be less than 0.5 second where the rise time is the time required for the load to rise from the 35 ± 10 mN preload to the 4000 ± 100 mN test load. During the rise time the system shall dampen the test load after the first five seconds to a constant ± 50 mN value.
- 6.1.1.5. *Load Cell*—A load cell with a minimum capacity of 9,806 mN and 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 ≤ 0.15 μ 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°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 0.2°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 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 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 0.15 μ m, and bath fluid temperature to the nearest 0.1°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 every 0.5 second starting at time 0.0 when the instantaneous load is applied. All readings shall be an average of three or more points within ± 0.2 second from the loading time, e.g., for a loading time of 7.8, 7.9, 8.0, 8.1, and 8.2 seconds.
- 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 or equal to ± 0.2 second of the reporting time.

- 6.2. *Cutting*—Masonry saw capable of cutting through 6-in.-diameter cylindrical asphalt concrete samples prepared using the Superpave Gyratory Compactor (SGC) or cored from the road. Quality tile saw capable of cutting asphalt concrete beams 12.7 by 6.35 by 127 mm.
- 6.3. *Temperature Measuring Equipment*—Thermometer for measuring temperature of fluid bath shall meet the requirements of M 339M/M 339 with a temperature range of at least -38 to 2°C , and an accuracy of $\pm 0.03^{\circ}\text{C}$ mounted within 50 mm of the midpoint of the test specimen supports.
Note 2—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer, special order; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Special order; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Special order.
- 6.4. *Items for Calibration or Verification*—The following items are required to verify and standardize the BBR.
- 6.4.1. *Stainless Steel (Thick) Beam for Compliance Measurement and Load Cell Calibration*—One stainless steel beam, 6.4 ± 0.1 mm thick by 12.7 and 0.25 mm wide by 127 ± 5 mm long, for measuring system compliance and calibrating the load cell.
- 6.4.2. *Stainless Steel (Thin) Beam for Overall System Check*—One stainless steel beam, 1.3 ± 0.3 mm thick by 12.7 ± 0.1 mm wide by 127 ± 5 mm long, with an elastic modulus reported to three significant figures by the manufacturer. The manufacturer shall measure and report the thickness of this beam to the nearest 0.01 mm and the width to the nearest 0.05 mm. The dimensions of the beam shall be used to calculate the modulus of the beam during the overall system check. See Section 10.1.2.1.
- 6.5. *Standard Masses*—One or more standard masses are required as follows:
- 6.5.1. *Verification of Load Cell Calibration*—One or more masses totaling 100 ± 0.2 g and two masses of 2 ± 0.2 g each (see Note 3) for verifying the calibration of the load cell.
Note 3—A coin may be used if the mass is confirmed to be 2 ± 0.2 g.
- 6.5.2. *Calibration of Load Cell*—Four masses, each of known mass ± 0.2 g, and equally spaced in mass over the range of the load cell.
- 6.5.3. *Daily Overall System Check*—Two or more masses, each of known mass to 0.2 g, for conducting overall system check as specified by the manufacturer.
- 6.5.4. *Accuracy of Masses*—Accuracy of the masses in Section 6.5 shall be verified at least once every three years.
- 6.6. *Thermometers*—Thermometers for daily verification of the bath temperature shall meet the requirements of M 339M/M 399 with a temperature range of at least -38 to 2°C , and an accuracy of $\pm 0.05^{\circ}\text{C}$.
Note 4—Thermometer types suitable for use include ASTM E1 mercury thermometer No. 133C; ASTM E879 thermistor thermometer, Special order; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Special order; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Special order.
- 6.7. *Thickness Gauge*—A stepped thickness gauge for verifying the calibrations of displacement transducer as described in Figure 2.