
Standard Method of Test for

Determining the Fracture Energy of Asphalt Mixtures Using the Semicircular Bend Geometry (SCB)

AASHTO Designation: T 394-22¹

Technically Revised: 2022

**Technical Subcommittee: 2d, Proportioning
of Asphalt–Aggregate Mixtures**



**American Association of State Highway and Transportation Officials
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1. SCOPE

- 1.1. This test method covers the determination of the fracture energy (G_f) of asphalt mixtures by means of the semicircular bend geometry (SCB). The method also includes procedures for calculating fracture toughness (K_{IC}) and stiffness (S). The SCB specimen is a half disc with a notch (its length expressed in meters) that makes an angle α with the vertical axis of the disc. The SCB test can be used to determine mode I and mixed mode I and II stress intensity factors (Lim et al., 1993). In this standard, only mode I fracture toughness is addressed (α is equal to zero).
- 1.2. The procedures in this standard provide parameters that describe the fracture resistance of asphalt mixtures at low temperatures. These parameters are used in the new low-temperature module of the *Mechanistic Empirical Pavement Design Guide*.
- 1.3. These procedures apply to test specimens having a maximum aggregate size of 19 mm or less. Specimens shall be 150 ± 9 mm in diameter and $24.7 \text{ mm} \pm 2 \text{ mm}$ thick. These procedures are valid at temperatures below the M 320 performance grade (PG) lower limit of the asphalt binder used to prepare the asphalt mixture plus 22°C.
- 1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*
- 1.5. *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 R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. AASHTO Standards:
 - < M 320, Performance-Graded Asphalt Binder
 - < M 339M/M 339, Thermometers Used in the Testing of Construction Materials

- < R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- < T 166, Bulk Specific Gravity (G_{mb}) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- < T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- < T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

2.2. *ASTM Standards:*

- < D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Asphalt Mixture Specimens
- < D5045, Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials
- < D5361/D5361M, Standard Practice for Sampling Compacted Asphalt Mixtures for Laboratory Testing
- < E399, Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials
- < E879, Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
- < E1137/E1137M, Standard Specification for Industrial Platinum Resistance Thermometers

2.3. *International Electrotechnical Commission Standard:*

- < IEC 60751: 2008 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors

2.4. *Referenced Documents:*

- < Li, X., and M. O. Marasteanu. Investigation of Low Temperature Cracking in Asphalt Mixtures by Acoustic Emission. *Road Materials and Pavement Design*, Vol. 7, No. 4. Taylor and Francis Group, England and Wales, London, SW1P 1WG, 2006, pp. 491–512.
- < Lim I. L., I. W. Johnston, and S. K. Choi. Stress Intensity Factor for Semi-Circular Specimen under Three-Point Bending. *Engineering Fracture Mechanics*, Vol. 44, No.3. Science Direct, Elsevier B.V., Amsterdam, Netherlands, 1993, pp. 363–382.

3. TERMINOLOGY

3.1. *Definitions:*

- 3.1.1. *crack mouth*—portion of the notch that is on the flat bottom surface of the specimen, that is, opposite the notch tip.
- 3.1.2. *crack mouth opening displacement (CMOD)*—relative displacement of the crack mouth.
- 3.1.3. *load line displacement (LLD)*—the displacement measured in the direction of the load application.
- 3.1.4. *linear variable differential transformer (LVDT)*—sensor device for measuring linear displacement.
- 3.1.5. *semicircular bend (SCB) geometry*—a geometry that utilizes a semicircular specimen.
- 3.1.6. *fracture energy, G_f* —the energy required to create a unit surface area of a crack.

- 3.1.7. *stiffness, S* —the slope of the linear part of the ascending load-load line displacement curve.
- 3.1.8. *linear elastic fracture mechanics (LEFM)*—a method of fracture analysis for determining the stress required to induce fracture instability in a structure containing a crack-like flaw of known size and shape.
- 3.1.9. *mode I stress intensity factor, K_I* —the parameter used to characterize the mode I stress field in the vicinity of the crack tip in the LEFM analysis.
- 3.1.10. *mode I critical stress intensity factor, K_{IC}* —stress intensity factor corresponding to the initiation of the crack, also referred to as fracture toughness.

4. SUMMARY OF TEST METHOD

- 4.1. A semicircular asphalt mixture specimen is positioned with the flat side on two rollers that are covered with a friction-reducing material. A load is applied along the vertical diameter of the specimen and the load and load line displacement are measured during the entire duration of the test. The load is applied such that a constant CMOD of 0.0005 mm/s is obtained and maintained for the duration of the test to ensure stable crack growth conditions.
- 4.2. Fracture energy (G_f), stiffness (S), and fracture toughness (K_{IC}) are calculated from the load and load line displacement results.

5. SIGNIFICANCE AND USE

- 5.1. The SCB test is used to determine the low-temperature fracture energy and fracture toughness of asphalt mixtures. These parameters describe the fracture resistance of asphalt mixtures.
- 5.2. Fracture energy can be used as an index parameter to identify mixtures with increased fracture resistance. It also represents the main parameter used in more complex analyses based on a fictitious crack (cohesive zone) model.
- 5.3. Fracture toughness obtained with this test method can be used as an index parameter to identify mixtures with increased fracture resistance.
- 5.4. Stiffness obtained with this test method can be related to the elastic modulus of asphalt mixtures at low temperatures.
- 5.5. The specimens can be easily cut from Superpave gyratory-compacted cylinders and from field cores with a diameter of 150 mm.

6. APPARATUS

- 6.1. *Semicircular Bend (SCB) Test System*—A semicircular bend (SCB) test system consisting of a closed-loop axial loading device, a load measuring device, a bend test fixture, specimen deformation measurement devices, an environmental chamber, and a control and data acquisition system (see Figure 1).
- 6.1.1. *Axial Loading Device*—The loading device shall be capable of delivering a minimum load of 10 kN in compression with a resolution of 20 N or better. The load apparatus shall be capable of maintaining a constant crack mouth opening displacement within 1 percent of the target value throughout the test. The loading head shall be similar to the one described for the bend test fixture in ASTM E399 (see Figure 1).

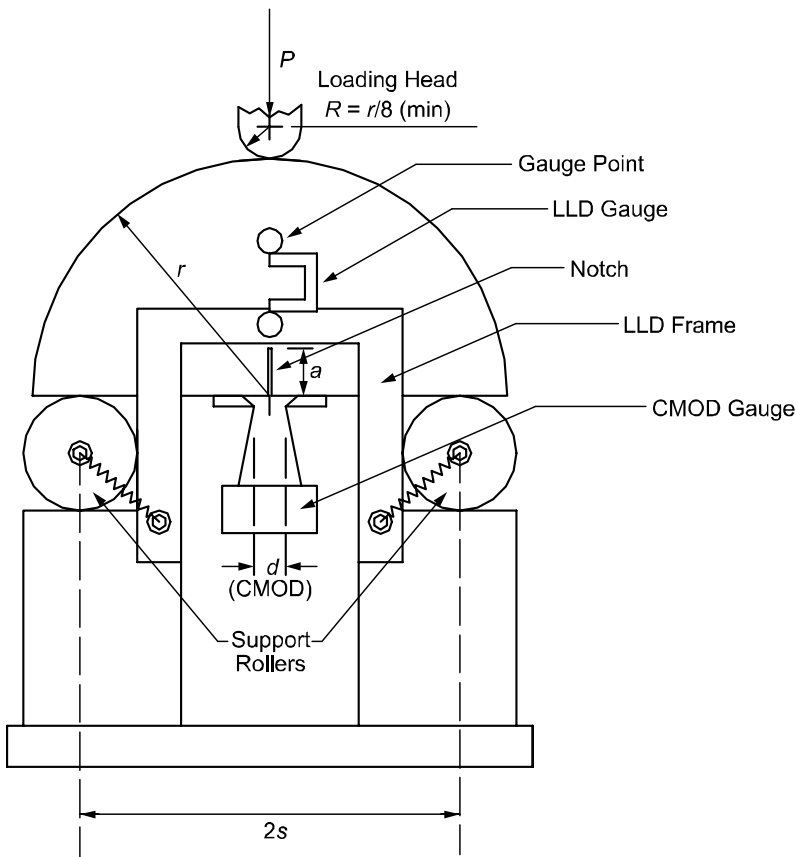


Figure 1—SCB Loading Setup for Front and Back Sides of Test Specimen

- 6.1.2. *Load Measuring Device*—The load measuring device shall consist of an electronic load cell, designed for placement between the loading platen and piston, with a minimum capacity of 10 kN and a sensitivity of 10 N or better.
- 6.1.3. *Bend Test Fixture*—The test fixture is composed of a steel base plate, two L-shaped roller support steel blocks, two steel rollers, and two U-shaped frames (see Figure 2). The loading fixture is designed to minimize frictional effects through the use of rollers (as suggested by ASTM E399). The surface of the rollers is covered with polytetrafluoroethylene (PTFE) strips to further reduce friction. The initial roller position is maintained by soft springs and backstops that establish the test span dimension. The support rollers are allowed to rotate out away from the backstops during the test but will remain in contact with the sample. The roller support blocks are secured to a 12.7-mm thick base plate with a 9.5-mm-diameter dowel hole for alignment with the actuator center. To obtain an accurate measure of the load-line displacement (LLD), two U-shaped reference frames are secured to the L-shaped roller support blocks, one on each side of the blocks. A steel gauge point (see Section 6.1.5) is permanently attached to the center of the upper arm of each of the reference frames.