INTERNATIONAL

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.

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[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

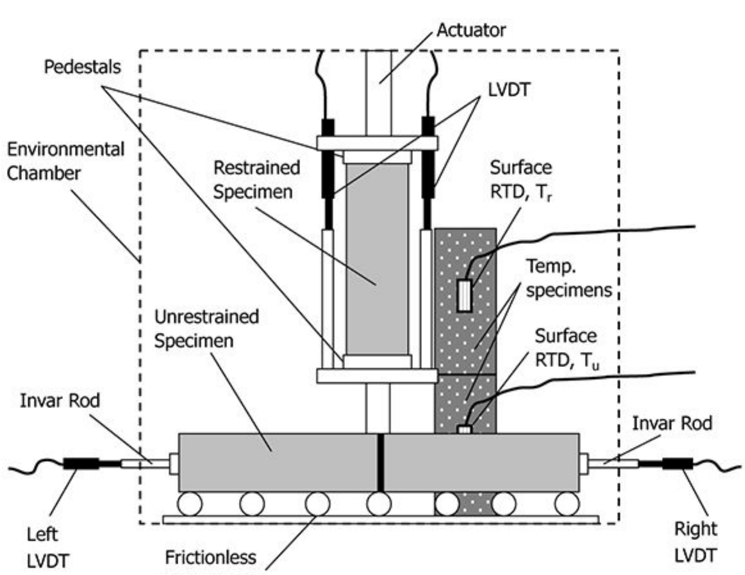

FIG. 1 Uniaxial Thermal Stress and Strain Tester (UTSST)