Designation: D8303 – 20

Standard Test Method for Determining Thermal Cracking Properties of Asphalt Mixtures Through Measurement of Thermally Induced Stress and Strain[1]

This standard is issued under the fixed designation D8303; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This method of test is used to determine the thermal viscoelastic and thermal volumetric properties of field-cored or laboratory-compacted asphalt mixture specimens by measuring the thermally induced stress and strain while being cooled at a constant rate from an initial equilibrium temperature. The thermal stress and strain shall be measured using the uniaxial thermal stress and strain tester (UTSST).

1.2 This standard test method covers procedures for preparing and testing asphalt mixtures to measure thermal stress and strain and directly calculate: (*1*) the coefficient of axial thermal contraction, and (*2*) the modulus of asphalt mixture over a range of temperatures.

1.3 The procedure described in this standard provides required information for estimation of thermal cracking susceptibility of asphalt mixtures. The procedure applies to test specimens having a maximum aggregate size of 19 mm or less.

1.4 This standard can be used for conventional and nonconventional asphalt mixtures including but not limited to: hot asphalt mixtures, asphalt mixture with recycled materials, cold asphalt mixtures, warm asphalt mixtures, and neat or modified asphalt mixtures (for example, polymer or rubber-modified).

1.5 This standard can be used to determine the following:

1.5.1 Thermal stress buildup in asphalt mixture during a single cooling event.

1.5.2 Thermal strain in asphalt mixtures as a function of temperature.

1.5.3 Coefficient of axial thermal contraction.

1.5.4 Modulus of asphalt mixture as a function of temperature.

1.5.5 Thermal viscoelastic properties of asphalt mixture: viscous softening, viscous-glassy transition, glassy hardening, crack initiation, fracture temperature, and fracture stress.

1.5.6 UTSST cracking resistance index (*CRI*).

1.5.7 UTSST *CRI* adjusted for environmental condition (CRI_{Env}).

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

D8 Terminology Relating to Materials for Roads and Pavements

D979/D979M Practice for Sampling Bituminous Paving Mixtures

D2041/D2041M Test Method for Theoretical Maximum Specific Gravity and Density of Asphalt Mixtures

D2726/D2726M Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Asphalt Mixtures

D3203/D3203M Test Method for Percent Air Voids in Compacted Asphalt Mixtures

D3549/D3549M Test Method for Thickness or Height of

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.26 on Fundamental/Mechanistic Tests.

Current edition approved July 1, 2020. Published July 2020. DOI: 10.1520/D8303-20.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Compacted Asphalt Mixture Specimens
D3665 Practice for Random Sampling of Construction Materials
D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
D5361/D5361M Practice for Sampling Compacted Asphalt Mixtures for Laboratory Testing
D6752/D6752M Test Method for Bulk Specific Gravity and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method
D6857/D6857M Test Method for Maximum Specific Gravity and Density of Asphalt Mixtures Using Automatic Vacuum Sealing Method
D6925 Test Method for Preparation and Determination of the Relative Density of Asphalt Mix Specimens by Means of the Superpave Gyratory Compactor
D7981 Practice for Compaction of Prismatic Asphalt Specimens by Means of the Shear Box Compactor
D8079 Practice for Preparation of Compacted Slab Asphalt Mix Samples Using a Segmented Rolling Compactor
F1684 Specification for Iron-Nickel and Iron-Nickel-Cobalt Alloys for Low Thermal Expansion Applications

2.2 *AASHTO Standard:*[3]
R 30 Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)

3. Terminology

3.1 *Definitions*—For definitions of general terms used in this standard, refer to Terminology D8.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of axial thermal contraction, α(T), n*—the fractional change in size in the axial direction associated with a temperature change (/°C).

3.2.2 *cooling rate (°C/hour), n*—constant rate at which the temperature of the asphalt mixture specimen decreases with time during the test.

3.2.3 *crack initiation stage, n*—in this stage micro-cracks occur in the specimen due to the induced thermal stresses when the asphalt mixture is characterized as glassy.

3.2.4 *critical temperature (°C), $T_{critical}$, n*—critical low pavement temperature for a given project location.

3.2.5 *fracture stage, n*—at this stage the asphalt mixture specimen breaks due to the propagation of micro-cracks by the induced thermal stress.

3.2.5.1 *Discussion*—Identification of fracture is indicated by a significant reduction in the sustained load (25 % of the maximum load or greater) or global fracture of the specimen.

3.2.6 *fracture stress (kPa), n*—thermal tensile stress at fracture stage of the restrained specimen.

3.2.7 *fracture temperature (°C), $T_{fracture}$, n*—temperature at fracture stage of the restrained specimen.

3.2.8 *glassy hardening stage, n*—at this stage the behavior of the asphalt mixture is considered glassy.

3.2.9 *initial starting temperature (°C), $T_{initial}$, n*—temperature from which the test starts cooling the specimens at a constant rate.

3.2.9.1 *Discussion*—The asphalt mixture specimens have to be at thermal equilibrium at the initial starting temperature prior to the starting of the test.

3.2.10 *micro-crack, n*—microscopic damage initiated at a certain temperature in the restrained specimen while cooling, which leads to macro-cracking and eventually the fracture of the specimen.

3.2.11 *thermal viscoelastic properties, n*—viscoelastic properties of the asphalt mixture determined from the thermal loading history, including the viscous softening, viscous-glassy transition, glassy hardening, and crack initiation properties.

3.2.12 *uniaxial thermal strain (mm/mm), $\varepsilon(T_u)$, n*—accumulated axial contraction strain induced in the unrestrained specimen by decreasing the temperature from $T_{initial}$ when the sample is free to contract axially.

3.2.13 *uniaxial thermal stress (MPa), $\sigma(T_r)$, n*—accumulated axial tensile stress induced in the specimen by decreasing the temperature from $T_{initial}$ at a constant rate while maintaining the length of restrained specimen at the initial starting temperature length.

3.2.14 *UTSST modulus (MPa), $E_{UTSST}(t, T)$, n*—the time and temperature-dependent modulus of the asphalt mixture.

3.2.14.1 *Discussion*—The modulus is determined using simultaneous measures of thermal stress and strain resulting from the same change in temperature.

3.2.15 *viscous-glassy transition stage, n*—at this stage the glassy properties of the asphalt mixture overcome its viscous properties.

3.2.16 *viscous softening stage, n*—from this stage the relaxation modulus of the asphalt mixture increases rapidly, mostly in a linear fashion, with decreases in temperature.

4. Summary of Test Method

4.1 This standard describes the procedure for determining the thermal stress and thermal strain measurements from the axial restrained and axial unrestrained asphalt mixture specimens, respectively. The thermal stress and strain shall be determined using the uniaxial thermal stress and strain tester (UTSST).

4.2 Two cylindrical asphalt mixture specimens are cored or cut (or both) from Superpave gyratory or shear box compacted specimens, or from field cores of specific dimensions.

4.2.1 The restrained specimen is restricted from axial contraction by fixing to platens of a test system and is enclosed within an environmental chamber. A small initial tensile load is applied to the specimen and the specimen is cooled at a given temperature rate. The thermal contraction along the long axis of the specimen is monitored using linear variable displacement transformers (LVDTs) or other acceptable transducer, and the initial length of the specimen is maintained by automatic adjustment of the platens by the test system. The cooling process continues until tensile fracture of the restrained specimen occurs.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

4.2.2 Concurrently, an unrestrained specimen is set on a nearly frictionless roller stand or oriented vertically while maintaining zero load and contraction along the long axis of the specimen is recorded while cooling using LVDTs. The unrestrained sample is made by gluing two cylindrical specimens cored or cut (or both) from Superpave gyratory or shear box compacted specimens or field core specimens.

4.3 The induced strain measured data are used to determine the coefficient of axial thermal contraction.

4.4 The induced thermal stress and strain measured data are combined to determine the modulus of asphalt mixture, and to characterize the thermal viscoelastic properties of the asphalt mixture at different stages of the material behavior.

4.5 The thermal strain is determined by measuring the uniaxial deformation from an asphalt mixture specimen during cooling from an initial equilibrium temperature while it is free to contract without any restraint in a nearly frictionless apparatus.

4.6 The modulus is determined from the concurrent measured data of thermal stress and strain data from restrained and unrestrained asphalt mixture specimens, respectively.

4.7 The thermal viscoelastic properties of the asphalt mixture, including viscous softening, viscous-glassy transition, glassy hardening, and crack initiation are determined from the modulus curve in the temperature domain. The fracture stress and fracture temperature are determined from the induced thermal stress curve in the temperature domain.

4.8 The UTSST cracking resistance index (*CRI*) is calculated from the thermal stress-strain curve and adjusted for environmental conditions to obtain CRI_{Env}.

5. Significance and Use

5.1 The thermal strain measurements allow for the calculation of the coefficient of axial thermal contraction, which can be directly used in the mechanistic-empirical pavement design methods.

5.2 The thermal stress and strain measurements allow calculations of the modulus of asphalt mixture in the temperature domain.

5.3 From modulus versus temperature and thermal stress versus temperature relationships the thermal viscoelastic and fracture properties are determined for asphalt mixtures.

5.4 The derived modulus, thermal viscoelastic, and fracture properties may be used in evaluating the low-temperature cracking resistance of asphalt mixtures.

NOTE 1—The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Specification D3666 are generally considered capable of competent and objective testing, sampling, inspection, etc. Users of this standard are cautioned that compliance with Specification D3666 alone does not completely ensure reliable results. Reliable results depend on many factors; following the suggestions of Specification D3666 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.

6. Apparatus

6.1 *Uniaxial Thermal Stress and Strain Tester (UTSST)*—A closed-loop servo-controlled test system, as described in Fig. 1, capable of cooling unrestrained and restrained asphalt mixture specimens at a constant rate from an initial starting temperature through failure of the restrained specimen. The system shall be capable of measuring the tensile load in the restrained specimen, contraction deformation in the unrestrained specimen, and the temperature from a control specimen.

6.1.1 *Closed-Loop Servo-Controlled Test System*—A system capable of applying or maintaining the developed load based upon the response of two or more LVDTs attached to the restrained specimen. The test is conducted by allowing no net change in the LVDT displacement, that is, the platens must be held at a constant distance from each other with a minimum operational frequency of 60 Hz, for example, 60 actuator adjustments per second. The minimum capacity of the loading system is 20 kN including the load measurement device, that

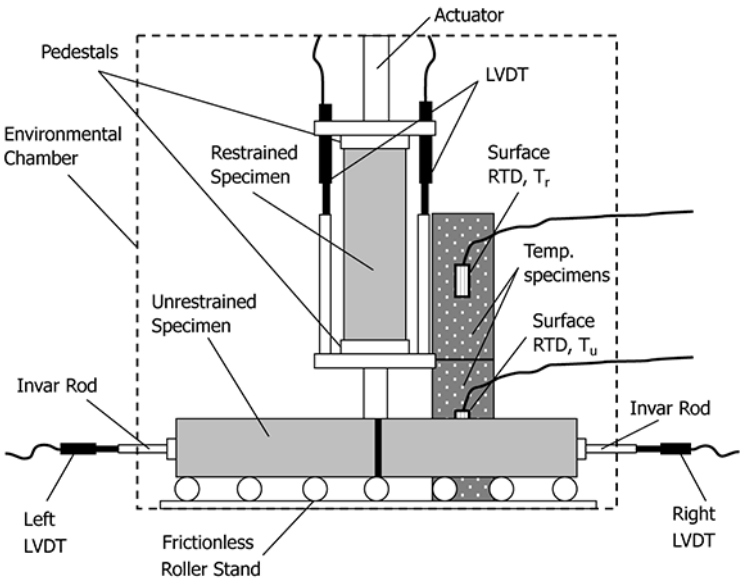

FIG. 1 Uniaxial Thermal Stress and Strain Tester (UTSST)

is, load cell and any attachment and connection fixtures such as described in 6.1. The measurements of the LVDTs within the environmental chamber must be corrected to remove the influence of the temperature change, whether electrical, mechanical, or a combination of both. This correction can be waived if the thermal influence has been verified and recorded to remain within the accuracy limits of 6.3.

NOTE 2—It has been found beneficial to include a safety mechanism within the control system to limit the movement of actuator following global failure of the restrained specimen to prevent damage of the restrained LVDTs. This mechanism may operate by any number of processes, but the intent is to prevent undesired movement of the actuator if the restrained specimen exhibits global fracture and moves far enough for the control LVDTs to lose contact with the connecting rods. Examples of such features may include limit switches on the magnitude of the restrained LVDTs, actuator movement, substantial drop in tensile loads (for example, 75 %), or development of compressive loads in the restrained specimen.

6.2 *Load Measurement*—Load levels are to be measured using a load cell with a resolution of 0.01 kN and an accuracy of 0.02 kN or smaller, or equivalent load measurement device.

6.3 *Deformation Measurements*—The deformation of the restrained and unrestrained samples can be measured by linear variable displacement transducers (LVDTs) or other suitable devices with a minimum range of 0.5 mm. The resolution and accuracy of the LVDTs or other device must be at least 0.01 mm and 0.02 mm, respectively.

6.4 *Temperature Measurement*—The temperature measurement and control is done using surface-mounted resistance temperature detectors (RTDs) or other suitable devices with a calibrated range of at least 30 °C to –50 °C with resolution of 0.1 °C and accuracy of 0.2 °C which have been installed on the temperature or dummy specimens in accordance with the manufacturer's recommendations.

6.5 *Restrained Specimen Mild Steel Platens*—Two platens per specimen, either circular (150 mm ± 25 mm) in diameter, square, or other geometry to provide similar surface area of sufficient thickness to prevent significant deflection during sample testing.

NOTE 3—Mild steel as defined in Specification A36/A36M platens with a diameter of 150 mm ± 25 mm and 25 mm thick with 9.5 mm hole diameters, or sufficient to match the LVDT diameter, spaced at 120° with a radial spacing of 50 mm, have been found sufficient for this purpose.

6.5.1 Each platen shall have holes containing set screws of the appropriate diameter to hold the LVDTs and the extension rods on the restrained specimen. These holes shall be at a constant and measurable radial distance and should align along the same axis (Fig. 2).

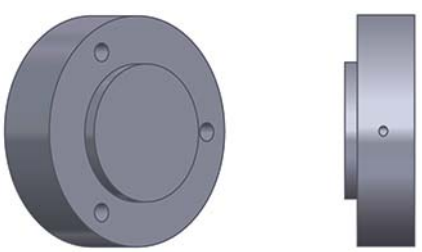

FIG. 2 Sketch of Restrained Specimen Platens

6.5.2 Each platen shall also have a pedestal approximately 5 mm in height and the same diameter as the specimen oriented along the central axis of the platen that will be used as a physical aid in aligning the restrained specimen during the gluing operations. The pedestal shall be machined along with the platen and not be a separate component.

6.6 *Environmental Chamber*—The environmental chamber shall be large enough to include the testing fixture described in the test method and equipped with temperature conditioners and controls capable of maintaining a test temperature between 30 °C and at least –50 °C inside the chamber with a predefined constant rate for cooling.

6.7 *Cooling/Heating System*—A cooling/heating system capable of applying temperatures as high as 30 °C and as low as –50 °C at a constant rate up to 20 °C/h is required. Air flow cooling systems may be utilized for this purpose.

6.8 *Thermally Stable Rods*—Rods made of invar (conforming to Specification F1684) or other equivalent material (for example, certain ceramics) with similarly low coefficient of thermal expansion and contraction of sufficient geometry to permit the necessary measurement and subsequent restraint of the asphalt mixture specimen.

6.8.1 For the restrained specimen, each LVDT requires one rod of sufficient length to span the distance between the two restrained specimen platens with a specimen glued in place, less a space of 20 mm ± 5 mm to permit room for the control LVDTs.

6.8.2 The unrestrained specimen requires one rod for each of the two LVDTs of sufficient geometry to permit physical connection between the unrestrained specimen and the unrestrained LVDTs, which may depend upon the test configuration.

NOTE 4—The unrestrained rods should be manufactured in a manner to reduce the amount of weight and potential for sagging or creep movement when cantilevered from the ends of the specimen. A geometry similar to that depicted in Fig. 1, with a nominal diameter of 5 mm ± 1 mm, has been found sufficient for this purpose.

6.9 *Deformation Measurement Device for Unrestrained Specimen*—The unrestrained asphalt mixture specimen may be measured by different orientations depending upon the specific configurations of the testing device.

6.9.1 *Horizontal-External*—In the horizontal-external configuration, the unrestrained specimen is placed in a horizontal configuration on a nearly frictionless roller stand during the test. The rollers should be smooth enough and have free movement to minimize friction. The asphalt mixture must be free to contract during cooling in order to obtain accurate strain measurements. Two invar rods are glued to the ends of the unrestrained specimen and must be long enough to extend to the outside of the environmental chamber to make contact with the LVDTs, which are maintained outside of the environmental chamber. This configuration is presented schematically in Fig. 1.

6.9.2 *Horizontal-Internal*—In the horizontal-internal configuration, the unrestrained specimen is placed in a horizontal configuration on a nearly frictionless roller stand during the test, in a similar manner to the externally measured

specimen. However, the measurement LVDTs and corresponding attachment configurations may vary with equipment geometry. The inclusion of the measurement LVDTs within the environmental chamber requires the same thermal correction of the LVDTs as in 6.1.1.

6.9.3 *Vertical-Internal*—In the vertical-internal configuration, a single unrestrained specimen is oriented in a vertical configuration, but is still unrestrained from thermal contraction and should be permitted to move without restriction. Although specific connections and configurations may vary by device, an example of the orientation is depicted by the restrained specimen presented in Fig. 1. However, the actuator may not restrict the thermal contraction of the CTC specimen, but such displacement shall be measured between the end plates and the LVDT extension rods as depicted in 11.2. With the LVDTs contained within the environmental chamber, the same correction in 6.1.1 applies.

NOTE 5—In addition to the LVDT thermal correction in 6.1.1, a physical correction may be required to ensure that any fixtures are not applying a force to the top end of the unrestrained specimen. Given the potential for varied configurations and designs, no specific corrections can be specified.

NOTE 6—Additional corrections should be included to account for the influence of gravitational forces adding to the thermal contraction of the vertically oriented specimen.

NOTE 7—Certain testing devices may not have sufficient space to permit the usage of two end-to-end samples for the unrestrained specimens. Thus a single sample may be used, provided the configuration includes sufficient accuracy in the displacement measurement and has been determined to not influence the final CTC determination compared to either of the horizontal unrestrained orientations.

6.10 *Data Acquisition System*—The data acquisition system shall be used to record the developed load in the restrained specimen, contraction deformation of unrestrained specimen, and the temperature of a control specimen over the duration of the test.

6.11 *Specimen Alignment Stand*—A device capable of providing concentric and perpendicular alignment of the platens/screw holes and restraining the specimen within axial alignment of the platen while the epoxy cures.

6.11.1 The alignment stand for the restrained specimen should rigidly affix the platens parallel and concentric to each other and permit the distance between the platens to be readily adjusted. The stand should also provide adjustable support to retain the specimen once it is concentrically aligned with the platens. It should also be capable of applying a small load or weight to the top platen to ensure complete contact and aid in bonding of the epoxy.

NOTE 8—Fig. 3 presents an example of a device that has been found satisfactory for gluing the restrained specimen.

6.11.2 The alignment stand for the unrestrained specimen shall be capable of restraining the specimens and the invar rods in axial alignment with each other. While being restrained, the specimens and the invar rods shall be compressed under a small load or weight to permit the adequate bonding of all epoxied surfaces, but not so large as to deform or damage the specimens.

NOTE 9—Fig. 4 presents an example of a device that has been found satisfactory for gluing the unrestrained specimen.

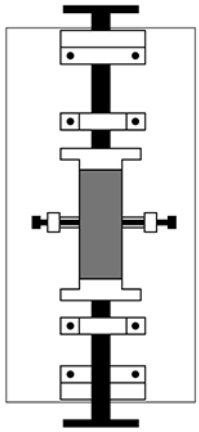

FIG. 3 Schematic Diagram of a Specimen Alignment Stand for the Restrained Specimen

6.12 *Square*—Precision square with a minimum 100 mm beam and 150 mm blade.

NOTE 10—McMaster Carr, High Accuracy Square, Catalog Number 2278A14 (www.mcmaster.com/#layout-squares/=15s569r) or equivalent has been found satisfactory for this purpose.

6.13 *Carbon Steel Wires*—Two carbon steel wires, 1.0 mm and 0.5 mm diameters, with a nominal length of 50 mm or longer.

NOTE 11—McMaster Carr, Catalog Numbers 8907K42 and 8907K21 or equivalent, respectively, have been found satisfactory for this purpose.

6.14 *Scale or Balance*—Scale or balance as necessary for Test Method D2041/D2041M, D2726/D2726M, D3203/D3203M, D6752/D6752M, or D6857/D6857M, which shall also be used to measure out epoxy proportions.

6.15 *Miscellaneous Apparatus*—Spatula (for proportioning and mixing epoxy components), metals pans, masking tape, and gloves.

7. Reagents and Materials

7.1 *Epoxy*—An epoxy with similar thermal properties (coefficient of thermal contraction) to asphalt mixtures and adequate adhesive properties at a temperature range of 30 °C to –50 °C is needed in several portions of the specimen preparation.

NOTE 12—Devcon Plastic Steel Putty (A) 10110 has been found satisfactory for this purpose, but is covered by a patent. Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

7.2 *Miscellaneous Materials*—240 grit sandpaper, masking or painter's tape, and acetone or other degreaser.

8. Hazards

8.1 Follow the safety requirements listed in the manufacturer's safety information sheet when using epoxy and acetone.

8.2 Portions of this test method include temperatures well below freezing. Exposure to low temperatures, whether in

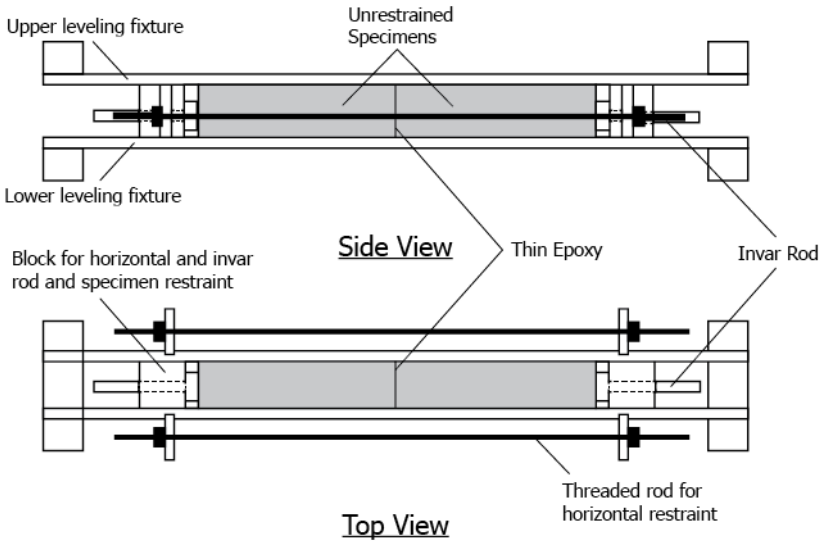

FIG. 4 Schematic Specimen Alignment Stand for the Unrestrained Specimen

direct contact or not, may cause burns or other health risks. Appropriate personal protective equipment (PPE) is recommended.

9. Test Specimens

9.1 *Laboratory Mixed Laboratory Compacted Asphalt Mixture Specimens*—Mix and compact the asphalt mixture specimens according to Test Method D6925 using the 150 mm diameter molds or other means of compaction described in Practices D7981 and D8079 to obtain test specimens. Follow the short-term and long-term aging recommendations of AASHTO Practice R 30 for mixture mechanical testing. Specimens should be compacted to obtain a target air void level ±0.5 % after trimming to the final dimensions as determined by Test Method D3549/D3549M.

9.2 *Plant Mixed Laboratory Compacted Asphalt Mixture Specimens*—Obtain the asphalt mixture samples in accordance with Practice D979/D979M. Reduce the sample to the appropriate specimen sizes according to Practice D5361/D5361M. Follow the applicable section of Test Method D6925 to compact the specimens using the 150 mm diameter molds or other means of compaction described in Practices D7981 and D8079 to obtain test specimens. Follow long-term aging recommendations of AASHTO Practice R 30 for mixture mechanical testing. Specimens should be compacted to obtain a target air void level ±0.5 % after trimming to the final dimensions as determined by Test Method D3549/D3549M.

9.3 *Plant Mixed Field Compacted Asphalt Mixture Specimens*—Obtain field cores in accordance with Practice D979/D979M, to obtain core samples nominally 150 mm in diameter and thick enough to core UTSST specimen from the layer of interest. Take care to prevent deformation or other disturbance of the samples during storage and transport to the testing location. When the samples are taken from existing pavement, obtain them in accordance with Practice D3665, unless specific locations are under investigation.

9.4 *Coring of Test Specimens*—Obtain the test specimens by laying the sample, either SGC sample or field core, on its side and core the test specimen 90° from the axis of compaction with a suitable coring operation to produce test specimens meeting the geometry requirements outlined in this section. Depending on the nominal maximum aggregate size (NMAS) of the mixture, the cored specimens, after side-coring, shall be 57 mm ± 5 mm in diameter for 19 mm NMAS mixtures and 45 mm ± 5 mm in diameter for 12.5 mm or smaller NMAS mixtures, respectively. However, the 57 mm samples may be used for 12.5 mm or smaller NMAS mixtures as well.

9.4.1 Trim the length of the side-cut cores using a suitable trimming device so that the ends of the sample are as perpendicular as possible to the sides. The length of the specimens shall be as long as possible, but sufficient to remove the curvature from the original sample geometry, as applicable to cores or Superpave gyratory samples. The final length of the test specimens should be no shorter than 132 mm.

9.4.2 Using the blade of the precision square as a straightedge, check the flatness of each end at three locations approximately 120° apart. At each location, place the blade of the precision square across the diameter of the specimen and check the maximum departure of the specimen from the blade using the 0.5 mm diameter carbon steel wire. Reject specimens if the 0.5 mm diameter carbon steel wire fits between the blade and the specimen at any location.

9.4.3 Check the perpendicularity of each end of the specimen using the precision square and the 1.0 mm carbon steel wire at two locations approximately 90° apart. Place the precision square on a table with the beam in contact with the table and the blade extending vertically. Place the long axis of the specimen on the beam such that the blade is in contact with the end of the specimen. Check the maximum departure of the specimen from the blade using the 1.0 mm diameter carbon steel wire. Reject specimens if the 1.0 mm diameter carbon steel wire fits between the blade and the specimen at any location.

9.5 *Bulk Specific Gravity*—Determine the bulk specific gravity according to Test Method D2726/D2726M or D6752/D6752M and the corresponding air voids in accordance with Test Method D3203/D3203M, making use of Test Method D2041/D2041M or D6857/D6857M.

9.6 *Drying of the Specimens*—Ensure the specimens are dry from appreciable moisture after the specific gravity determinations either by air drying in front of high-output fans for several days, or other sufficient means not to exceed 38 °C or produce observable deformation of the specimens. If fan drying, specimens shall be designated as dry once a constant mass has been achieved (mass repeats within 0.1 % following an additional 1 h of fan drying).

9.7 *Measurement of Core Specimens*—Determine the dimensions, diameter and height, of the specimens in accordance with Test Method D3549/D3549M. Use the average diameter to determine the cross-sectional area of the restrained specimen. Use the average height to determine the length of unrestrained specimen. Calculate the cross-sectional area to the nearest 1 mm^2 using the average measured specimen diameter and the height to the nearest 0.1 mm.

10. Specimen Preparation

10.1 *Restrained Specimen Preparation:*

10.1.1 *Platen Preparation*—Sand the platen surface with sandpaper to completely remove any epoxy or specimen-end residue remaining from prior tests and to provide a rough surface for epoxy adhesion. Clean the surface of the platen using acetone or other degreaser to remove all the debris remaining on the surface after sanding.

10.1.2 *Restrained Specimen Preparation*—Verify that the specimen has been sufficiently dried and is free from saw slurry, dust, grease, or other debris on the exterior of the specimen that may inhibit the bonding of epoxy to the surface. Prior to applying any epoxy, wrap a single layer of masking tape around the circumference of the sample, leaving the end and approximately 5 mm to 10 mm of the edge exposed and uncovered as depicted in Fig. 5. This will be to ensure a straight line of epoxy on the sample after gluing. It is recommended to leave a small tab of the tape wrapped back upon itself to aid in removal of the tape with minimal disturbance of the sample prior the epoxy setting.

FIG. 5 Example Restrained Specimen Prepared for Gluing

10.2 *Epoxy Preparation*—Follow the mixing, proportioning, applying, and curing instructions supplied by the manufacturer for the epoxy being used.

NOTE 13—If Devcon Plastic Steel Putty (A) 10110 is used, obtain 25 g or more of mixed epoxy blended by the recommended mix ratio (typically 9:1 by weight of resin and hardener, respectively). Thoroughly mix the two epoxy components until a uniform color and consistency result.

10.3 *Attaching the Restrained Specimen to Platens:*

10.3.1 Apply a 2 mm to 3 mm thick film of epoxy over the entire diameter of one end of the specimen. Holding the specimen in alignment with the center pedestal on the platen on the non-epoxied end of the specimen, apply the collar to ensure complete alignment between the sample and the platen. While holding the epoxied end in alignment with the pedestal with one's fingers, apply the axial load to ensure complete adhesion of the epoxy on the platens. While maintaining the specimen alignment, engage the horizontal alignment system to restrain the specimen in that position (Fig. 3).

10.3.2 Ensure that the epoxy has been squeezed out between the specimen and the platen pedestal and that no gaps exist around its perimeter. Ensure that the alignment of the specimen still coincides with the pedestals. Using the remainder of the epoxy, apply a small band of epoxy around the perimeter of both the specimen and the pedestal on the platen. The epoxy should cover the sample up to the masking tape and the remainder of the pedestal, but need not be a thick mass of epoxy such as a fillet weld would appear.

10.3.3 When the specimen is in alignment and restrained by the alignment stand and while the epoxy is still fresh and pliable, carefully remove the masking tape on the epoxied end of the specimen, revealing a clean line of epoxy around the perimeter of the specimen.

10.3.4 Alignment is critical to obtaining meaningful test results. Therefore, the alignment device must sufficiently align the platens and specimen, and support the specimen in a level position while the epoxy cures.

NOTE 14—Although not required, it is recommended to allow the first epoxied end of the specimen to mostly set before attempting to affix the other end. This operation can reduce the chance of misalignment due to handling while the first epoxied joint is still fresh.

10.3.5 To apply epoxy to the second end of the restrained specimen, make sure the specimen restraints are firmly in place without damaging the test specimen, remove the collar from the non-epoxied end of the specimen, and remove the load or weight to permit separation of the platen and non-epoxied end of the specimen. Visually verify that the specimen does not move and remains in alignment with the first platen. Apply a film of epoxy of approximately the same thickness as the first end to the now-exposed specimen end, making sure to get complete and uniform coverage of the specimen.

10.3.6 Make contact with the specimen and platen by applying the contact load or weight. Again, make sure the epoxy is squeezed from between the two with no gaps or voids.