Appendix C

Proposed revision to AASHTO TP124-18 Standard Method of Test for Determining the Fracture Potential of Asphalt Mixtures Using the Flexibility Index Test (FIT)

Standard Method of Test for Determining the Fracture Potential of Asphalt Mixtures Using the Flexibility Index Test (FIT)

AASHTO Designation: TP 124-18[1]

Technical Section: 2d, Bituminous Materials

Release: Group 3 (August)

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.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 67, Sampling Asphalt Mixtures after Compaction (Obtaining Cores)
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- 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 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
- TP 105, Determining the Fracture Energy of Asphalt Mixtures using Semicircular Bend Geometry (SCB)

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

2.3. *Other Publications*:

- Al-Qadi, I. L., H. Ozer, J. Lambros, A. El Khatib, P. Singhvi, T. Khan, and B. Doll. 2015. *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.
- Doll. B., H. Ozer, J. Rivera-Perez, J. Lambros, and I. L. Al-Qadi. 2016. Investigation of Viscoelastic Fracture Fields in Asphalt Mixtures using Digital Image Correlation. *International Journal of Fracture*, Vol. 205, No. 1, pp. 37–56.
- Ozer, H., I. L. Al-Qadi, J. Lambros, A. El-Khatib, P. Singhvi, and B. Doll. 2016a. 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, pp. 390–401.
- Ozer, H., and P. Singhvi, T. Khan, J. Rivera, I. L. Al-Qadi. 2016b. Fracture Characterization of Asphalt Mixtures with RAP and RAS Using the Illinois Semi-Circular Bending Test Method and Flexibility Index. *Transportation Research Record*, Transportation Research Board, National Research Council, Washington, DC, Vol. 2575, pp. 130–137.
- Ozer, H., I. L. Al-Qadi, P. Singhvi, J. Bausano, R. Carvalho, X. Li, and N. Gibson. 2017. 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.
- RILEM Technical Committee 50-FMC. 1985. "Determination of the Fracture Energy of Mortar and Concrete by Means of Three-Point Bend Tests on Notched Beams." *Materials and Structures*, Springer Netherlands for International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM), Dordrecht, The Netherlands, No. 106, July–August 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*—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 ± 0.5°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 FIT fixture and 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.

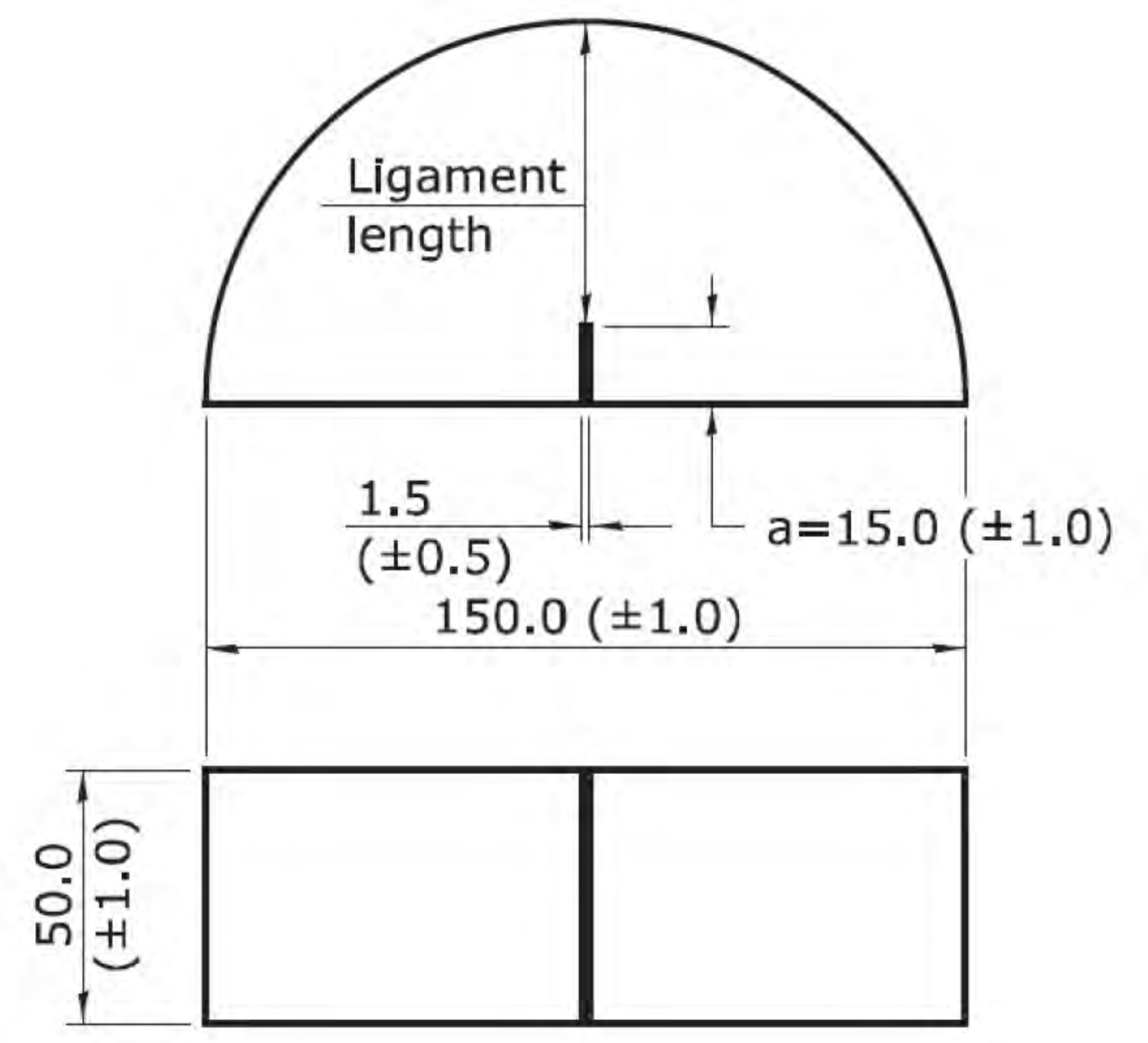

Figure 1 – FIT SGC Laboratory Compacted Specimen Configuration (dimensions in millimeters)

5. SIGNIFICANCE AND USE

5.1. The 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 is temperature dependent. 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) models. 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*—A 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 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 Figure 2 and Figure 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 De*vice—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 capable of maintaining specimen temperature as described in Section 10.1.

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

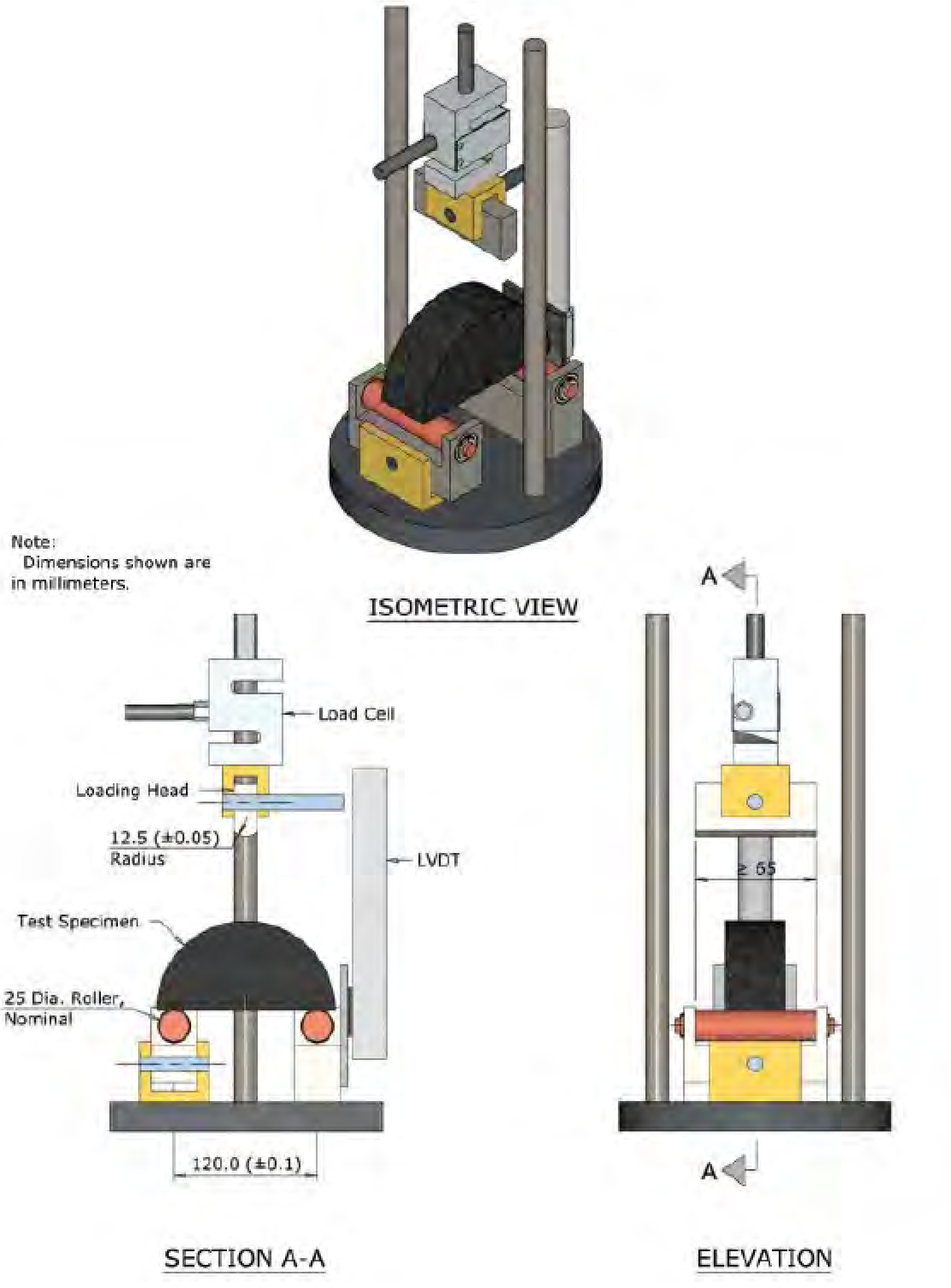

Figure 2 – Method A—Isometric, Cross-Section, and Elevation of the FIT Fixture (dimension in millimeters)

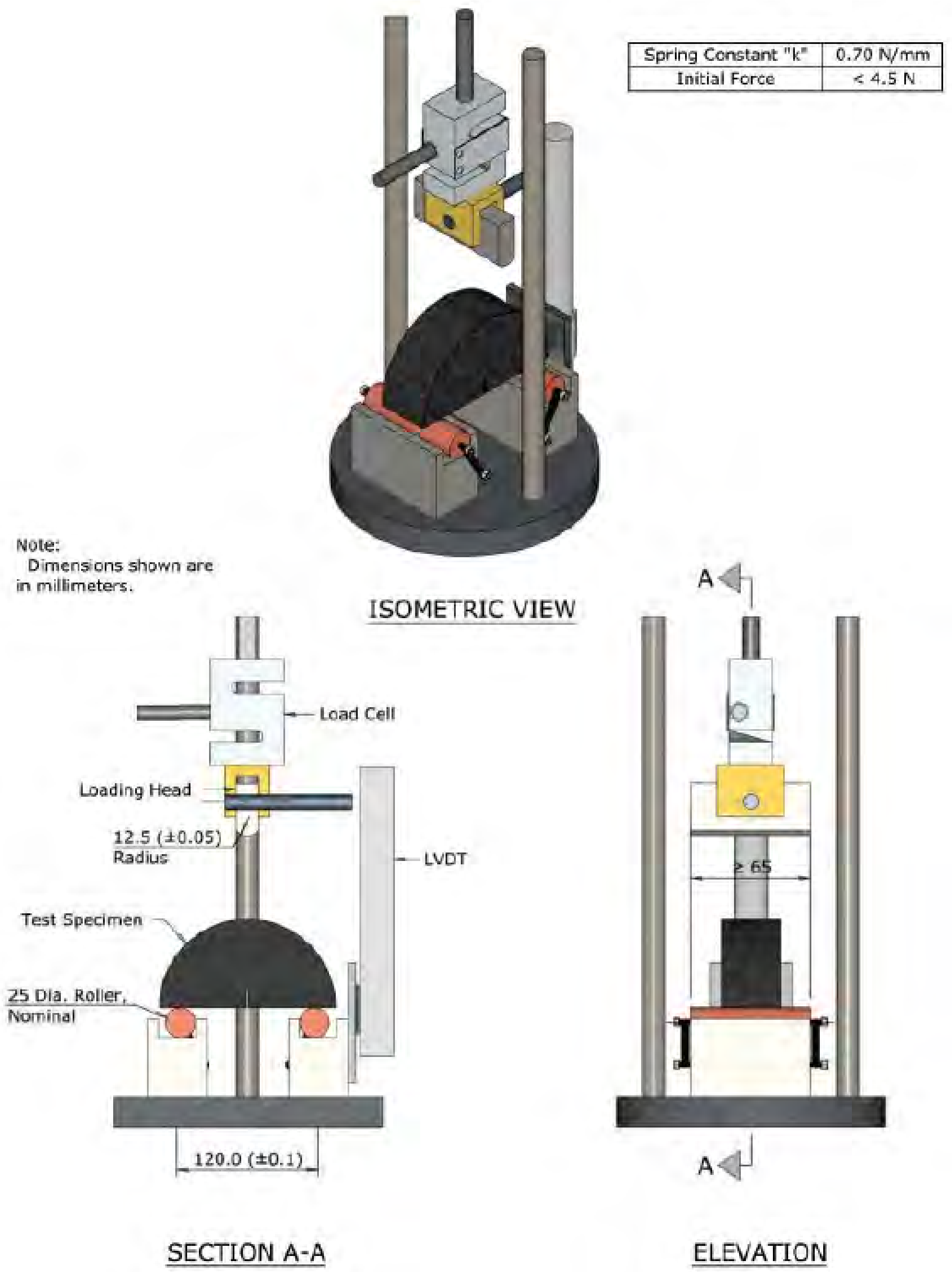

Figure 3 – Method B—Isometric, Cross-Section, and Elevation of the FIT Fixture (dimension in millimeters)

7. HAZARDS

7.1. Standard laboratory caution should be used in handling, compacting, and fabricating asphalt mixtures test specimens in accordance with T 312 and when using a saw for cutting specimens.

8. CALIBRATION AND STANDARDIZATION

8.1. A water bath as used in AASHTO T 283 or an environmental chamber will be used to maintain the specimen at a constant and uniform temperature.

8.2. Verify the calibration of all measurement components (such as load cells and LVDTs) of the testing system.

8.3. If any of the verifications yield data that does not comply with the accuracy specified, correct the problem prior to proceeding with testing. Appropriate action may include maintenance of system components, calibration of system components (using an independent calibration agency, service by the manufacturer, or in-house resources), or replacement of the system components.

9. PREPARATION OF TEST SPECIMENS AND PRELIMINARY DETERMINATIONS

9.1. *Test Specimen Size*—For mixtures with a NMAS of 19 mm or less, prepare the test specimens from a lab compacted SGC specimen or from pavement cores. If laboratory compacted SGC specimens are used, the final FIT specimens shall have smooth parallel faces with a thickness of 50 ± 1 mm and a diameter of 150 ± 1 mm (see Figure 4). If pavement cores are used, refer to Figure 1 for the notch width and notch length dimensions and tolerances. The final pavement core FIT specimen dimensions shall be 150 ± 8 mm in diameter with smooth parallel faces 25 to 50 ± 1 mm thick depending on available field layer thickness.

Note 3—A typical laboratory saw for mixture specimen preparation can be used to obtain cylindrical discs with smooth parallel surfaces. A tile saw is recommended for cutting the 15 ± 1 mm notch in the individual FIT specimens. Diamond-impregnated cutting faces and water cooling are recommended to minimize damage to the specimen. When cutting the FIT specimens into semi-circular halves, it is recommended not to push the two halves against each other because it may create an uneven base surface of the test specimen that can affect the FIT results.

9.1.1. *SGC Specimens*—Prepare one laboratory SGC specimen according to T 312 in the SGC with the compaction height a minimum of 160 mm ± 1 mm. From the middle of each 160 mm ± 1 mm tall specimen, obtain two cylindrical 50 ± 1 mm thick discs with smooth, parallel faces by saw cutting (see Figure 4). For laboratory compacted specimens, the air voids shall be determined for each of the two circular discs according to T 269. The air voids for each disc shall be 7.0 ± 0.5 percent. Cut each disc into two identical halves resulting in four individual FIT specimens. A minimum of three individual test specimens are required for one FIT result.

Note 4—It is suggested that the height of the gyratory compacted specimens should be a minimum 160 ± 1 mm height to achieve the target 7.0 ± 0.5 percent air voids in each of the top and bottom discs (see Figure 4). If target air voids cannot be achieved for each disc with 160 ± 1 mm height of the compacted specimens, then the specimen height can be increased. If specimen height cannot be increased or if a SGC has difficulty in compacting 160 ± 1 mm tall specimens, then two SGC specimens, each at least 115 ± 1 mm tall, may be compacted and used instead. A 50 ± 1 mm thick disc will be cut from the middle of each gyratory specimen, which will result in four individual FIT specimens (see Figure 4).

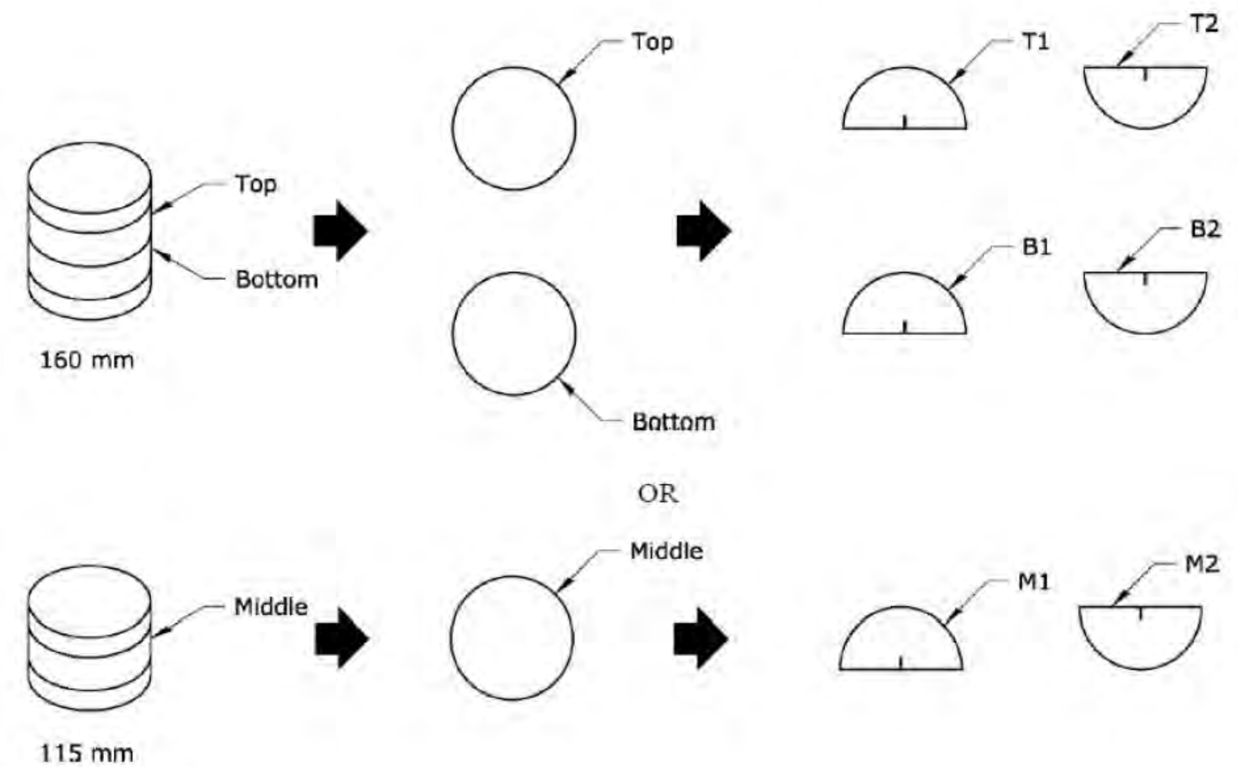

Figure 4 – Specimen preparation from 160 mm or 115 mm tall SGC specimens

9.1.2. *Pavement Cores*—Obtain pavement cores in accordance with R 67. Obtain one 150 mm diameter pavement core if the lift thickness is greater than or equal to 100 mm, or two 150 mm diameter pavement cores if the lift thickness is less than 100 mm.

9.1.2.1. *Pavement Core Specimen Preparation*—Prepare four replicate FIT specimens using pavement cores obtained from a pavement lift, with smooth, parallel surfaces that conform to the height and diameter requirements specified herein. To preserve and maximize core thickness, the as-compacted face shall be utilized as well as a sawed face. The thickness of test specimens in most cases for pavement cores may vary from 25 to 50 ± 1 mm. If the lift thickness is less than 50 ± 1 mm, test specimens should be prepared as thick as possible but in no case be less than two times the nominal maximum aggregate size of the mixture or 25 ± 1 mm, whichever is greater. If lift thickness is greater than 50 ± 1 mm, a 50 -± 1 mm disc shall be prepared as specified in Section 9.1. Cores from pavements with lifts greater than 75 ± 1 mm may be cut to provide two cylindrical specimens of equal thickness. In the upper-most pavement layer when cored, the as-compacted face will remain intact and one cut will be made to produce a disc at least two times the nominal maximum aggregate size of the mixture or 25 ± 1 mm, whichever is greater. In all subsequent discs cut from that pavement core, two sawed faces may be used to produce smooth, parallel surfaces. The air void contents of each disc shall be determined according to AASHTO T 269. Pavement cores will not be subject to air void content tolerances. Cut each cylindrical specimen in half to produce two semicircular specimens. The height of the semi-circular specimen shall be 73.5 ± 2 mm. Each disc of the pavement core shall have parallel smooth faces.

9.2. *Determining the Bulk Specific Gravity*—Determine the bulk specific gravity directly on the discs obtained from SGC specimens or pavement cores according to T 166.

9.3. *Notch Cutting*—Cut a notch along the axis of symmetry of each individual semicircular specimen to a depth of 15 ± 2 mm and 1.5 ± 0.5 mm in width (see Figure 1). The maximum allowable offset between the notch center and the axis of symmetry of the specimen is 2mm.

Note 5—If the notch terminates in an aggregate particle 9.5 mm or larger on both faces of the specimen, the specimen shall be discarded.

9.4. *Determining Specimen Dimensions*—Measure the notch depth on both faces of the specimen and record the average value to the nearest 0.5 mm. Measure and record the ligament length (see Figure 1) and thickness of each specimen. The ligament length may be measured *directly* on both faces of the specimen with the average value recorded, or the ligament length may be measured *indirectly* by subtracting the notch depth from the entire width (radius) of the specimen on both faces of the specimen and averaging the two measurements. Measure the specimen thickness approximately 19.0 mm on either side of the notch and on the curved edge directly across from the notch. Average the three measurements and record as the average thickness to the nearest 0.1 mm.

10. TEST PROCEDURE

10.1. *Conditioning*—Test specimens shall be conditioned in a water bath or an environmental chamber at 25 ± 0.5 °C for 2 h ± 10 min.

10.1.1. *Test Temperature Control*—Immediately after removing the test specimen from the conditioning water bath or environmental chamber, complete positioning and testing of the FIT specimen within 5 ± 1 min to ensure that the specimen temperature is maintained.

10.2. *Position Specimen*—Position the test specimen in the test fixture on the rollers so that it is centered in both the "x" and the "y" directions and so that the vertical axis of loading is aligned to pass from the center of the top radius of the specimen through the middle of the notch.

10.3. *Contact Load*—First, impose a contact load of 0.1 ± 0.01 kN in stroke control with a loading rate of 0.05 kN/s.

10.3.1. *Record Contact Load*—Record the contact load to ensure it is achieved.

10.3.2. *Loading*—After the contact load of 0.1 kN is reached, the test is conducted using LLD control at a rate of 50 mm/min. The test stops when the load drops below 0.1 kN.

10.3.3. Repeat Sections 10.1 through 10.3.2 for each test specimen.

11. PARAMETERS

11.1. *Determining Work of Fracture (W_f)*—The work of fracture is calculated as the area under the load–LLD curve (see Figure 5). If the test is stopped prior to reaching 0.1 kN, the remainder of the load–LLD curve should be produced by extrapolation techniques. The area under the load–LLD curve is calculated using a numerical integration technique. In order to apply the numerical integration, raw load-displacement data shall be divided into two curves described by an appropriate fitting equation. A polynomial equation with a degree of six is sufficient for the curve prior to peak load (Equation 1). An exponential-based function (Equation 2) is used for the post-peak load portion of the curve. Then, analytical integration shall be applied to calculate the area under each curve (Equation 3).

For displacements (u) prior to the peak load (P_{max}):

$$P_1(u) = c_1 \times u^6 + c_2 \times u^5 + c_3 \times u^4 + c_4 \times u^3 + c_5 \times u^2 + c_6 \times u^1 + +c_7 \quad (1)$$

where:

c_i = polynomial coefficients.

For displacements (u) after the peak load (P_{max}) to the cut-off displacement (u_{final}):

$$P_2(u) = \sum_{i}^{n=4} d_i \exp\left[-\left(\frac{u - e_i}{f_i}\right)^2\right] \tag{2}$$

where:

d, e, f = polynomial coefficients, n is the number of exponential terms.

Work of fracture can be analytically or numerically calculated using the integral equation below and boundaries of displacement:

$$W_f = \int_0^{u_0} P_1(u)\, du + \int_0^{u_{final}} P_2(u)\, du \tag{3}$$

where:

u_0 = displacement at the peak load;

u_{final} = displacement at the 0.1 kN cut-off load.

Note 6—Due to the relative difference between the compliance of testing frame and specimen, displacement recorded may vary. A correction factor may need to be considered to correct recorded displacements when applicable.

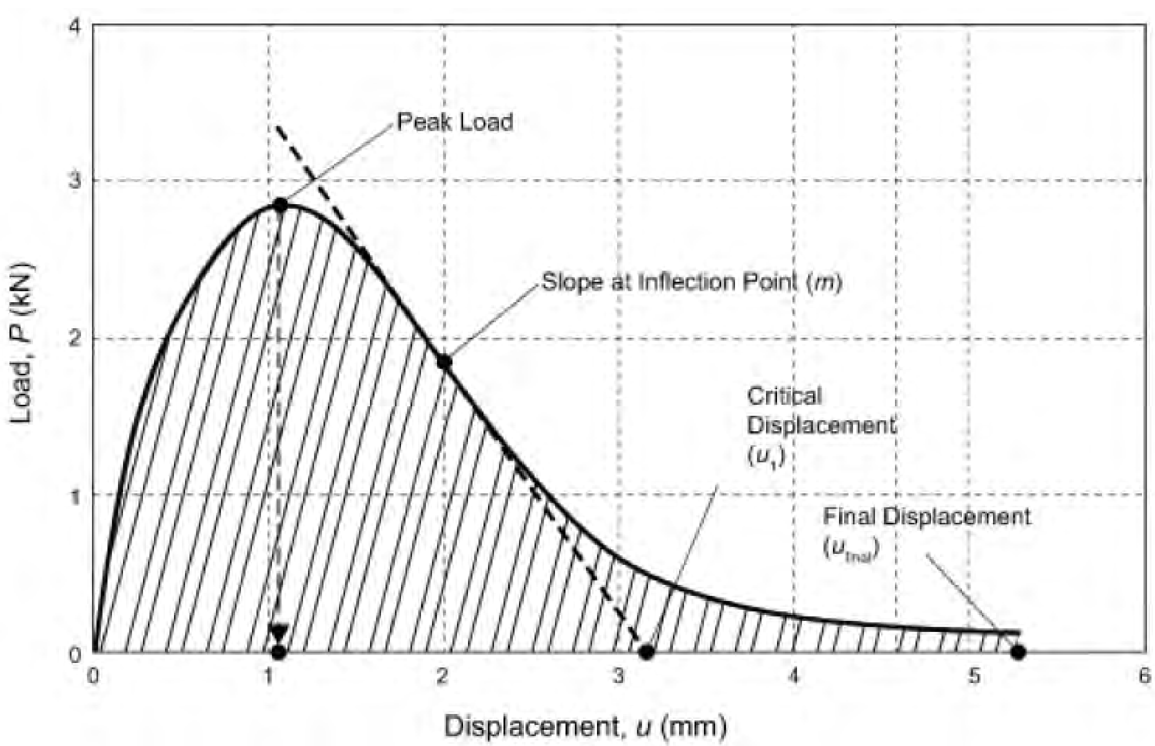

Figure 5 – Recorded Load (P)–Load Line Displacement (u) Curve

11.2. *Fracture Energy (G_f)*—The fracture energy G_f, determined as per the RILEM TC 50-FMC (1985) approach, is calculated by dividing the work of fracture (the area under the load–LLD curve; see Figure 5) by the ligament area (the product of the ligament length and the thickness of the specimen) of the FIT specimen prior to testing:

$$G_f = \frac{W_f}{Area_{lig}} \times 10^6 \tag{4}$$

where:

G_f	=	fracture energy (Joules/m^2);
W_f	=	work of fracture (Joules);
P	=	load (kN);
u	=	load line displacement (mm);
$Area_{lig}$	=	ligament area = $(r - a) \times t$, (mm^2);
r	=	Specimen radius (mm);
a	=	notch length (mm);
t	=	specimen thickness (mm).

Note 7—G_f is a size dependent property. This specification does not aim at calculating size independent G_f. Therefore, cracking resistance of asphalt mixtures quantified with G_f may vary when the notch length to radius ratio changes.

11.3. *Determining Post-Peak Slope (m)*—The inflection point is determined on the load–LLD curve (Figure 5) after the peak load. The slope of the tangential curve drawn at the inflection point represents post-peak slope.

11.4. *Determining Displacement at Peak Load (u_0)*—The displacement when peak load is reached.

11.5. *Determining Critical Displacement (u_1)*—Intersection of the tangential post-peak slope with the displacement axis yields the critical displacement value. A straight line is drawn connecting the inflection point and displacement axis with a slope *m*.

11.6. *Flexibility Index (FI)*—FI can be calculated from the parameters obtained using the load–LLD curve (Al-Qadi et al. (2015), Ozer et al. (2016a), Ozer et al. (2016b)). The factor *A* is used for unit conversion and scaling. *A* is equal to 0.01. Complete details of the analysis procedure are provided in Appendix A.

$$FI = \frac{G_f}{|m|} \times A \tag{5}$$

where:

m = absolute value of post-peak load slope *m* (kN/mm).

12. CORRECTION FACTORS

12.1. *Correction Factors for Flexibility Index*—Flexibility index correction factors for pavement core specimen thickness and differences between field and lab compaction may be needed. A thickness correction factor may be applied for pavement cores tested at thickness less than 45 mm. The correction factors may require local calibration to consider locally available materials and mixture design requirements.

13. REPORT

13.1. Report the following information:

13.1.1. Bulk specific gravity of each specimen tested, to the nearest 0.001;

13.1.2. Air void content of each disc, to the nearest 0.1 percent;

13.1.3. The number of cut faces for each specimen tested, if pavement cores were used.

13.1.4. Average thickness t and average ligament length of each specimen tested, to the nearest 0.1 mm;

13.1.5. Initial notch length a, to the nearest 0.5 mm;

13.1.6. Average and coefficient of variation (COV) of peak load, to the nearest 0.1 kN;

13.1.7. Average and COV of recorded time at peak load, to the nearest 0.1 s;

13.1.8. Average and COV of load-line displacement at the peak load (u_0), to the nearest 0.1 mm;

13.1.9. Average and COV of critical displacement (u_1), to the nearest 0.1 mm;

13.1.10. Average and COV of post-peak slope (m), to the nearest 0.1 kN/mm;

13.1.11. Average and COV of fracture energy G_f , to the nearest 1 J/m^2; and

13.1.12. Average and COV of flexibility index to the nearest 0.1.

14. PRECISION AND BIAS

14.1. *Precision*—The research required to develop precision estimates has not been conducted.

14.2. *Bias*—The research required to establish the bias of this method has not been conducted.

15. KEYWORDS

Asphalt mixture; flexibility index; flexibility index test (FIT); fracture energy; semicircular bend (SCB); stiffness; work of fracture.

[1] This provisional standard was first published in 2016.