Standard Method of Test for

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

AASHTO Designation: T 322-07 (2011)

AASHTO

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. 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 concerns 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*:

- PP 3, Hot Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor[1]
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 320, Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST)

2.2. *ASTM Standards*:

- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D4123, Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures (Withdrawn 2003)
- D5361/D5361M, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

2.3. *SHRP Document*:

- *The Superpave Mix Design Manual for New Construction and Overlays*

3. TERMINOLOGY

3.1. *Definitions*:

3.2. *creep*—the time-dependent part of strain resulting from stress.

3.3. *creep compliance*—the time-dependent strain divided by the applied stress.

3.4. *tensile strength*—the strength shown by a specimen subjected to tension, as distinct from torsion, compression, or shear.

3.5. *Poisson's ratio* (ν)—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 the procedure for determining the tensile creep and tensile strength to be determined on the same specimen for thermal 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 nonlinear 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 for Superpave mixtures to determine the master relaxation modulus curve and fracture parameters. This information is used to calculate the 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 thermal 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 newly prepared mixtures, reheated, and recompacted mixtures. Reheated and recompacted mixtures will have lower creep compliance values than newly prepared mixtures when measured under these specific loading conditions and temperatures.

5.5. This procedure is applicable for mixtures with a maximum aggregate size of 38 mm or less.

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 100 kN with a resolution of at least 20 N and constant rate of ram displacement of at least 12 mm/min.

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 20 N and a minimum capacity of 100 kN.

6.1.3. *Specimen Deformation Measurement Devices*—The specimen deformation measurement devices shall consist of four displacement transducers with a range of at least 25 mm, reducible to 0.25 mm through software, and a minimum resolution throughout the range of 0.10 μm.

6.1.4. *Environmental Chamber*—The environmental chamber shall be equipped with temperature conditioners and controls capable of generating test temperatures between –30 and +10°C inside the chamber and maintaining the desired test temperature to within ±0.5°C. The internal dimensions of the environmental chamber shall be sufficient to hold a minimum of three test specimens for a period of 12 h prior to testing.

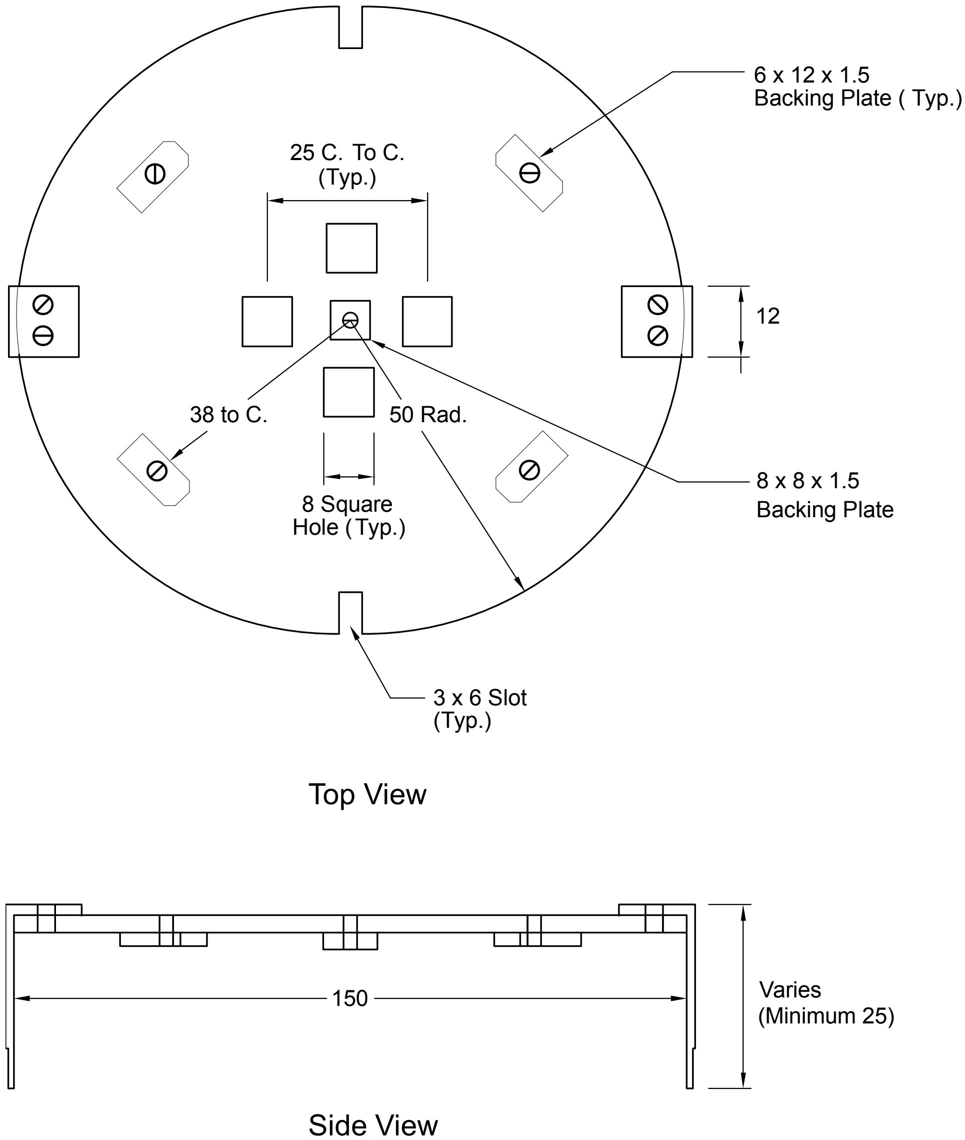
6.1.5. *Control and Data Acquisition System*—Specimen behavior in the creep compliance test is evaluated from time records of applied load and specimen deformation. These parameters shall be recorded on an analog to digital data acquisition device.

6.1.5.1. When determining the 100-s 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 1000-s tensile creep, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 s, 1 Hz for the next 90 s, and 0.1 Hz for the rest of 900 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 normally required to obtain the resolution needed when determining the tensile creep and the range needed when determining the tensile strength.

6.1.6. *Gauge Points*—Eight brass gauge 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 that has been used successfully for placing and mounting the brass gauge points to each side of the test specimen (four per side) is illustrated in Figure 1, which shows an example of a template for use with 150-mm diameter specimens. Other similar and comparable systems such as those used in T 320 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 20 N 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. The frame may be configured with two support columns or four support columns (Figure 2).



Notes:
1. All dimensions shown in millimeters unless otherwise noted.
2. Tolerances ±0.2 mm unless otherwise noted.
3. Not to scale.

Figure 1—150-mm Gauge Point Template

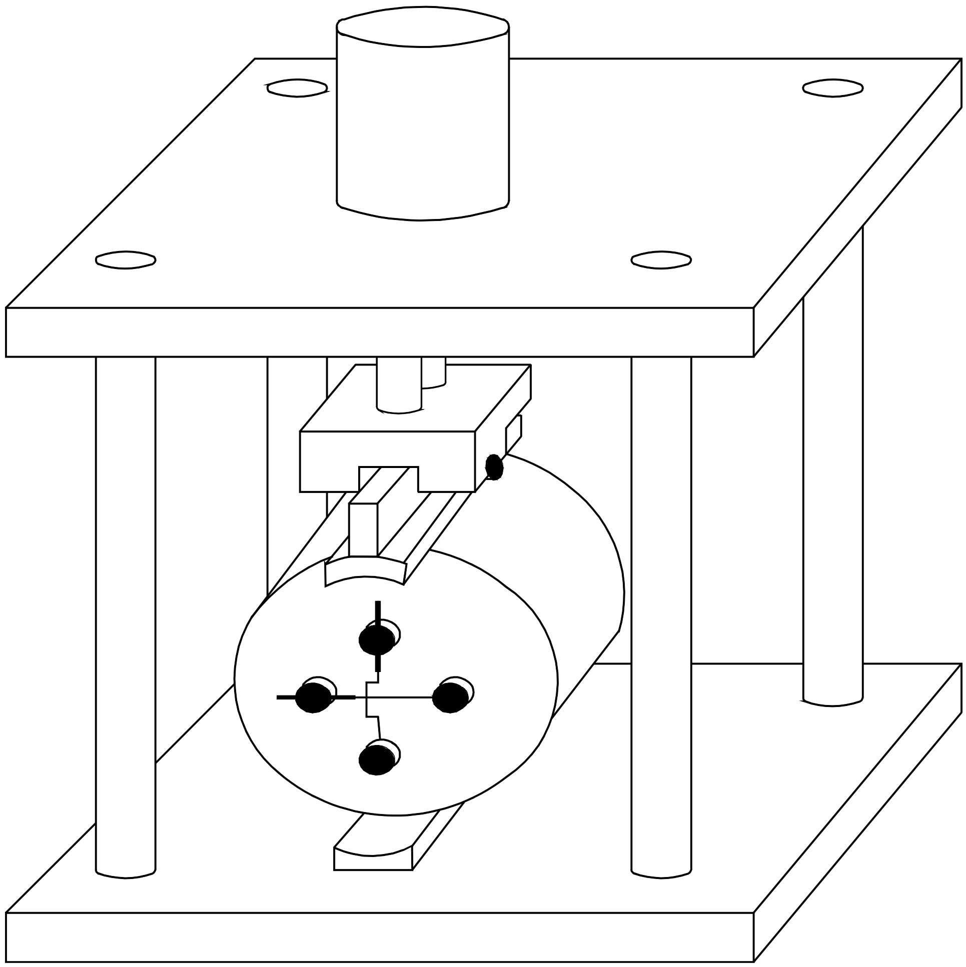


Figure 2—Specimen Loading Frame

7. HAZARDS

7.1. Observe standard laboratory safety precautions when preparing and testing HMA specimens.

8. STANDARDIZATION

8.1. Calibrate the testing system prior to initial use and at least once a year thereafter.

8.1.1. Calibrate the environmental control component to maintain the required temperature within the accuracy specified.

8.1.2. Calibrate all measurement components (such as load cells and displacement transducers) of the testing system.

8.1.3. If any of the verifications yield data that do 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 a minimum of three replicate laboratory molded specimens, in accordance with T 312 or PP 3. If PP 3 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/D5361M. Prepare cores with smooth and parallel surfaces that conform to the height and diameter requirements specified in Section 10.2. Prepare a minimum of three replicate cores.

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 gauges.

Note 1—Measurements taken on cut faces yield more consistent results, and gauge points can be attached with much greater bonding strength.

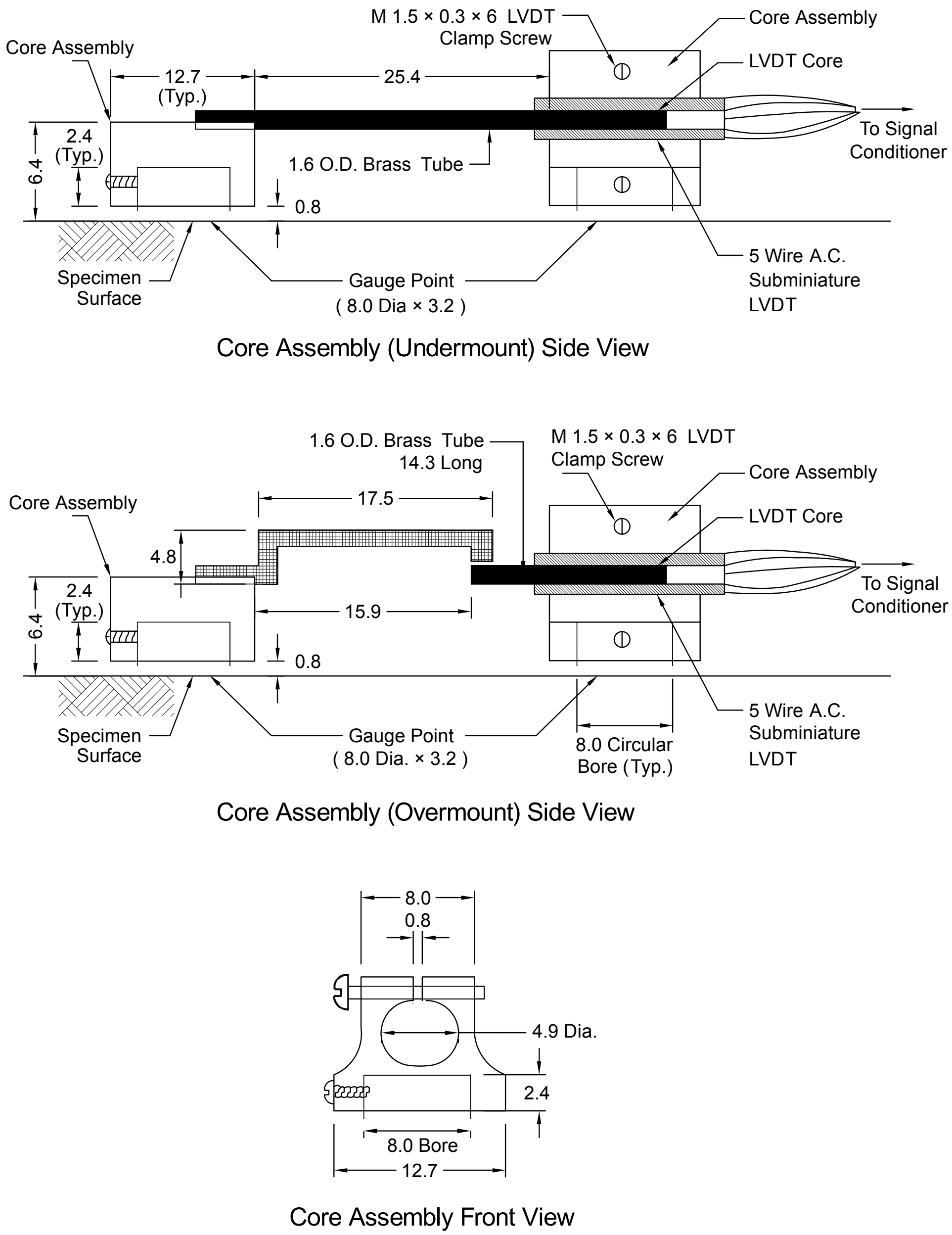
10.2. *Specimen Size*—Prepare specimens with a height of 38 to 50 mm and a diameter of 150 ± 9 mm.

10.3. *Determining Specimen Height and Diameter*—Determine and record the diameter and height (thickness) of each specimen in accordance with ASTM D3549/D3549M, to the nearest 1 mm.

10.4. *Determining the Bulk Specific Gravity*—Determine the specific gravity of each specimen in accordance with T 166, except that if the water absorbed by the specimen exceeds 2 percent, substitute a thin, adherent plastic wrap membrane that 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 Displacement Transducers*—Attach four brass gauge points with epoxy to each flat face of the specimen (four per face). On each flat face of the specimen, two gauge 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 gauge points on each face shall produce a mirror image of each other. Mount the displacement transducers on the gauge points such that the transducer's center line is 6.4 mm above the specimen's surface. Figure 3 shows a system for mounting linear variable transducers that has been successfully used for IDT creep measurements at low temperature.



Notes: 1. All dimensions shown in millimeters unless otherwise noted.
2. Tolerances ±0.2 mm unless otherwise noted.
3. Not to scale.

Figure 3—Cross Section of LVDT Mounting System for 150-mm Specimen

11. TENSILE CREEP/STRENGTH TESTING (THERMAL CRACKING ANALYSIS)

11.1. Determine the tensile creep compliance of each of the three specimens at three measurements at 10°C intervals. The following test temperatures are recommended:

- For mixtures made using binder grades PG XX-34 or softer: −30, −20, and −10°C;

- For mixtures made using binder grades PG XX-28 and PG XX-22, or mixtures for which binder grade is unknown: −20, −10, and 0°C;
- For mixtures made using binder grades PG XX-16 or harder: −10, 0, and +10°C; and
- For mixtures subjected to severe age hardening, the test temperatures should be increased by 10°C.

Note 2—The original Superpave mixture analysis procedures specified 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 ±0.5°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 more than 24 h.

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. 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 and allow a recovery time of 5 min before restarting with an adjusted load. Comply strictly with these limits to prevent both nonlinear 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 creep tests have been completed at each temperature, determine the tensile strength by applying a load to the specimen at a rate of 12.5 mm of ram (vertical) movement per min. Record the vertical and horizontal deformations on both ends of the specimen and the load until the load starts to decrease. The tensile strength should normally be determined at the middle temperature used for the creep tests.

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. CALCULATIONS

12.1. Calculate the air voids for each test specimen in accordance with T 269.

12.2. *Creep Compliance—Mathematical Model*:

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

12.2.2. Obtain average thickness and diameter in mm and creep load in kN for the three replicates:

$$D_{avg} = \frac{\sum_{n=1}^{3} b_n}{3} \quad (1)$$

$$D_{avg} = \frac{\sum_{n=1}^{3} D_n}{3} \quad (2)$$

$$P_{avg} = \frac{\sum_{n=1}^{3} P_n}{3} \quad (3)$$

where:

$\sum$ = sum of the three specimens, values for thickness, diameter, creep load, kN;
b_{avg}, D_{avg}, P_{avg} = average thickness, diameter, and creep load of three replicate specimens; and
b_n, D_n, P_n = thickness, diameter, and creep load of specimen n (n = 1 to 3).

12.2.3. Compute normalized horizontal and vertical deformation arrays for each of the six specimen faces (three specimens, two faces per specimen).

$$\Delta X_{n,i,t} = \Delta X_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n} \tag{4}$$

$$\Delta Y_{n,i,t} = \Delta Y_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n} \tag{5}$$

where:

$\Delta X_{n,i,t}$ = normalized horizontal deformation for face i (i = 1 to 6) at time t (t = 0 to t_{final}, where t_{final} is the total creep time);
$\Delta Y_{n,i,t}$ = normalized vertical deformation for face i at time t;
$\Delta X_{i,t}$ = measured horizontal deformation for face i at time t; and
$\Delta Y_{i,t}$ = measured vertical deformation for face i at time t.

12.2.4. Obtain the average horizontal and vertical deformations $\Delta X_{a,i}$ and $\Delta Y_{a,i}$ at a time corresponding to one half the total creep test time for each of the six specimen faces. Thus, for a 100-s creep test, obtain the deformations corresponding to t = 50 s.

$$\Delta X_{a,i} = \Delta X_{n,i,t_{mid}} \tag{6}$$

$$\Delta Y_{a,i} = \Delta Y_{n,i,t_{mid}} \tag{7}$$

where:

$\Delta X_{a,i} + \Delta Y_{a,i}$ = average horizontal and vertical deformations for face i;
$\Delta X_{n,i,t_{mid}}$ = normalized horizontal deformation at a time corresponding to half the total creep test time for face i; and
$\Delta Y_{n,i,t_{mid}}$ = normalized vertical deformation at a time corresponding to half the total creep test time for face i.

12.2.5. Obtain the trimmed mean of the deflections ΔX_t and ΔY_t. This is accomplished by numerically ranking the six $\Delta X_{a,i}$ and $\Delta Y_{a,i}$ values and averaging the four middle values. Thus, the highest and lowest values of horizontal and vertical deformation are not included in the trimmed mean. Compute:

$$\Delta X_t = \frac{\sum_{j=2}^{5} \Delta X_{r,j}}{4} \tag{8}$$

$$\Delta Y_t = \frac{\sum_{j=2}^{5} \Delta Y_{r,j}}{4} \tag{9}$$

where:

$\Delta X_{r,j}$ = $\Delta X_{a,i}$ values sorted in ascending order;
$\Delta Y_{r,j}$ = $\Delta Y_{a,i}$ values sorted in ascending order;
ΔX_t = trimmed mean of horizontal deformations; and
ΔY_t = trimmed mean of vertical deformations.

12.2.6. Obtain the ratio of the horizontal to vertical deformations, X/Y, as follows:

$$\frac{X}{Y} = \frac{\Delta X_t}{\Delta Y_t} \tag{10}$$

12.2.7. Compute the trimmed mean, $\Delta X_{tm,t}$, of the six horizontal deformation arrays.

$$\Delta X_{tm,t} = \frac{\sum_{j=2}^{5} \Delta X_{r,j,t}}{4} \tag{11}$$

where:

$\Delta X_{r,j,t}$ = $\Delta X_{i,t}$ arrays sorted, where the $i = 6$ arrays are sorted according to the sorting order already established in Section 12.2.5 for $\Delta X_{r,j}$; and

$\Delta X_{tm,t}$ = trimmed mean of the $\Delta X_{i,t}$ arrays.

12.2.8. Compute creep compliance, $D(t)$:

$$D(t) = \frac{\Delta X_{tm,t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl} \tag{12}$$

where:

$D(t)$ = creep compliance at time t (kPa); and

GL = gauge length in meters (38×10^{-3} for 150-mm diameter specimens); and

$$C_{cmpl} = 0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332 \tag{13}$$

$$\left[0.704 - 0.213\left(\frac{b_{avg}}{D_{avg}}\right)\right] \le C_{cmpl} \le \left[1.566 - 0.195\left(\frac{b_{avg}}{D_{avg}}\right)\right]$$

12.2.9. Poisson's ratio, ν, may be computed as:

$$v = -0.10 + 1.480\left(\frac{X}{Y}\right)^2 - 0.778\left(\frac{b_{avg}}{D_{avg}}\right)^2\left(\frac{X}{Y}\right)^2 \tag{14}$$

where:

$0.05 \le \nu \le 0.50$

12.3. *Tensile Strength—Mathematical Model*:

12.3.1. Calculate tensile strength for each specimen, $S_{t,n}$, as:

$$S_{t,n} = \frac{2 \times P_{f,n}}{\pi \times b_n \times D_n} \tag{15}$$

where:

$P_{f,n}$ = maximum load observed for specimen, n; and

$S_{t,n}$ = tensile strength of specimen, n.

12.3.2. Compute the average tensile strength:

$$S_t = \frac{\sum_{n=1}^{3} S_{t,n}}{3} \tag{16}$$

where:

S_t = average tensile strength of mixture.

13. REPORT

13.1. *Report the following information*:

13.1.1. Bulk specific gravity of each specimen tested to the nearest 0.001;

13.1.2. Maximum specific gravity of the asphalt concrete mixture to the nearest 0.001;

13.1.3. Air voids of each specimen to the nearest 0.1 percent;

13.1.4. Height and diameter of all test specimens to the nearest millimeter;

13.1.5. Test temperature to the nearest 0.5°C, and for creep testing the load levels used during the test to the nearest 5 N;

13.1.6. Tensile creep compliance values $D(t)$; and

13.1.7. Tensile strength (σ_t) of the mixture to the nearest pascal as computed.

14. PRECISION AND BIAS

14.1. *Precision*—The research required to develop precision estimates has not been conducted.

14.2. *Bias*—The research required to establish the bias of this method has not been conducted.

15. KEYWORDS

15.1. Creep compliance; diametral creep compliance; linear variable differential transducer; tensile creep test; tensile failure test; tensile strength.