Designation: D8458 – 22

Standard Test Method for Evaluation of Fatigue Performance of Asphalt Mixtures Using the Three-Point Bending Cylinder (3PBC) Test[1]

This standard is issued under the fixed designation D8458; 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 test method provides a procedure to determine the fatigue life (number of cycles to failure, N_f) of asphalt mixtures, and also the reduction in dynamic modulus (|E*|) with loading cycles, using cylindrical samples subjected to three-point cyclic bending. The results obtained from this test can be used to calibrate Viscoelastic Continuum Damage (VECD) models to obtain a damage characteristic curve, which in turn can be used to obtain fatigue lives (N_f) at a variety of temperatures, strain levels, and frequencies (a separate standard practice is being drafted for this procedure). Even though this test method is intended primarily for displacement (strain) controlled fatigue testing, certain sections may provide useful information for force-controlled tests.

1.2 The test method describes the testing apparatus, instrumentation, specimen fabrication, and analysis procedures required to determine the number of cycles to failure of asphalt concrete.

1.3 The text of this test method 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 test method.

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

1.5 *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.*

1.6 *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]

D8 Terminology Relating to Materials for Roads and Pavements

D979/D979M Practice for Sampling Asphalt Mixtures

D3549/D3549M Test Method for Thickness or Height of Compacted Asphalt Mixture Specimens

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

D6373 Specification for Performance-Graded Asphalt Binder

2.2 *AASHTO Standards:*[3]

R 30 Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)

R 83 Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)

T 378 Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

M 320 Standard Specification for Performance-Graded Asphalt Binder

M 332 Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test

3. Terminology

3.1 *Definitions:*

3.1.1 *dynamic modulus, |E*|*—the amplitude of the complex modulus that defines the relationship between the stress and strain of viscoelastic materials. The |E*| is simply the peak-to-peak stress divided by peak-to-peak strain in a cyclic test run at a constant frequency.

[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.

[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.

3.1.2 *initial dynamic modulus,* $|E^*|_0$—initial undamaged dynamic modulus determined at approximately 50 load cycles.

3.1.3 *Poisson's ratio*—the ratio of transverse to longitudinal strains of a loaded specimen.

3.1.4 *Timoshenko beam theory*—the theory which considers the bending and shear effects when subjected to loading, and commonly used in low aspect ratio beams (that is, when length-to-diameter ratio of a beam is <6).

3.2 For definitions of other terms used in this standard, refer to Terminology D8.

4. Summary of Test Method

4.1 A cylindrical specimen is clamped using C-shaped clamps in a three-point bending setup and subjected to sinusoidal actuator displacement-controlled loading with zero mean. While the loading is applied at the central clamp, the side clamps hold the sample in a fixed position. The actuator displacement is set such that the initial strain ranges from 200 to 800 × 10^{-6} mm/mm. The recommended loading frequency rate is from 5 Hz to 10 Hz. The load and deflection at the central clamp are measured during the entire duration of the test to be later analyzed by Timoshenko beam theory formulations to calculate the change in dynamic modulus ($|E^*|$) per loading cycle.

5. Significance and Use

5.1 This test method can be utilized to determine the fatigue resistance of asphalt mixtures. The test method is generally valid for specimens that are tested at intermediate temperatures. The three-point bending cylinder test samples are obtained by coring a 68 mm diameter cylinder from the center of a 150 mm diameter gyratory compacted sample, or horizontal coring from field cores or slabs cut from field sections. After coring, the sample is ready for testing and no further sample preparations steps are required. The two ends of the 68 mm diameter three-point bending cylinder sample do not need to be sliced.

5.2 The Timoshenko beam theory is used to calculate the reduction in dynamic modulus for each loading cycle. The test can be used to investigate the fatigue behavior of asphalt mixtures at various strain levels, temperatures, and frequencies. The results can be used to compare the fatigue life (N_f) for different asphalt mixtures. The N_f value can be calculated as the 50 % reduction in dynamic modulus. The N_f value is an indicator of fatigue performance of asphalt mixtures containing various mix design properties, asphalt binder types and modifications, gradations, and recycled materials. Typically, a higher N_f value indicates better fatigue performance. The N_f value may be used to identify crack-prone mixtures in performance-based mix design or in construction acceptance procedures, or both.

NOTE 1—The quality of the results produced by this test method 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 test method are cautioned that compliance with Specification D3666 alone does not completely ensure reliable results. Reliable results may 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 *Test System*—The test system consists of a three-point bending cylinder test setup, a load frame capable of providing cyclic load and displacement, an environmental chamber (temperature control system), and closed-loop control and data acquisition system. Fig. 1 illustrates the details of the three-point bending cylinder setup. The side clamps shall hold the asphalt sample fixed with no sliding, rotation, or combination thereof. High-strength steel shall be used in the production of the fixture. The test system's minimum requirements are specified in Table 1.

6.2 *Three-Point Bending Cylinder (3PBC) Test Fixture*—The test fixture is composed of a 175 mm solid base, two fixed 95 mm end supports used to clamp the sample, and a 95 mm central clamp for application of cyclic (zero-mean) vertical load. Supports and loading clamps are composed of two C-shaped pieces, which are screwed together to hold the asphalt sample in place. The lower C-shaped pieces are welded to the base plate. The distance between two supports is 125 mm and the inner diameters of clamps are 68 mm each. Top bars are placed on side clamps to prevent any potential deflection of the side clamps (see Fig. 1). All the parts (except the LVDT holders) are made of high-strength steel to prevent any undesirable deformation during the test. It is noted that dimensional tolerances shown in Fig. 1 are mandatory.

6.3 *Loading Device*—The test system includes a closed-loop, computer-controlled loading component which, during each load cycle in response to commands from the data processing and control component, adjusts and applies a load such that the specimen experiences a constant level of displacement during each loading cycle. The loading device should be capable of providing peak-peak sinusoidal loading with zero mean at a frequency range of 5 Hz to 10 Hz. Fig. 2(a) and Fig. 2(b) show the three-point bending cylinder setup with a mounted specimen in a material testing system and asphalt mixture performance tester, respectively.

6.4 *Environmental Chamber (Temperature Control System)*—The environmental chamber shall enclose the entire specimen and the fixture and maintain the specimen at the desired test temperature within ±0.5 °C throughout the conditioning and testing times. An environmental chamber is not required if the temperature of the surrounding environment can be maintained within the specified limits.

6.4.1 *Control and Data Acquisition System*—During each load cycle, the control and data acquisition system shall be capable of measuring the displacement of the beam specimen, and adjusting the load applied by the loading device such that the specimen experiences a constant level of displacement on each load cycle. In addition, it shall be capable of recording load cycles, applied loads, beam displacements, and temperature while computing and recording the maximum tensile stress, maximum tensile strain, phase angle, and dynamic modulus at load cycle intervals specified by the user.