5.9.60 INDIRECT TENSILE TEST  (Kansas Test Method KT-60)

1. SCOPE

This test method provides procedures used to determine tensile creep compliance in hot mix asphalt. It also provides the data to conduct thermal cracking and fatigue cracking analysis.

KT-60 reflects testing procedures found in AASHTO T 322-07.

Note: Procedure for critical cold temperature selection:
Specification temperature shall be chosen using FHWA LTPPBind software (Version 3.1) using the weather station closest to the project. The required temperature for the specification is the coldest temperature at the top of the asphalt concrete layer in the pavement structure. Use 98 percent reliability.

2. REFERENCED DOCUMENTS

2.1. KT-15 Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

2.2 KT-56 Resistance of Compacted Asphalt Mixture to Moisture Induced Damage

2.3 KT 58 Method For Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

2.4 AASHTO T322-07; Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device

3. SIGNIFICANCE AND USE

3.1. 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 the asphalt concrete. The master relaxation modulus curve controls thermal crack development, while the fracture parameter defines a mixture’s resistance to fracture.

3.2. 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.

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

3.4. 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.

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

4.1 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.

4.1.1. The axial loading device shall be capable of providing a fixed or constant load of 100 kN (22,500 lbf) with a resolution of at least 20 N (5 lbf) and constant rate of ram displacement of at least 12 mm (0.5 in.)/minute.

4.1.2. 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 (5 lbf), and a minimum capacity of 100 kN (22,500 lbf).

4.1.3. The specimen deformation measurement devices shall consist of four displacement transducers with a range of at least 25 mm (1.0 in.), reducible to 2.5 mm (0.1 in.) through software, and a minimum resolution throughout the range of 0.10 μm (3.936996e-006 in.).

4.1.4. The environmental chamber shall be equipped with temperature conditioners and controls capable of generating test temperatures between -40°C (-40°F) and +10°C (+50°F) inside the chamber and maintaining the desired test temperature to within ±0.5°C (±0.9°F). 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.

4.1.5. 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.

4.1.5.1. When determining the 100-second tensile creep for Superpave, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 seconds and 1 Hz for the next 90 seconds. When determining the 1000-second tensile creep, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 seconds, 1 Hz for the next 90 seconds, and 0.1 Hz for the rest of 900 seconds. 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.

4.1.6. Eight brass gauge points having a diameter of 8 mm (0.315 in.) and a height of 6 mm (0.236 in.) are required per specimen.

4.1.7. A mounting template that has been used successfully for placing and mounting the gauge points to each side of the test specimen (four per side) is illustrated in AASHTO T322-07 Figure 1, which shows an example of a template for use with 150-mm (5.9 in.) diameter specimens.

4.1.8. The specimen load frame shall be capable of delivering test loads coincident with the vertical diametral plane of the test specimen and with less than 20 N (5 lbf) 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.
4.1.9. Use metal loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. Strips are to be 19.0 mm (0.75 in) wide with rounded edges.

5. STANDARDIZATION

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

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

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

5.1.3. 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.

6. SAMPLING

6.1. Laboratory Molded Specimens—Prepare a minimum of six laboratory molded samples, in accordance with KT 58.

6.2. Roadway Specimens—Obtain core samples with smooth and parallel surfaces that conform to the height and diameter requirements specified in Section 7.2. Prepare a minimum of six samples.

7. SPECIMEN PREPARATION AND PRELIMINARY DETERMINATIONS

7.1. 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.

7.2. Specimens using the medium gradation as specified in Section 5.3.4 page 1 Part V of the Construction Manual, shall be 150 mm (5.9 in.) in diameter and at least 115 mm (4.5 in.) in height and compacted to air voids +/- 1 percent of design air voids at the design emulsion content. A trial specimen is suggested for this. Test specimens shall be cured at 60°C (140°F) no less than 48 hours and no more than 72 hours. Check specimen mass every 2 hours after 48-hour cure to check with compliance of no more than 0.05% change in mass in 2 hours. After curing, two specimens shall be cut from each compacted specimen to 50mm (2.0 in.) in height and 150 mm (5.9 in.) in diameter. Perform bulk specific gravity after cutting.

7.3. Determine and record the diameter and height (thickness) of each specimen in accordance with KT-56.

7.4. Determining the Bulk Specific Gravity—Determine the specific gravity of each specimen in accordance with KT-15.
7.5. 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.

7.6. Attach four -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 (1.50 ± 0.10 in.) for a specimen diameter of 150 ± 9 mm (5.9 ± 0.35 in.). 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 (0.25 in.) above the specimen’s surface. AASHTO T 322-07 Figure 3 shows a system for mounting linear variable differential transducers (LVDT’s) that has been successfully used for IDT creep measurements at low temperature.

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

8.1. Select two temperatures at 10°C (18°F) intervals that bracket the required specification. For example, if the required specification temperature is -25°C (-13°F), then select testing temperatures of -20°C (-4°F) and -30°C (-22°F). A temperature of -10°C (14°F) or -40°C (-40°F) should then be selected to complete the third required temperature.

8.2. Lower the temperature of the environmental chamber to the test temperature and, once the test temperature ±0.5°C (±0.9°F) is achieved, allow each specimen to remain at the test temperature from 3 ± 1 hours prior to testing. If the test temperature is below 0°C (32°F), allow the specimen to remain at the test temperature for 6 ± 1 hours prior to testing. Under no circumstances shall the specimen be kept at 0°C (32°F) or less for more than 24 hours.

8.3. 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 seconds. If a complete analysis is required, a period of 1000 ± 20.5 seconds has been found suitable. Use a fixed load that produces a horizontal deformation of 0.00125 mm (4.921245e-005 in.) to 0.0190 mm (7.480292e-004 in.) for 150-mm (5.9 in.) diameter specimens. If either limit is violated, stop the test and allow a recovery time of 5 minutes 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.

8.4. The tensile strength test shall be carried out on each specimen directly after the tensile creep test at the same temperature as the creep test 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.

9. CALCULATIONS

9.1. Calculate the air voids for each test specimen in accordance with KT-56.

9.2. Creep Compliance—Mathematical Model:
9.2.1. The three reference specimens are analyzed simultaneously to reduce variability in determining Poisson’s ratio and, therefore, creep compliance.

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

\[ D_{avg} = \frac{\sum_{n=1}^{3} D_n}{3} \]

\[ b_{avg}, D_{avg}, P_{avg} = \text{average thickness, diameter, and creep load of three replicate specimens; and} \]

\[ b_n, D_n, P_n = \text{thickness, diameter, and creep load of specimen } n \text{ (} n = 1 \text{ to } 3). \]

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

\[ \Delta X_{n,i,t} = \Delta X_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n} \]

\[ \Delta Y_{n,i,t} = \Delta Y_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n} \]

where:

\[ \Delta X_{i,t} = \text{normalized horizontal deformation for face } i \text{ at time } t \text{ (} t = 0 \text{ to } t_{final}, \text{ where } t_{final} \text{ is the total creep time)}; \]

\[ \Delta Y_{i,t} = \text{normalized vertical deformation for face } i \text{ at time } t; \]

\[ \Delta X_{n,i} = \text{measured horizontal deformation for face } i \text{ at time } t; \text{ and} \]

\[ \Delta Y_{n,i} = \text{measured vertical deformation for face } i \text{ at time } t. \]

9.2.4. Obtain the average horizontal and vertical deformation \( \Delta X_{n,i} \) and \( \Delta Y_{n,i} \) at a time corresponding to one half the total creep test time for each of the six specimen faces. Thus, for a 100-second creep test, obtain the deformations corresponding to \( t = 50 \) seconds.
\[ \Delta X_{a,j} = \Delta X_{n,i,t_{mld}} \]
\[ \Delta Y_{a,i} = \Delta Y_{n,i,t_{mld}} \]

where:
\[ \Delta X_{a,i} + \Delta Y_{a,i} \] = average horizontal and vertical deformations for face \( i \);
\[ \Delta X_{n,i,t_{mld}} \] = normalized horizontal deformation at a time corresponding to half the total creep test time for face \( i \); and
\[ \Delta Y_{n,i,t_{mld}} \] = normalized vertical deformation at a time corresponding to half the total creep test time for face \( i \).

9.2.5. Obtain the trimmed mean of the deflections \( \Delta X \) and \( \Delta Y \). 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:

\[ \Delta X_t = \frac{\sum_{j=2}^{5} \Delta X_{r,j}}{4} \]
\[ \Delta Y_t = \frac{\sum_{j=2}^{5} \Delta Y_{r,j}}{4} \]

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;
\( \Delta X_t \) = trimmed mean of horizontal deformations; and
\( \Delta Y_t \) = trimmed mean of vertical deformations.

9.2.6. Obtain the ratio of the horizontal to vertical deformations, \( X/Y \), as follows:

\[ \frac{X}{Y} = \frac{\Delta X_t}{\Delta Y_t} \]
9.2.7. Compute the trimmed mean, $\Delta X_{m,t}$, of the six horizontal deformation arrays.

$$\Delta X_{m,t} = \frac{\sum_{i=2}^{5} \Delta X_{r,f,t}}{4}$$

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 9.2.5, for $\Delta X_{r,j}$ and $\Delta X_{m,t}$ = Trimmed mean of the $\Delta X_{r,j}$ arrays.

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

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

where:
- $D(t) = \text{creep compliance at time } t$(kPa); and
- $GL = \text{gauge length in meters (38 x } 10^{-3}\text{ for 150 mm diameter specimens}); and
- $C_{\text{cmpl}} = 0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332$

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

9.2.9. Poisson’s ratio, $v$, may be computed as:

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

where:
- $0.05 \leq v \leq 0.50$

9.3. Tensile Strength – Mathematical Model:

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

$$S_{t,n} = \frac{2 \times P_{f,n}}{\partial \times b_{n} \times D_{n}}$$

where:
- $P_{f,n} = \text{maximum load observed for specimen, } n$;
- $S_{t,n} = \text{tensile strength of specimen, } n$. 
9.3.2. Compute the average tensile strength:

\[
S_t = \frac{\sum_{n=1}^{3} S_{t,n}}{3}
\]

where:
\[S_t\] = average tensile strength of mixture.

9.3.3. The critical cracking temperature is defined as the intersection of the calculated pavement thermal stress curve (derived from the creep data) and the tensile strength line (the line connecting the results of the average tensile strength at the two temperatures).

10. REPORT

10.1. Report the following information:

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

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

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

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

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

10.1.6. Tensile creep compliance values \(D(t)\); and

10.1.7. Tensile strength \((\sigma_t)\) of the mixture to the nearest pascal as computed.

11. PRECISION AND BIAS

11.1. Precision: The research required to develop precision estimates has not been conducted.

11.2. Bias: The research required to establish the bias of this method has not been conducted.