

**Standard Test Method for
Determining the Creep Compliance and
Strength of Hot Mix Asphalt (HMA)
Using the Indirect Tensile Test Device**

AASHTO Designation: TP9-96^{1, 2}

1. Scope

1.1 This standard provides procedures for determining the tensile creep compliance at different loading times, tensile strength and Poisson's ratio of hot mix asphalt (HMA) using indirect loading techniques.

1.2 The procedures described in this standard provide the data required to conduct the thermal cracking analysis using SHRP's Superpave™ software and fatigue cracking analysis. [1] These procedures apply to test specimens having a maximum aggregate size of 38 mm or less. Specimens shall be 38 to 50 mm high and 150 ± 9 mm in diameter.

1.3 *This test 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 standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 AASHTO Standards

- T166 Bulk Specific Gravity of Compacted Bituminous Mixtures
- T209 Maximum Specific Gravity of Bituminous Paving Mixtures
- T269 Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- TP4 Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave™ Gyratory Compactor
- TP7 Determining Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt (HMA) Using the Simple Shear Test (SST) Device
- PP3 Preparing and Determining the Air

Voids of Hot Mix Asphalt (HMA)
Specimens by Means of the Rolling
Wheel Compactor

2.2 ASTM Standards

- D3549 Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D4123 Indirect Tension Test for Resilient Modulus of Bituminous Mixtures
- D5361 Sampling Compacted Bituminous Mixtures for Laboratory Testing

2.3 Other Documents

The Superpave™, Mix Design
Manual for New Construction and
Overlays

3. Terminology (Definitions)

3.1 Creep - the time-dependent part of strain resulting from stress.

3.2 Creep Compliance - the time-dependent strain divided by the applied stress.

3.3 Tensile Strength - the strength shown by a specimen subjected to tension, as distinct from torsion, compression or shear.

3.4 Poisson's Ratio, μ - the absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

4. Summary of Method

4.1 This standard describes two procedures. For one procedure, the tensile creep and tensile strength are determined on the same specimen for thermal cracking analyses, and for the other procedure the

¹ This standard is based on SHRP Product 1020.

² Approved in October 1994, this provisional standard was first published in March 1995. Reconfirmed in January 2001.

tensile strength is determined separately for fatigue cracking analyses.

4.2 The tensile creep is determined by applying a static load of fixed magnitude along the diametral axis of a specimen. The horizontal and vertical deformations measured near the center of the specimen are used to calculate a tensile creep compliance as a function of time. Loads are selected to keep horizontal strains in the linear viscoelastic range (typically below a horizontal strain of 500×10^{-6} mm/mm) during the creep test. By measuring both horizontal and vertical deformations in regions where the stresses are relatively constant and away from the localized non-linear effects induced by the steel loading strips, Poisson's ratio can be more accurately determined. Creep compliance is sensitive to Poisson's ratio measurements.

4.3 The tensile strength is determined immediately after determining the tensile creep or separately by applying a constant rate of vertical deformation (or ram movement) to failure.

5. Significance and Use

5.1 Tensile creep and tensile strength test data are required in Superpave™ levels 2 and 3 designs to determine the master relaxation modulus curve and fracture parameters. This information is used to calculate the fatigue performance and thermal cracking of HMA. The master relaxation modulus curve controls thermal crack development while the fracture parameter defines a mixture's resistance to fracture.

5.2 The values of creep compliance, tensile strength and Poisson's ratio determined with this method can be used in linear viscoelastic analysis to calculate the low temperature and fatigue cracking potential of asphalt concrete.

5.3 Tensile creep data may be used to evaluate the relative quality of materials.

5.4 This procedure is applicable to reheated, recompacted mixtures, but creep compliance values will be lower than for newly prepared mixtures, because of changes in binder viscosity; the binder viscosity is an important factor of creep strains, when measured under these specific loading conditions and temperatures.

6. Apparatus

6.1 Indirect Tensile Test System - The indirect tensile test system shall consist of an axial loading device, a load measuring device, specimen deformation measurement devices, an environmental chamber and a control and data acquisition system.

6.1.1 Axial Loading Device - The loading device shall be capable of providing a fixed or constant load of 98 kN with a resolution of at least 5 N and constant rate of ram displacement between 12 and 75 mm/minute.

6.1.2 Load Measuring Device - The load measuring device shall consist of an electronic load cell, designed for placement between the loading platen and piston, with a sensitivity of 5 N, and a minimum capacity of 98 kN.

6.1.3 Specimen Deformation Measurement Devices - The specimen deformation measurement devices shall consist of four linear variable differential transducers (LVDT) with a range of at least 0.25 mm and a minimum resolution throughout the range of 0.125 μ m.

6.1.4 Environmental Chamber - The environmental chamber shall be equipped with temperature conditioners and controls capable of generating test temperatures between -30 and +30°C inside the chamber and maintaining the desired test temperature to within $\pm 0.2^\circ\text{C}$. The internal dimensions of the environmental chamber shall be sufficient to hold a minimum of three test specimens for a period of 12 hours prior to testing.

6.1.5 Control and Data Acquisition System - Specimen behavior in the creep compliance test is evaluated from time records of applied load and specimen deformation. These parameters shall be recorded on an analog to digital data acquisition device.

6.1.5.1 When determining the tensile creep for Superpave™, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 s and 1 Hz for the next 90 s. When determining the tensile strength test, digital data acquisition devices shall provide a sampling frequency of 20 Hz through the entire test. A 16-bit A/D board is required to obtain the resolution needed when determining the tensile creep and the range needed when determining the tensile strength.

6.1.6 Gage Points - Eight brass gage points having a diameter of 8 mm and a height of 3.2 mm are required per specimen.

6.1.7 Mounting Template - A mounting template for placing and mounting the brass gage points to each side of the test specimen (four per side) which have been used successfully are shown in Figures 1 and 2. An example of a template for use with 150 mm diameter specimens is shown in Figure 1. Other similar and comparable systems such as used in TP7 can be used.

6.1.8 Test Specimen Loading Frame - The specimen load frame shall be as described in ASTM D4123 and capable of delivering test loads coincident with the vertical diametral plane of the test specimen and with less than 2 kg frictional resistance in guides and/or bearings. Often a smaller guide frame with special alignment capabilities is used in conjunction with the larger loading frame to accomplish this. (Figure 2)

7. Hazards - Observe standard laboratory safety precautions when preparing and testing HMA specimens.

8. Standardization

8.1 The testing system shall be calibrated prior to initial use and at least once a year thereafter.

8.1.1 Verify the capability of the environmental control component to maintain the required temperature within the accuracy specified.

8.1.2 Verify the calibration of all measurement components (such as load cells and LVDTs) of the testing system.

8.1.3 If any of the verifications yield data that does not comply with the accuracy specified, correct the problem prior to proceeding with testing. Appropriate action may include correction of menu entries, maintenance on system components, calibration of system components (using an independent calibration agency, or service by the manufacturer, or in-house resources), or replacement of system components.

9. Sampling

9.1 Laboratory Molded Specimens - Prepare three replicate laboratory molded specimens, as a minimum for each test temperature, in accordance with TP4 or PP3. If PP3 is used, use a suitable core drill to cut specimens from the sample after compaction.

9.2 Roadway Specimens - Obtain roadway specimens from the pavement in accordance with ASTM D5361. Prepare cores with smooth and parallel surfaces that conform to the height and diameter requirements specified in Section 10.2. Prepare three replicate cores for each test temperature.

10. Specimen Preparation and Preliminary Determinations

10.1 Saw at least 6 mm from both sides of each test specimen to provide smooth, parallel (saw-cut) surfaces for mounting the measurement gages.

Note 1 -- Measurements taken on cut faces yield more consistent results and gage points can be epoxied with much greater bonding strength.

10.2 Specimen Size - For mixtures with a maximum aggregate size of 38 mm or less, prepare specimens with a height of 38 to 50 mm and a diameter of 150 ± 9 mm.

10.3 Determining Specimen Height and Diameter - Measure and record the diameter and height (thickness) of each specimen in accordance with ASTM D3549, and determine individual measurements to the nearest 1 mm.

10.4 Determining the Bulk Specific Gravity - Determine the specific gravity of each specimen in accordance with T166, except that if the water absorbed by the specimen exceeds 2 percent, substitute a thin adherent plastic wrap membrane which is water resistant instead of the paraffin coating.

10.5 Specimen Drying - If specimens were immersed directly into the water, after determining the bulk specific gravity allow each specimen to dry at room temperature to a constant mass.

10.6 Mounting LVDT's - Epoxy four brass gage points to each flat face of the specimen (4 per face). On each flat face of the specimen, two gage points shall be placed along the vertical and two along the horizontal axes with a center to center spacing of 38.0 ± 0.2 mm for a specimen diameter of 150 ± 9 mm. The placement and location of the gage points on each face shall produce a mirror image of each other. Mount the LVDTs on the gage points such that the transducer's centerline is 6.4 mm above the specimen's surface. (Figure 3)

11. Tensile Creep/Strength Testing (Thermal Cracking Analysis)

11.1 Determine the tensile creep/strength test using test temperatures 0°C or less. A minimum of three test temperatures is required.

Note 2 -- Superpave™ mixture analysis procedures specify test temperatures of 0, -10 and -20°C .

11.2 Lower the temperature of the environmental chamber to the test temperature and, once the test temperature $\pm 0.2^{\circ}\text{C}$ is achieved, allow each specimen to remain at the test temperature from 3 ± 1 h prior to testing. Under no circumstances shall the specimen be kept at 0°C or less for over 24 hours.

11.3 Zero or rebalance the electronic measuring system and apply a static load of fixed magnitude (± 2 percent) without impact to the specimen for 100 ± 2 s. This time period corresponds to the input need for the Superpave™ software. If a complete analysis is required, a period of 1000 ± 20.5 s has been found suitable. Use a fixed load that produces a horizontal deformation of 0.00125 mm to 0.0190 mm for 150-mm diameter specimens. If either limit is violated, stop the test, allow a recovery time of 5 minutes before restarting with an adjusted load. Comply strictly with these limits to prevent both non-linear response, characterized by exceeding the upper limit, and significant problems associated with noise and drift inherent in sensors, when violating the lower deformation limit.

11.4 After the fixed load has been applied or reapplied, determine the tensile strength by applying a load to the specimen at a rate of 12.5 mm of ram (vertical) movement per minute. Record the vertical and horizontal deformations on both ends of the specimen and the load, until the load starts to decrease.

Note 3 -- In some cases, it is acceptable to unload the specimen between the creep compliance and strength tests. This will facilitate control on certain testing machines.

12. Tensile Strength Testing (Fatigue Cracking Analysis)

12.1 Use a test temperature 20°C or less for fatigue cracking analyses. Note 2 shall apply if the analysis is used for Superpave™ level 2 and 3 design.

12.2 Lower the temperature of the environmental chamber to the test temperature and, once the test temperature $\pm 0.2^{\circ}\text{C}$ is achieved, allow each specimen to remain at the test temperature from 3 ± 1 h prior to testing.

12.3 Zero or rebalance the electronic measuring system and apply a load to the specimen at a rate of 50 mm of ram (vertical) movement per minute. Record the vertical and horizontal movement and the load until the load begins to decrease. Stop the test as soon as the load begins to decrease to prevent damage to the LVDT equipment from a sudden failure within the specimen.

13. Calculations

13.1 Calculate the air voids for each test specimen in accordance with T269.

13.2 Creep Compliance and Tensile Strength Calculations

13.2.1 Superpave™ software yields a set of six vertical and horizontal deformations needed for mixture analysis. The output also gives the tensile strength of the mix. The software program is derived from the relationships given in the sections that follow.

13.3 Creep Compliance - Mathematical Model

13.3.1 The three reference specimens are analyzed simultaneously to reduce variability in determining Poisson's ratio and, therefore, creep compliance.

13.3.2 Obtain average thickness and diameter in mm and creep load in kN for the 3 replicates: