Standard Method of Test for

Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST)

AASHTO Designation: T 320-07 (2011)

AASHTO

1. SCOPE

1.1. This standard provides performance-related test procedures for the determination of stiffness and permanent shear strain of asphalt mixtures using the Superpave Shear Tester (SST). Modified and unmodified asphalt mixtures can be tested and analyzed using this standard.

1.2. This standard is applicable to specimens prepared in a laboratory or cored from a pavement for postconstruction analysis. It is intended for use with specimens having the following minimum dimensions:

Nominal Maximum Aggregate Size in Asphalt Mixture, mm	Specimen Diameter	Specimen Height
19	150	50
12.5, 9.5, 4.75	150	38

Note 1—*Nominal maximum aggregate size* is defined in R 35 as the sieve greater than the first sieve to retain more than 10 percent of the total aggregate. Asphalt mixtures with a nominal maximum aggregate size greater than 19 mm can be tested using this procedure, but it is not recommended. The larger aggregate sizes may significantly interfere with the material response, thereby affecting the repeatability of the test.

Note 2—The SST is only capable of testing specimens with a maximum diameter of 150 mm. The specimen height of 50 mm is preferred, but may not be available in roadway cores where layer thickness may only be 38 mm. Specimen heights less than 38 mm usually cannot be tested because of equipment constraints.

Note 3—The diameter-to-height ratio for shear test specimens should be 3:1 or greater. This effectively eliminates the use of 100-mm diameter specimens (because of minimum height requirement for testing discussed in Note 2).

1.3. *This practice may involve hazardous materials, operations, and equipment. It does not purport to address all the safety concerns associated with its use. It is the responsibility of the user of this practice to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- R 35, Superpave Volumetric Design for Asphalt Mixtures
- R 66, Sampling Asphalt Materials

- T 2, Sampling of Aggregates
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- 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

2.2. *ASTM Standards*:

- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D5361/D5361M, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

3. SIGNIFICANCE AND USE

3.1. The test procedures and associated analysis techniques described in this method can be used to determine shear stiffness and permanent shear strain of asphalt mixtures. The shear frequency sweep test at constant height can be used to determine mixture stiffness. The simple shear test at constant height can be used to determine shear deformation from the application of a static shear load. The repeated shear test at constant height can be used with corresponding analysis procedures to estimate the rutting susceptibility of an asphalt mixture.

4. EQUIPMENT AND MATERIALS

4.1. *Shear Test System*—The shear test system shall consist of a loading device, specimen deformation measurement equipment, an environmental chamber, and a control and data acquisition system. It shall accommodate test specimens 150 mm in diameter and 50 mm in height.

4.1.1. *Loading Device*—The loading device shall be capable of simultaneously applying both vertical and horizontal loads to a specimen. It shall also be capable of applying static, ramped (increasing or decreasing), and repetitive loads of various waveforms. As a minimum, the loading device shall be capable of applying horizontal shear load pulses in a haversine waveform with a load duration of 0.1 s with 0.6 s between load pulses. Loading shall be provided by two hydraulic actuators (one each horizontal and vertical) and shall be controlled by closed-loop feedback using either stress or strain control throughout the entire range of frequencies and temperatures. The loading device shall be capable of meeting the minimum requirements specified in Table 1.

Table 1—Minimum Test System Requirements

Measurement and Control Parameters	Range	Resolution	Accuracy
Load, N	0 to 31,000	2	5
Axial LVDT, mm	0 to 5	0.0025	0.005
Shear LVDT, nmm	0 to 0.05	0.001	0.002
Temperature, ˚C	0 to 80	0.25	0.5

4.1.2. *Environmental Chamber*—The environmental chamber shall be capable of maintaining the temperature of the test specimen as specified in Table 1 during the testing sequence.

4.1.3. *Data Acquisition and Control System*—The data acquisition and control system shall automatically control user-selected measurement parameters, within the accuracy specified in

Table 1, during the testing sequence. The system shall record load cycles, applied horizontal and vertical loads, specimen deformation in two directions (vertical and horizontal), environmental conditions, and the required frequency of data sampling. At the conclusion of the test, the data acquisition and control system shall provide all applicable test data.

4.2. *Conditioning Chamber*—The conditioning chamber shall be capable of maintaining the specimen conditioning temperatures as specified in Table 1.

4.3. *Platen-Specimen Assembly Device (optional)*—The platen-specimen assembly device is used to facilitate bonding the specimen to the loading platens with adhesive. The device shall maintain the platens in a parallel position (relative to each other) during the gluing operation. The platens must remain parallel so that stresses do not develop in the specimen when the specimen-platen assembly is clamped in the test system. The device shall be capable of testing specimens with a maximum diameter of 150 mm and maximum height of 50 mm.

4.4. *Aluminum Loading Platens*—Top and bottom aluminum loading platens at least 6.35 mm greater in diameter than the diameter of the specimen to be tested and at least 20 mm thick. The bearing face of each platen shall be plane to 0.025 mm.

4.5. *Adhesive*—Quickset adhesive with a minimum hardened stiffness modulus of 2000 MPa for bonding the platens to the specimen ends.

Note 4—Devcon™ 5-Minute Plastic Steel Epoxy Cement is one possible material that is satisfactory for tests conducted at 20°C or higher.

4.6. *Solvent*—Acetone, kerosene, or other equivalent solvent for cleaning the platens after testing.

Note 5—Most of the epoxy and samples can be removed by heating and scraping the platens. The solvent is used only for a final cleaning.

5. STANDARDIZATION

5.1. The testing system shall be standardized prior to initial use and at least once every 12 months thereafter.

5.1.1. Verify the capability of the environmental control chamber to maintain the required temperature within the accuracy specified in Table 1.

5.1.2. Verify the calibration of all measurement components [such as load cells and linear variable differential transducers (LVDTs)] of the testing system.

5.1.3. If any of the verifications yield data that do not comply with the accuracy requirements specified in Table 1, correct the problem prior to proceeding with testing. Appropriate action may involve correction of menu entries, maintenance of system components, calibration of system components (using an independent calibration service, manufacturer service, or in-house resources), or replacement of system components.

6. SAMPLING AND SPECIMEN PREPARATION

6.1. Five test specimens are preferred, and a minimum of three specimens are required, for performing the repeated shear test at constant height. Three test specimens are preferred for performing the shear frequency sweep test at constant height and the simple shear test at constant height.

6.2. *Laboratory-Mixed, Laboratory-Compacted (LMLC) Specimens*—Sample asphalt binder and aggregates in accordance with R 66 and T 2, respectively. Use the appropriate proportions of asphalt binder and aggregates according to the final asphalt mix design.

6.2.1. Prepare aggregate batches of the appropriate size to produce a compacted specimen that will be 150 mm in diameter and 75 mm in height. Heat the aggregate batches to the appropriate mixing temperature.

Note 6—The Appendix contains information on the calculation of the appropriate aggregate batch weight to achieve the correct specimen dimension at the proper percentage of air voids.

6.2.2. Heat the asphalt binder to the appropriate mixing temperature. Mix the correct proportions of asphalt binder and combined aggregates to match the asphalt mix design.

6.2.3. After mixing, condition the asphalt mixture for 4.0 ± 0.1 h at 135 ± 5°C in accordance with "Short-Term Conditioning for Mixture Mechanical Property Testing," R 30.

6.2.4. Compact the HMA mixture in accordance with T 312 to obtain a specimen with the appropriate percentage of air voids as follows:

Test	Air Voids, %
Repeated shear test	3.0 ± 0.5
Simple shear test	7.0 ± 0.5
Shear frequency sweep test	7.0 ± 0.5

Note 7—Other compaction procedures than the Superpave gyratory compactor (T 312) and other target air void percentages may be used. However, caution is needed to prevent comparisons between asphalt mixtures with different target air voids or compaction. The test procedures and analyses are sensitive to both the percentage of air voids and the compaction procedure.

Note 8—Specimens are often compacted to a target air void percentage that is higher than the anticipated percentage of air voids in the cut test specimen. This is done because cutting the top and bottom of a compacted specimen removes lower density material, thereby raising the density (lowering the air voids) of the test specimen. The magnitude of the difference between the target percentage of air voids for the compacted specimen and the target percentage of air voids for the test specimen is dependent upon the nominal maximum aggregate size of the mixture and the mixture gradation. Coarse mixes, and/or mixes with a larger nominal maximum aggregate size, tend to have greater differences between the compacted specimen air voids and the test specimen air voids. In general, a 1.0 percent offset (compact to a target of 4.0 percent air voids or 8.0 percent air voids) should be sufficient to achieve the appropriate percentage of air voids in the test specimen.

6.2.5. Cool the compacted specimen to room temperature. Cut the compacted specimen to a height of 50 mm with two parallel faces. Determine and record the height of the cut specimen at the least and greatest heights. If the difference in the least and the greatest height is more than 2 mm, then discard the specimen and prepare another.

6.2.6. Determine the percentage of air voids in the test specimens in accordance with T 269. Determine the height and diameter of the test specimens in accordance with ASTM D3549/D3549M.

6.3. *Field-Mixed, Laboratory-Compacted (FMLC) Specimens*—Obtain HMA samples in accordance with T 168. Compact specimens in accordance with T 312 to the appropriate percentage of air voids. (See Section 6.2.4 and Notes 7 and 8.)

6.3.1. Cool the compacted specimen to room temperature. Cut the compacted specimen to a height of 50 mm with two parallel faces. Determine and record the height of the cut specimen at the least and greatest heights. If the difference in the least and the greatest height is more than 2 mm, then discard the specimen and prepare another.

6.3.2. Determine the percentage of air voids in the test specimens in accordance with T 269. Determine the height and diameter of the test specimens in accordance with ASTM D3549/D3549M.

6.4. *Field-Mixed, Field-Compacted (FMFC), or Pavement Core Specimens*—Obtain asphalt pavement specimens having a diameter of 150 mm and a minimum thickness of 38 mm in accordance with ASTM D5361/D5361M.

6.4.1. Cut the specimens to the proper test dimensions. Cool the compacted specimen to room temperature. Cut the compacted specimen to a height of 50 mm with two parallel faces. Determine and record the height of the cut specimen at the least and greatest heights. If the difference in the least and the greatest height is more than 2 mm, then discard the specimen and prepare another.

6.4.2. Determine the percentage of air voids in the test specimens in accordance with T 269. Determine the height and diameter of the test specimens in accordance with ASTM D3549/D3549M.

6.5. *Preparing the Specimens for Testing*—The following steps discuss the bonding of the test specimen to the platens for testing in the shear tester.

6.5.1. Ensure that the platens are clean, aligned, and clamped in place in the platen-specimen assembly device (optional) or shear test device.

6.5.2. Prepare the adhesive. If using an epoxy, proportion and mix the resin and hardener together in accordance with the manufacturer's instructions (Note 4).

6.5.3. Apply a thin coating of the adhesive to the top of the test specimen and to the bottom platen. Center the test specimen on the bottom platen and lower the top platen onto the specimen. Rotate the specimen slightly to ensure good bonding.

Note 9—Approximately 135 g of epoxy cement has been found suitable to provide bonding without excess waste. Half of the epoxy cement should be used on the bottom platen and the other half on the top of the specimen.

6.5.4. Bond the specimen to the platens using a light pressure (approximately 35 kPa) for 5 min. Begin removing excess adhesive from the sides of the test specimen by trimming as soon as the light pressure is applied.

6.5.5. After the adhesive has stabilized, remove the test assembly (specimen with attached platens) from the platen-specimen assembly device (optional) or shear test device and allow the adhesive to cure for the minimum time recommended by the manufacturer.

7. PROCEDURE A—SHEAR FREQUENCY SWEEP TEST AT CONSTANT HEIGHT (STIFFNESS)

7.1. Turn on the hydraulic system at least 1 h before starting the test to allow sufficient warm-up time. Warm up the actuators and hydraulic oil by using a sinusoidal waveform in stroke control.

7.2. Determine the lowest temperature at which the specimen will be tested and precondition the test specimens from 2 to 4 h (Note 11) at the required test temperature ±0.5°C. Set the temperature for the environmental chamber of the shear test device at the required test temperature.

Note 10—Many specimens are tested at multiple temperatures depending on the desired data. For example, stiffness at an intermediate temperature (such as 20°C) may be desired to provide inputs to a fatigue analysis procedure. Stiffness at a higher temperature (such as 40°C) may be desired to provide an indication of the expected high temperature stiffness of an asphalt mixture. Because of equipment constraints, testing can only be conducted at temperatures where the mixture stiffness is less than approximately 3000 MPa (435 ksi). Because of nonlinear responses, testing should also be confined to temperatures no higher than 12°C below the high-temperature grade of the asphalt binder (i.e., 52°C for a PG 64-22 asphalt binder).

Note 11—A conditioning chamber is preferred because it allows the shear test device to be free to perform tests rather than be occupied for temperature conditioning.

7.3. After the conditioning period, remove the specimen (attached to platens) from the conditioning chamber. Quickly attach the shear and vertical linear variable differential transducers (LVDTs) to the specimen platens. Open the environmental chamber of the shear tester and place the sample with the attached LVDTs on the shear table.

7.4. Ensure that the LVDTs are plugged into the proper data acquisition ports within the shear tester's environmental chamber. Zero the shear and vertical LVDTs.

7.5. Confirm that the vertical test system heads are positioned to allow the platen-specimen assembly to slide between the bottom horizontal and top vertical heads. Confirm that the horizontal test head is positioned such that the top and bottom test heads are aligned vertically. Center the specimen between the heads and secure the platens. Close the environmental chamber.

7.6. Confirm that the environmental chamber temperature control is activated and on the proper setting to maintain the required test temperature with a tolerance of ±0.5°C. Allow the specimen temperature to stabilize for a minimum of 20 min and a maximum of 60 min. This stabilization time allows the specimen to reacquire the proper test temperature (lost during LVDT instrumentation) and for the LVDTs to stabilize after the temperature change.

7.7. Execute the shear frequency sweep test at constant height.

7.7.1. Precondition the specimen by applying a sinusoidal shear strain consisting of a peak-to-peak amplitude of 0.0001 mm/mm (0.01 percent) at 10 Hz for 100 cycles. During the loading cycle, maintain the specimen height constant, within ±0.013 mm, by applying sufficient axial stress during the loading cycle. This is accomplished by controlling the vertical actuator using closed-loop feedback from the axial LVDT.

7.7.2. Perform the shear frequency sweep test by applying a sinusoidal shear strain of 0.0001 mm/mm (0.01 percent) at each of the following frequencies—10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01 Hz. Use 50 cycles each for the 10-Hz and 5-Hz frequencies. Use 20 cycles each for the 2-Hz and 1-Hz frequencies. Use 7 cycles each for the 0.5-, 0.2-, and 0.1-Hz frequencies. Use 4 cycles each for the 0.05-, 0.02-, and 0.01-Hz frequencies.

7.7.3. Record the axial and shear deformations (from the LVDTs) and axial and shear loads. Record at a minimum rate of 50 data points per second for the number of cycles specified for each frequency in Section 8.7.2.

7.7.4. At the conclusion of the test, release the loads and return the actuators to the pretest position. Switch the control back to the actuators (from the axial LVDT) and disconnect the LVDTs.

Note 12—Because the shear frequency sweep test is executed in the (theoretically) linear viscoelastic region, the same specimen can be tested using either the simple shear test at constant height (Procedure B) or repeated shear test at constant height (Procedure C). At high temperatures (40°C and higher), the simple shear test at constant height will induce sufficient permanent shear strain to affect further mixture properties. The repeated shear test at constant height should always induce sufficient permanent shear strain to affect mixture properties. Both tests should be considered "destructive" tests. Therefore, it is recommended that shear frequency sweep testing not be conducted on specimens that have been subjected to "destructive" testing.

7.8. Remove the specimen from the test chamber.

Note 13—The shear frequency sweep test at constant height takes approximately 45 min to execute from the time the specimen is removed from the conditioning chamber until the test is completed and the specimen is removed from the shear tester.

7.9. If stiffness will be determined at other test temperatures, either: (a) return the specimen to the conditioning chamber and change the temperature of the SST and conditioning chamber to the next desired temperature; or (b) set the specimen aside without cleaning and wait until the temperature of the SST chamber can be adjusted.

7.10. Once stiffness has been determined at all desired temperatures, clean the specimen from the platens by placing the specimen-platen assembly in an oven at approximately 135°C for 60 min to debond the specimen and adhesive from the platens. Scrape the platens clean with a scraper. Use acetone or other suitable solvent to remove any remaining adhesive.

8. PROCEDURE B—SIMPLE SHEAR TEST AT CONSTANT HEIGHT

8.1. Turn on the hydraulic system at least 1 h before starting the test to allow sufficient warm-up time. Warm up the actuators and hydraulic oil by using a sinusoidal waveform in stroke control.

8.2. Determine the lowest temperature at which the specimen will be tested (Note 14) and precondition the test specimens from 2 to 4 h (Note 11) at the required test temperature ±0.5°C. Set the temperature for the environmental chamber of the shear test device at the required test temperature.

Note 14—Specimens may be tested at multiple temperatures. However, because this test does induce some permanent shear strain, the same specimen should not be tested at temperatures of 40°C or higher. At temperatures less than 40°C, the permanent shear strain should be sufficiently small to allow the specimen to be tested at other temperatures.

8.3. After the conditioning period, remove the specimen (attached to platens) from the conditioning chamber. Quickly attach the shear and vertical linear variable differential transducers (LVDTs) to the specimen platens. Open the environmental chamber of the shear tester and place the specimen on the shear table.

8.4. Ensure that the LVDTs are plugged into the proper data acquisition ports within the shear tester's environmental chamber. Zero the shear and vertical LVDTs.

8.5. Confirm that the vertical test system heads are positioned to allow the platen-specimen assembly to slide between the bottom horizontal and top vertical heads. Confirm that the horizontal test head is positioned such that the top and bottom test heads are aligned vertically. Center the specimen between the heads and secure the platens to the heads. Close the environmental chamber.

8.6. Confirm that the environmental chamber temperature control is activated and on the proper setting to maintain the required test temperature with a tolerance of ±0.5°C. Allow the specimen temperature to stabilize for a minimum of 20 min and a maximum of 60 min. This stabilization time allows the specimen to reacquire the proper test temperature (lost during LVDT instrumentation) and for the LVDTs to stabilize after the temperature change.

8.7. Execute the simple shear test at constant height.

8.7.1. Determine the specified shear stress level for the test. Perform the test by increasing the shear stress at a rate of 70 kPa/s to: 345 ± 5 kPa (4°C); 105 ± 5 kPa (20°C); or 35 ± 1 kPa (40°C). Maintain the stress at the specified level for 10 ± 1 s. Reduce the shear stress to 0 kPa at a rate of 25 ± 1 kPa/s. Continue the test at a stress level of 0 kPa for an additional 10 ± 1 s. During the test, maintain the specimen height constant, within ±0.013 mm, by applying sufficient axial stress during the loading cycle. This is accomplished by controlling the vertical actuator using closed-loop feedback from the axial LVDT.

8.7.2. Record the axial and shear deformations (from the LVDTs) and axial and shear loads. Record at a minimum rate of 50 data points per second.

8.7.3. At the conclusion of the test, release the loads and return the actuators to the pretest position. Switch the control back to the actuators (from the axial LVDT) and disconnect the LVDTs.

8.8. Remove the specimen from the test chamber.

Note 15—The simple shear test at constant height takes approximately 30 min to execute from the time the specimen is removed from the conditioning chamber until the test is completed and the specimen is removed from the shear tester.

8.9. If the simple shear test will be executed at other test temperatures, either: (a) return the specimen to the conditioning chamber and change the temperature of the SST and conditioning chamber to the next desired temperature; or (b) set the specimen aside without cleaning and wait until the temperature of the SST chamber can be adjusted.

8.10. Once the simple shear test has been executed at all desired temperatures, clean the specimen from the platens by placing the specimen-platen assembly in an oven at approximately 135°C for 60 min to debond the specimen and adhesive from the platens. Scrape the platens clean with a scraper. Use acetone or other suitable solvent to remove any remaining adhesive.

9. PROCEDURE C—REPEATED SHEAR TEST AT CONSTANT HEIGHT

9.1. Turn on the hydraulic system at least 1 h before starting the test to allow sufficient warm-up time. Warm up the actuators and hydraulic oil by using a sinusoidal waveform in stroke control.

9.2. Determine the test temperature (Note 15) and precondition the test specimens from 2 to 4 h at the required test temperature ±0.5°C (Note 11). Set the temperature for the environmental chamber of the shear test device at the required test temperature.

Note 16—The test temperature can be determined in many ways, but is most commonly calculated as the 7-day maximum pavement temperature (at a depth of 50 mm) for the project location. If the mixture in question is the wearing (surface) course, and the thickness of the layer is less than 50 mm, then the actual layer thickness (e.g., 38 mm) may be used as the depth for calculating the test temperature. Information on calculating pavement temperatures is available in SHRP A-648A and LTPP's LTPPBind software.

9.3. After the conditioning period, remove the specimen (attached to platens) from the conditioning chamber. Quickly attach the shear and vertical linear variable differential transformers to the specimen platens. Open the environmental chamber of the shear tester and place the specimen on the shear table.

9.4. Ensure that the LVDTs are plugged into the proper data acquisition ports within the shear tester's environmental chamber. Zero the shear and vertical LVDTs.

9.5. Confirm that the vertical test system heads are positioned to allow the platen-specimen assembly to slide between the bottom horizontal and top vertical heads. Confirm that the horizontal test head is positioned such that the top and bottom test heads are aligned vertically. Center the specimen between the heads and secure the platens to the heads. Close the environmental chamber.

9.6. Confirm that the environmental chamber temperature control is activated and on the proper setting to maintain the required test temperature with a tolerance of ±0.5°C. Allow the specimen temperature to stabilize for a minimum of 20 min and a maximum of 60 min. This stabilization time allows the specimen to reacquire the proper test temperature (lost during LVDT instrumentation) and for the LVDTs to stabilize after the temperature change.

9.7. Execute the repeated shear test at constant height.

9.7.1. Apply a repeated haversine shear stress to the test specimen consisting of 69 ± 5 kPa (approximately 1220-N shear load for a 150-mm diameter test specimen) for 0.1 s followed by a 0.6-s rest period. During the loading cycle, maintain the specimen height constant, within ±0.013 mm, by applying sufficient axial stress during the loading cycle. This is accomplished by controlling the vertical actuator using closed-loop feedback from the axial LVDT.

9.7.2. Continue the test sequence for 5000 cycles or until the shear LVDT exceeds its range (usually at 2.5-mm or 5 percent shear strain), whichever comes first.

9.7.3. Record the axial and shear deformations (from the LVDTs) and axial and shear loads. Record at a minimum rate of 50 data points per second during the intervals specified in Table 2.

Table 2—Required Interval Ranges for Recording Data for Procedures B and C

Data	Cycles
1 through 10	1599 through 1601
19 through 21	1799 through 1801
29 through 31	1999 through 2001
49 through 51	2249 through 2251
79 through 81	2499 through 2501
99 through 101	2749 through 2751
199 through 201	2999 through 3001
299 through 301	3249 through 3251
399 through 401	3499 through 3501
499 through 501	3749 through 3751
599 through 601	3999 through 4001
799 through 801	4249 through 4251
999 through 1001	4499 through 4501
1199 through 1201	4749 through 4751
1399 through 1401	4999 through 5000

9.7.4. At the conclusion of the test, release the loads and return the actuators to the pretest position. Switch the control back to the actuators (from the axial LVDT) and disconnect the LVDTs.

9.8. Remove the specimen from the test chamber.

Note 17—The repeated shear test at constant height takes approximately 90 min to execute from the time the specimen is removed from the conditioning chamber until the test is completed and the specimen is removed from the shear tester.

9.9. Clean the specimen from the platens by placing the specimen-platen assembly in an oven at approximately 135°C for 60 min to debond the specimen and adhesive from the platens. Scrape the platens clean with a scraper. Use acetone or other suitable solvent to remove any remaining adhesive.

10. DATA ANALYSIS

10.1. *Procedure A (Shear Frequency Sweep Test at Constant Height)*—For each specimen, determine the complex shear modulus (G^*) and phase angle (δ) at each frequency. These values are usually calculated by software programs from the measured values of shear load, axial load, shear displacement, and axial displacement.

10.2. *Procedure B (Simple Shear Test at Constant Height)*—For each specimen, calculate the maximum shear strain achieved in Equations 1 and 2:

$$\gamma_{max} = \frac{\delta_{\text{shear, maximum}} - \delta_{\text{shear, initial}}}{h} \quad (1)$$

where:

γ_{max} = maximum shear strain;
$\delta_{\text{shear, maximum}}$ = maximum recorded deformation by the shear LVDT;
$\delta_{\text{shear, initial}}$ = initial shear deformation at the start of the test (nominally zero); and
H = specimen height (platen-to-platen measurement only).

10.2.1. The recovery can also be calculated as follows:

$$\text{recovery} = \frac{\delta_{\text{shear, maximum}} - \delta_{\text{shear, final}}}{\delta_{\text{shear, maximum}}} \quad (2)$$

where:

recovery = calculated recovery of the specimen;
$\delta_{\text{shear, maximum}}$ = maximum recorded deformation by the shear LVDT; and
$\delta_{\text{shear, final}}$ = final recorded shear deformation at the end of the test.

10.3. *Procedure C (Repeated Shear Test at Constant Height)*—For each specimen, determine the permanent shear strain at the end of the test (nominally 5000 cycles). The permanent shear strain (γ_p) is calculated as the change in shear deformation from the start of the test to the end of the test divided by the gauge length (nominally 50 mm when using platen-to-platen measurement) in Equation 3:

$$\gamma_p = \frac{\delta_{\text{shear, final}} - \delta_{\text{shear, initial}}}{h} \quad (3)$$

where:

γ_p = permanent shear strain;
$\delta_{\text{shear, final}}$ = final recorded deformation by the shear LVDT at the end of the test;
$\delta_{\text{shear, initial}}$ = initial shear deformation at the start of the test (nominally zero); and
H = specimen height (platen-to-platen measurement only).

10.3.1. The permanent shear strain can also be expressed as a percentage by multiplying by 100.

11. REPORT

11.1. *Report the following information for each test specimen*:

11.1.1. Mixture identification and specimen identification;

11.1.2. Percentage of air voids in the test specimen, or bulk specific gravity;

11.1.3. Conditioning time and temperature (within 0.1°C);

11.1.4. Equilibration or stabilization time, minutes;

11.1.5. Measured temperature during the test (within 0.1°C);

11.1.6. Note any deviations from the test procedures for each specimen (i.e., shear loads out of tolerance).

11.2. *Report the following information for Procedure A (Shear Frequency Sweep Test at Constant Height)*:

11.2.1. For each specimen, report the complex shear modulus (G^*) and phase angle (δ) at each frequency.

11.3. *Report the following information for Procedure B (Simple Shear Test at Constant Height)*:

11.3.1. For each specimen, report the maximum shear strain obtained (usually expressed in terms of microns, or 10^{-6} mm/mm) and recovery (expressed as a percentage).

11.4. *Report the following information for Procedure C (Repeated Shear Test at Constant Height)*:

11.4.1. For each specimen, report the permanent shear strain obtained at 5000 cycles. If the test stops before 5000 cycles, report the permanent shear strain and the number of cycles.

12. PRECISION AND BIAS

12.1. *Precision*—The research required to develop precision estimates for the shear frequency sweep, simple shear, and repeated shear test procedures has not been formally conducted.

12.2. *Bias*—The research required to determine the bias of the procedures has not been conducted.

13. KEYWORDS

13.1. Frequency sweep; permanent strain; repeated shear; shear testing; simple shear; stiffness.

APPENDIX

(Nonmandatory Information)

X1. CALCULATING AGGREGATE BATCH WEIGHT FOR LABORATORY-MIXED, LABORATORY-COMPACTED SPECIMENS

X1.1. Calculate the aggregate batch weight required for laboratory-mixed, laboratory-compacted (LMLC) specimens, using Equation X1.1 (valid for 150-mm diameter specimens):

$$\text{mass} = \frac{17.671 \times \text{height} \times G_{mm} \times (1 - AV)}{(1 - AC)} \quad (X1.1)$$

where:

mass = aggregate batch weight, g;

height = target compacted height of the specimen, mm;

G_{mm} = maximum theoretical specific gravity (T 209) of the mixture;

AV = percentage of air voids desired, expressed as a decimal (i.e., 0.04 rather than 4.0 percent); and

AC = asphalt binder content of the mix, expressed as a decimal (i.e., 0.045 rather than 4.5 percent).

Example: A mixture with a 5.2 percent asphalt binder content and a G_{mm} of 2.533 is intended to be evaluated in the repeated shear test to estimate rutting susceptibility. The technician desires the test specimen to have 4.0 ± 0.5 percent air voids. Therefore, anticipate compacting a specimen to a height of 75 mm and allowing a 1 percent offset in air voids between the compacted specimen and the cut test specimen (Note 8). Using Equation X1.1, the aggregate batch weight is determined:

$$\text{mass} = \frac{17.671 \times 75 \times 2.533 \times (1 - 0.05)}{(1 - 0.052)} = 3364 \text{ g} \quad (X1.2)$$

X2. CALCULATING MIXTURE SAMPLE WEIGHT FOR FIELD-MIXED, LABORATORY-COMPACTED SPECIMENS

X2.1. Calculate the mixture sample weight required for field-mixed, laboratory-compacted (FMLC) specimens, using Equation X2.1 (valid for 150-mm diameter specimens):

$$\text{mass} = 17.671 \times \text{height} \times G_{mm} \times (1 - AV) \quad (X2.1)$$

where:

mass = aggregate batch weight, g;

height = target compacted height of the specimen, mm;

G_{mm} = maximum theoretical specific gravity (T 209) of the mixture; and

AV = percentage of air voids desired, expressed as a decimal (i.e., 0.04 rather than 4.0 percent).

X2.2. Alternatively, determine the compacted specimen height if the sample mass is known:

$$\text{height} = \frac{\text{mass}}{17.671 \times G_{mm} \times (1 - AV)} \quad (X2.2)$$

Example: A mixture sample of 4220 g is obtained. The G_{mm} of the mixture is determined to be 2.471. To produce a test specimen having approximately 4.0 ± 0.5 percent air voids, the target compacted height should be calculated as follows:

$$\text{height} = \frac{4220}{17.671 \times 2.47 \times (1 - 0.05)} = 101.7 \text{ mm} \quad (X2.3)$$