
Standard Method of Test for

Determining the Fracture Potential of Asphalt Mixtures Using the Illinois Flexibility Index Test (I-FIT)

AASHTO Designation: T 393-22¹

Adopted with Revisions: 2021

Editorially 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 Mode I (tensile opening mode during crack propagation) cracking resistance properties of asphalt mixtures at intermediate test temperatures. Specimens are tested in the semicircular bend geometry, which is a half disc with a notch parallel to the direction of load application. The data analysis procedure associated with this test determines the fracture energy (G_f) and post peak slope (m) of the load–load line displacement (LLD) curve. These parameters are used to develop a flexibility index (FI) to predict the fracture resistance of an asphalt mixture at intermediate temperatures. The FI can be used as part of the asphalt mixture approval process.
- 1.2. These procedures apply to test specimens having a nominal maximum aggregate size (NMAS) of 19 mm or less. Lab compacted and pavement core specimens can be tested according to this test procedure. A thickness correction factor will need to be developed and applied for pavement cores tested at a thickness less than 45 mm.
- 1.3. *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 and follow appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.*
- 1.4. *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.*
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2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- < 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
 - < R 67, Sampling Asphalt Mixtures after Compaction (Obtaining Cores)
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- < 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 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- < T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

2.2. *ASTM Standards:*

- < D8, Standard Terminology Relating to Materials for Roads and Pavements
- < D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- < E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- < E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- < E879, Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
- < E1137/E1137M, Standard Specification for Industrial Platinum Resistance Thermometers
- < E2877, Standard Guide for Digital Contact Thermometers

2.3. *International Electrotechnical Commission Standards:*

- < IEC 60584-1: 2013 Thermocouples - Part 1: EMF Specifications and Tolerances
- < IEC 60751: 2008 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors

2.4. *Other Publications:*

- < Al-Qadi, I. L., H. Ozer, J. Lambros, A. El Khatib, P. Singhvi, T. Khan, and B. Doll. *Testing Protocols to Ensure Performance of High Asphalt Binder Replacement Mixes Using RAP and RAS*, FHWA ICT-15-07. Illinois Center for Transportation, Rantoul, IL, 2015.
- < Doll, B., H. Ozer, J. Rivera-Perez, J. Lambros, and I. L. Al-Qadi. Investigation of Viscoelastic Fracture Fields in Asphalt Mixtures Using Digital Image Correlation. *International Journal of Fracture*, Vol. 205, No. 1. Springer Nature Switzerland AG, January 2017, pp. 37–56.
- < Ozer, H., I. L. Al-Qadi, J. Lambros, A. El-Khatib, P. Singhvi, and B. Doll. Development of the Fracture-Based Flexibility Index for Asphalt Concrete Cracking Potential Using Modified Semi-Circle Bending Test Parameters. *Construction and Building Materials*, Vol. 115. Science Direct, Elsevier B.V., Amsterdam, Netherlands, 2016a, pp. 390–401.
- < Ozer, H., and P. Singhvi, T. Khan, J. Rivera, I. L. Al-Qadi. Fracture Characterization of Asphalt Mixtures with RAP and RAS Using the Illinois Semi-Circular Bending Test Method and Flexibility Index. *Transportation Research Record*, Vol. 2575. Transportation Research Board, National Research Council, Washington, DC, 2016b, pp. 130–137.
- < Ozer, H., I. L. Al-Qadi, P. Singhvi, J. Bausano, R. Carvalho, X. Li, and N. Gibson. Assessment of Asphalt Mixture Performance Tests to Predict Fatigue Cracking in an Accelerated Pavement Testing Trial. *International Journal of Pavement Engineering*, Special Issue for Cracking in Flexible Pavements and Asphalt Mixtures: Theories to Modeling, and Testing to Mitigation, 2017.
- < RILEM Technical Committee 50-FMC. Determination of the Fracture Energy of Mortar and Concrete by Means of Three-Point Bend Tests on Notched Beams. *Materials and Structures*, No. 106, July–August 1985. Springer Netherlands for International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM), Dordrecht, The Netherlands, 1985, pp. 285–290.

3. TERMINOLOGY

3.1. Definitions:

- 3.1.1. *critical displacement, u_1* —displacement at the intersection of the post-peak slope with the displacement-axis.
- 3.1.2. *displacement at peak load, u_0* —recorded displacement at peak load.
- 3.1.3. *final displacement, u_{final}* —recorded displacement at the 0.1 kN cut-off load.
- 3.1.4. *flexibility index, FI*—index intended to characterize the cracking resistance of asphalt mixture, calculated by multiplying the ratio of fracture energy to post-peak slope by a constant multiplier.
- 3.1.5. *fracture energy, G_f* —energy required to create a unit surface area of a crack.
- 3.1.6. *ligament area, Area_{lig}* —cross-sectional area of specimen through which the crack propagates, calculated by multiplying ligament width (test specimen thickness) and ligament length.
- 3.1.7. *linear variable displacement transducer (LVDT)*—sensor device for measuring linear displacement.
- 3.1.8. *load line displacement (LLD)*—displacement measured in the direction of the load application.
- 3.1.9. *post-peak slope, m* —slope at the first inflection point of the load–LLD curve after the peak.
- 3.1.10. *semicircular bend (SCB) geometry*—a half disc with a notch parallel to the direction of load application.
- 3.1.11. *work of fracture (W_f)*—calculated as the area under the load–LLD curve.

4. SUMMARY OF METHOD

- 4.1. A superpave gyratory compactor (SGC) compacted asphalt mixture specimen or an asphalt pavement core is trimmed and cut in half to create a semicircular test specimen. A notch is sawn in the flat side of the semicircular specimen opposite the curved edge. The specimen is conditioned and maintained through testing at $25 \pm 0.5^\circ\text{C}$. The specimen is positioned in the fixture with the notched side down centered on two rollers. A load is applied along the vertical radius of the specimen and the load and load line displacement (LLD) are measured during the entire duration of the test. The load is applied such that a constant LLD rate of 50 mm/min is obtained and maintained for the duration of the test. The I-FIT fixture and I-FIT specimen geometry for an SGC laboratory compacted specimen are shown in Figure 1.
- 4.2. Fracture energy (G_f), post-peak slope (m), displacement at peak load (u_0), critical displacement (u_1), and a flexibility index (FI) are calculated from the load and LLD results.

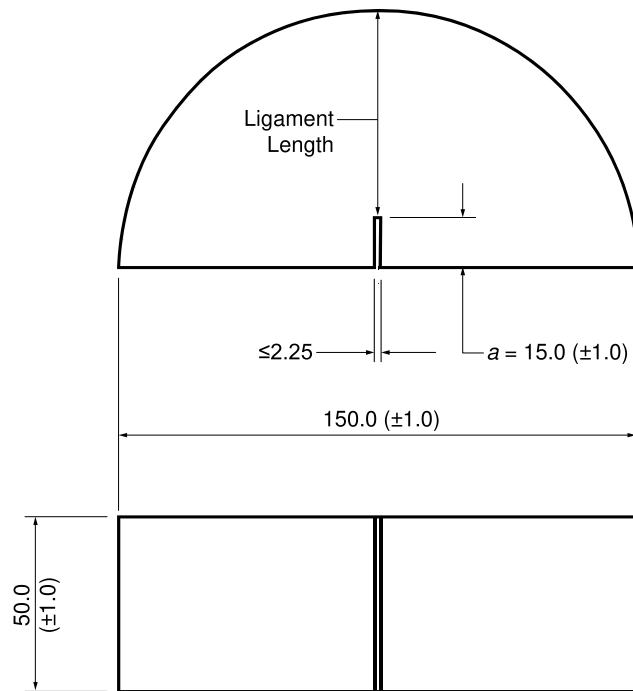


Figure 1—I-FIT SGC Laboratory Compacted Specimen Configuration (dimensions in millimeters)

5. SIGNIFICANCE AND USE

- 5.1. The I-FIT is used to determine fracture resistance parameters of an asphalt mixture at an intermediate temperature (Al-Qadi et al., 2015; Ozer et al., 2016a; Ozer et al., 2016b). From the fracture parameters of G_f and m obtained, the FI of an asphalt mixture is calculated. The FI provides a means to identify brittle mixtures that may be prone to premature cracking. The range for an acceptable FI will vary according to local environmental conditions, application of mixture, nominal maximum aggregate size (NMAS), asphalt binder content, asphalt binder performance grade (PG), air voids, and expectation of service life, etc. (Al-Qadi et al., 2015; Ozer et al., 2016a; Ozer et al., 2016b; Ozer et al., 2017).
- 5.2. The calculated FI indicates an asphalt mixture's overall capacity to resist cracking related damage (Al-Qadi et al., 2015). Generally, a mixture with higher FI can resist crack propagation for longer time duration under tensile stress. The FI should not be directly used in structural design and analysis of pavements. FI values, obtained using this procedure, are used in ranking the cracking resistance of alternative mixtures for a given layer in a structural design. The G_f parameter is dependent on specimen size, loading time, and temperature. Fracture mechanisms for viscoelastic materials are influenced by crack front viscoelasticity and bulk material (far from the crack front) viscoelasticity. Total calculated G_f from this test includes the amount of energy dissipated by crack propagation, viscoelastic mechanisms away from the crack front, and other inelastic irreversible processes (frictional and damage processes at the loading support points) (Doll et al., 2016).
- 5.3. G_f is one of the parameters used to calculate the FI, which is further used to predict AC mixture fracture potential. It also represents the main parameter input in more complex analyses based on a theoretical crack (cohesive zone) model. In order to be used as part of a cohesive zone model, fracture energy as calculated from the experiment shall be corrected to determine energy associated with crack propagation only. A correction factor may be used to eliminate other sources of inelastic energy contributing to the total fracture energy calculated directly from the experiment.

- 5.4. This test method and FI can be used to rank the cracking resistance of asphalt mixtures containing various asphalt binders, modifiers of asphalt binders, aggregate blends, fibers, and recycled materials.
- 5.5. The specimens can be readily obtained from SGC compacted cylinders or from pavement cores with a diameter of 150 mm.

6. APPARATUS

- 6.1. *Testing Machine*—An I-FIT system consists of a closed-loop axial loading device, a load measuring device, a bend test fixture, specimen deformation measurement devices, and a control and data acquisition system. A constant displacement-rate device, such as a closed loop, feedback-controlled servo-hydraulic load frame, shall be used.
- Note 1**—An electromechanical, screw-driven machine may be used if results are comparable to a closed loop, feedback-controlled servo-hydraulic load frame.
- 6.1.1. *Axial Loading Device*—The loading device shall be capable of delivering loads in compression with a maximum resolution of 10 N and a capacity of at least 10 kN.
- 6.1.2. *Bend Test Fixture*—The fixture is composed of a loading head, a steel base plate, and two steel rollers with a nominal diameter (D) of 25 mm. The tip of the loading head has a contact curvature with a radius of 12.5 ± 0.05 mm. The horizontal loading head shall pivot relative to the vertical loading axis to conform to slight specimen variations. The length of the two roller supports in Figure 2 and Figure 3 shall be a minimum of 65 mm. Illustrations of the loading and supports are shown in Figures 2 and 3.
- 6.1.2.1. *Method A*—Typically two steel rollers with a nominal diameter of 25 mm are mounted on bearings through their axis of rotation and attached to the steel base plate with brackets. One of the steel rollers may pivot on an axis perpendicular to the axis of loading to conform to slight specimen variations. A distance of 120 ± 0.1 mm between the two steel rollers is maintained throughout the test.
- 6.1.2.2. *Method B*—An alternate fixture design uses two steel rollers with a nominal diameter of 25 mm that each rotate in a U-shaped roller support steel block. The initial roller position is fixed by springs and backstops that establish the initial test span dimension of 120 ± 0.1 mm. The support rollers are allowed to rotate away from the backstops during the test; but remain in contact with the sample.
- 6.1.3. *Internal Displacement Measuring Device*—The displacement measurement can be performed using the machine's stroke (position) transducer if the resolution of the stroke is sufficient (0.01 mm or lower). The fracture test displacement data may be corrected for system compliance, loading-pin penetration and specimen compression by performing a calibration of the testing system.
- 6.1.4. *External Displacement Measuring Device*—If an internal displacement measuring device does not exist or has insufficient precision, an externally applied displacement measurement device such as a linear variable differential transducer (LVDT) accurate to 0.01 mm can be used (Figure 2 and Figure 3).
- 6.1.5. *Control and Data Acquisition System*—Time and load, and LLD (using external and/or internal displacement measurement device) are recorded. The control data acquisition system is required to apply a constant LLD rate at a precision of 50 ± 1 mm/min and collect data at a minimum sampling frequency of 20 Hz in order to obtain a smooth load–LLD curve.

Note 2—The use of two LLD transducers 180 degrees from one another and on each side of a test specimen may be used. In this approach, an average LLD value is computed to control the test. Controlling the test using an average LLD value may reduce test variability.

6.1.6. *Saw*—Laboratory saw capable of cutting asphalt specimens; must be capable of cutting the notch described in Figure 1.

6.1.7. *Conditioning Chamber*—Water bath or environmental chamber of sufficient size, capable of maintaining a uniform temperature, used within their proper operating temperature range, to conditioned samples at $25 \pm 0.5^{\circ}\text{C}$. The thermometer for measuring the temperature of water baths shall meet the requirements of M 339M/M 339 with a temperature range of at least 20 to 30°C , and an accuracy of $\pm 0.13^{\circ}\text{C}$.

Note 3—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer, Special order; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Special order; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Special order.

6.1.8. *Measuring Device*—Caliper or ruler accurate to ± 0.1 mm for specimen thickness and area measurement.

6.1.9. *Oven*—A forced-draft oven, properly standardized, thermostatically controlled, and capable of maintaining a uniform temperature of 95°C within $\pm 3^{\circ}\text{C}$. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer for measuring the temperature of materials shall meet the requirements of M 339M/M 339 with a temperature range of at least 25 to 185°C , and an accuracy of $\pm 0.75^{\circ}\text{C}$.

Note 4—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E230/E230M thermocouple thermometer, Type T, Special Class; IEC 60584 thermocouple thermometer, Type T, Class 1; or E2877 digital metal stem thermometer.