

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

AASHTO Designation: TP1-98^{1,2}

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 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 T240 (RTFOT) or PP1 (PAV). The test apparatus is designed for testing within the temperature range from - 36 to 22°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 problems 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.*

2. Reference Documents

2.1 AASHTO Standards

MP1	Specification for Performance-Graded Asphalt Binder
PP1	Accelerated Oxidative Aging of Asphalt Binder Using Pressurized Air and Elevated Temperature (PAV)
T40	Sampling Bituminous Materials
T240	Effect of Heat and Air on Rolling Film of Asphalt (Rolling Thin-Film Oven Test)

2.2 ASTM Standards

- C802 Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials
E77 Standard Test Method for Inspection and Verification of Liquid-in-Glass Thermometers

2.3 Deutsche Industrie Norm (DIN) Standards

- 43760 Platinum Resistance Thermometer.

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 non-particulate 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.

3.2 Descriptions of Terms Specific to this Standard.

3.2.1 flexural creep - a material characteristic determined by a test in which a simply-supported 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 flexural creep stiffness, $S(t)$ - ratio obtained by dividing the maximum bending stress in the beam by the maximum bending strain.

3.2.3 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.

¹ This Provisional Standard is based on SHRP Product 1002.

² Approved in 1993, the standard was first published in January 1994 with last edition published in June 1998. Again, it was balloted and approved for publication in October 1998.

3.2.4 m - absolute value of the slope of the logarithm of the stiffness curves versus the logarithm of the time.

3.2.5 contact load - load required to maintain positive contact between the beam and the loading shaft; 35 ± 10 mN.

3.2.6 seating load - load of 1-s duration required to seat the beam; 980 ± 50 mN.

3.2.7 test load - load of 240-s duration required to determine the stiffness of material being tested; 980 ± 50 mN.

3.2.8 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).

4. Summary of Test Method

4.1 The bending beam rheometer measures the mid-point deflection of a simply supported beam of asphalt binder subjected to a constant load applied to the mid-point 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-seconds. The test load (980 ± 50 mN) and the mid point 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 seconds. 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 at 0.5 second are reported to verify that the full testing load (980 ± 50 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 (stiction), 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.

Note 1 -- stiction can be checked by placing a load of 3 grams or less on the loading shaft while in floatation position and observing that the loading shaft moves when applying the load.

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 MP1.

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 provides a buoyant force to counterbalance the force resulting from the mass of the beam, and (3) a computer controlled automated data acquisition component.

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.

6.1.1.1 Sample Supports - Sample supports with specimen support strips $3.0 (\pm 0.25)$ mm in top radius and inclined at an angle of 45° with the horizontal (see Figure 1). The supports, made of stainless steel (or other corrosion resistant metal), are spaced 102.0 ± 0.5 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 alignment pins placed at the top point of the 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.

6.1.1.2 Loading Shaft - A blunt-nosed loading shaft (with a spherical contact point $6.25 (\pm 0.25)$ 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 980 ± 50 mN within ± 5 mN using differential air pressure or other means such as electro-hydraulic for adjustment. 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 ± 10 mN preload to the 980 ± 50 mN test load. During the rise time the system shall dampen the test load after the first 5 seconds to a constant ± 10 mN value.

6.1.1.3 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.

6.1.1.4 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 ≤ 2.5 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 22°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 iso-thermal 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 6.1.1.3 and 6.1.1.4.

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 6.1.1.3 and 6.1.1.4.

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 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 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 ± 0.2 seconds 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 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 s of the reporting time.

6.2 Temperature Measuring Equipment - A calibrated temperature transducer capable of measuring the temperature to 0.1°C over the range -36 to 22°C mounted within 50 mm of the midpoint of the test specimen supports.

Note 2 - Required temperature measurement can be accomplished with an appropriately calibrated platinum resistance thermometer (RTD) or a thermistor. Calibrations of RTD or thermistor can be verified as per Section 6.6. The platinum resistance thermometer meeting DIN Standard 43760 (Class A) are

recommended for this purpose. The required precision and accuracy cannot be obtained unless each RTD is calibrated as a system with its respective meter or electronic circuitry.

6.3 Test Beam Molds - Test beam molds of suitable dimensions to yield demolded test beam 6.35 ± 0.05 mm thick by 12.70 ± 0.05 mm wide by 127 ± 2.0 mm long fabricated from aluminum flat stock as shown in Figure 2.

6.4 Stainless Steel Beams - One stainless steel beam 6.35 ± 0.10 mm thick by 12.7 ± 0.2 mm wide by 127 ± 2.0 mm long for measuring system compliance and one stainless steel beam 1.0 to 1.6 mm thick by 12.7 ± 0.1 mm wide measured to ± 0.01 mm by 127 mm long measured to ± 1.0 mm with a known elastic modulus (as specified by the manufacturer) for performing periodic checks on the performance of the BBR. The thickness and the width of the latter beam shall be measured and reported for calculation to ± 0.01 mm.

6.5 Standard Masses - One or more standard masses 50.0 to 100.0 g certified to ± 0.2 g for periodic BBR calibration verification.

6.6 Calibrated Thermometers - Calibrated liquid-in-glass thermometers for verification of the temperature transducer of suitable range with subdivisions of 0.1°C . These thermometers shall be calibrated in accordance with ASTM E77.

6.7 Thickness Gauge - A stepped thickness gauge for verifying the calibrations of displacement transducer as described in Figure 3.

7. Materials

7.1 Plastic Sheeting - Clear plastic sheeting 0.08 to 0.15 mm thick, for lining the interior faces of the three long aluminum mold sections. Sheeting should not be distorted by hot asphalt binder. Transparency film sold for use with laser printers has been found suitable.

7.2 Petroleum Based Grease - A petroleum based grease used to hold the plastic strips to the interior faces of the three long aluminum mold sections. (Warning: do not use any silicone based products).

7.3 Glycerol-Talc Mixture - Used to coat the end pieces of aluminum molds. A mixture of 20 percent by weight USP grade glycerin and 80

percent USP grade talc or kaolin (china clay) is suitable for this purpose.

7.4 Bath Fluid - A bath fluid that is not absorbed by or does not affect the properties of the asphalt binder tested. The mass density of the fluid bath shall not exceed 1.05 kg/m^3 at testing temperatures. The bath fluid shall be optically clear at all testing temperatures. Suitable bath fluids include ethanol, methanol, and glycol-methanol mixtures (e.g. 60 percent glycol, 15 percent methanol, 25 percent water).

8. Hazards - Observe standard laboratory safety procedures when handling hot asphalt binder and preparing test specimens.

9. Preparation of Apparatus

9.1 Clean the supports, loading head and bath fluid of any particulates and coatings as necessary.

Note 3 - Because of the brittleness of asphalt binder at the specified test temperatures, small fragments of asphalt binder can be introduced into the bath fluid. If these fragments are present on the supports or the loading head, the measured deflection will be affected. The small fragments, because of their small size, will deform under load and add an apparent deflection of the beam. Filtration of the bath fluid will aid in preserving the required cleanliness.

9.2 Select the test temperature and adjust the bath fluid to the selected temperature. Wait until the temperature stabilizes and then allow the bath to equilibrate to the test temperature $\pm 0.1^{\circ}\text{C}$.

9.3 Activate the data acquisition system and load the software as explained in the manufacturer's manual for the test system.

10. Standardization

10.1 Verify the calibration of the displacement transducer, load cell, and temperature transducer as described in Sections 10.1.1 through 10.1.3 and 10.2. Conduct each of the steps in this section each day before conducting any tests. Also perform an overall check on performance of the BBR as described in Section 10.3.

10.1.1 Verify the calibration of the displacement transducer using a stepped thickness gauge of known dimensions similar to the one shown in Figure 3. Place the gauge on a reference platform underneath the loading shaft in accordance with the manufacturers instructions. Measure the rise of the steps relative to the top of surface of the gauge with the displacement transducer. If the measurements vary by more than $\pm 5\mu\text{m}$ from the known dimensions specified by the manufacturer, further calibration or maintenance is required. Report the calibration constants ($\mu\text{m/bit}$) for the displacement transducers to three significant figures. The calibration constants should be repeatable from day-to-day otherwise the operations of the system may be suspect.

10.1.2 Verify the calibration of the load cell using four standard dead masses evenly distributed over the range of the testing load. Perform the calibration by resting the load shaft against the 6.35 mm thick standard steel beam and loading it with the four standard masses sequentially in four steps while recording the load after each step. If the load indicated by the data acquisition system does not agree with the force imposed by the standard masses within $\pm 2\text{ mN}$ at all steps, further calibration or maintenance is required. Report the calibration constants (mN/bit) for the load transducers to three significant figures. The calibration measurements should be repeatable day-to-day otherwise the operation of the system may be suspect.

10.1.3 Verify calibration of the temperature detector by using a calibrated thermometer of suitable range meeting the requirements of Section 6.6. Immerse the thermometer in the liquid bath close to the thermal detector and compare the temperature indicated by the calibrated thermometer to the detector signal being displayed. If the temperature indicated by the thermal detector does not agree with the mercury in glass thermometer within $\pm 0.1^\circ\text{C}$, apply an appropriate temperature correction to the temperature measurement indicated by the temperature detector or further calibration or maintenance is required.

10.2 Determine the compliance of the loading system by placing the 6.35 mm thick stainless steel beam on the testing supports, resting the loading tip of the loading shaft against the stainless steel beam and applying a load to the shaft of $980 \pm 50\text{ mN}$. Any measured deflection is caused by the load cell or other parts of the test system. The data acquisition system should be capable of dividing the deflection measured under this load by applied

load. The quotient, which is reported by the data acquisition system, is the compliance of the loading system in $\mu\text{m/N}$. The typical value of the compliance should be in the range of 2 to 5 $\mu\text{m/N}$. If the compliance is more than 5 $\mu\text{m/N}$, further calibration or maintenance is required. The data acquisition system should automatically subtract the compliance value for the load applied from the deflection measured during a test.

10.3 Perform a daily overall check on performance system using the 1.0 to 1.6 mm thick stainless steel beam of known modulus. Load the steel beam with 1961 mN (200 g) using the standard masses and measure the deflection at mid-span. Using the load applied and deflection measured, calculate the elastic modulus of the beam. Compare the calculated modulus to the known modulus of the beam. If the calculated modulus differs from the known modulus (as specified by the manufacturer) by 10 percent or more, the operation of the system is suspect. Perform required maintenance on the system and then repeat Section 10. The data acquisition system can be used to record the deflection after loading for a specific time (usually 20 seconds), perform the calculations of modulus, and compare to the known modulus. The comparison between the measured and known modulus should be recorded as part the actual asphalt test results for the same day.

11. Preparation of Molds and Test Specimens

11.1 To prepare molds, spread a very thin layer of petroleum based grease, only sufficient to hold plastic to the aluminum, on the interior faces of the three long aluminum mold sections. Place the plastic strips over the aluminum faces and rub the plastic with firm finger pressure. Assemble the mold as shown in Figure 2 using the rubber O-rings to hold the pieces of the mold together. Inspect the mold and press the plastic film against the aluminum to force out any air bubbles. If air bubbles remain, disassemble the mold and recoat the aluminum faces with grease. Cover the inside faces of the two end pieces with a thin film of glycerol and talc to prevent the asphalt binder from sticking to the aluminum end pieces. After assembly keep the mold at room temperature until pouring the asphalt binder.

Note 4 - The thickness of the specimen is controlled by the end pieces. The thickness of the end pieces should be measured periodically to make sure that it meets the