

**Standard Test Method for Determining
the Fatigue Life of Compacted Hot-Mix Asphalt (HMA)
Subjected to Repeated Flexural Bending**

AASHTO Designation: TP8-94^{1,2} (Reapproved 1996)

1. Scope

1.1 This standard provides procedures for determining the fatigue life and fatigue energy of 380 mm long by 50 mm thick by 63 mm wide hot mix asphalt (HMA) beam specimens sawed from laboratory or field compacted HMA and subjected to repeated flexural bending until failure.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.*

2. Referenced Documents

2.1 AASHTO Standards.

- R11 Indicating Which Places of Figures are to be Considered Significant in Specifying Limiting Values
- T2 Sampling Aggregates
- T40 Sampling Bituminous Materials
- T168 Sampling Bituminous Paving Mixtures
- T269 Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- TP38 Preparing and Determining the Air Voids of Hot Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor

2.2 ASTM Standards

- D3202 Preparation of Bituminous Mixture Beam Specimens by Means of the California Kneading Compactor
- D3549 Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D5361 Sampling Compacted Bituminous Mixtures for Laboratory Testing

3. **Terminology** - Failure Point - the load cycle at which the specimen exhibits a 50 percent reduction in stiffness relative to the initial stiffness.

4. **Significance and Use** - The fatigue life and failure energy determined by this standard can be used to estimate the fatigue life of HMA pavement layers under repeated traffic loading. The performance of HMA can be more accurately predicted when these properties are known.

5. Apparatus

5.1 Test System - The test system shall consist of a loading device, an environmental chamber (optional) and a control and data acquisition system. The test system shall meet the minimum requirements specified in Table 1.

5.1.1 Loading Device - The test system shall include 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 strain during each load cycle. The loading device shall be capable of (1) providing repeated sinusoidal loading at a frequency range of 5 to 10 Hz, (2) subjecting specimens to 4-point bending with free rotation and horizontal translation at all load and reaction points, and (3) forcing the specimen back to its original position (i.e., zero deflection) at the end of each load pulse. (Figure 1 illustrates the loading conditions.)

5.1.2 Environmental Chamber (optional) - The environmental chamber shall enclose the entire specimen and maintain the specimen at $20.0 \pm 0.5^{\circ}\text{C}$ during testing. An environmental chamber is not required if the temperature of the surrounding environment can be maintained within the specified limits.

¹ This standard is based on SHRP Product 1019.

² Approved in October 1994, this provisional standard was first published in March 1995. Reconfirmed in January 2001.

5.1.3 Control and Data Acquisition System - During each load cycle the control and data acquisition system shall be capable of measuring the deflection of the beam specimen, computing the strain in the specimen and adjusting the load applied by the loading device such that the specimen experiences a constant level of strain on each load cycle. In addition, it shall be capable of recording load cycles, applied loads, and beam deflections and computing and recording the maximum tensile stress, maximum tensile strain, phase angle, stiffness, dissipated energy, and cumulative dissipated energy at load cycle intervals specified by the user.

5.2 Miscellaneous Apparatus and Materials - a screw, nut (suggested size M 8 x 1) and block assembly for referencing the linear variable differential transducer (LVDT) to the neutral axis of the specimen, a jig for setting the proper clamp spacing and epoxy for attaching the nut to the specimen, a suitable saw for cutting the beams

6. Hazards - Observe standard laboratory safety precautions when preparing and testing HMA specimens.

7. Sampling and Specimen Preparation

7.1 Laboratory Mixed and Compacted Specimens - Sample asphalt binder in accordance with T40 and sample aggregate in accordance with T2. Prepare three replicate hot mix asphalt beam specimens, from slab(s) or beam(s) compacted in accordance with TP38 or ASTM D3202.

Note 1 -- The type of compaction device may influence the test results.

Note 2 -- Normally test specimens are compacted using a standard compactive effort. However, the standard compactive effort may not reproduce the air voids of roadway specimens measured according to T269. If specimens are to be compacted to a target air void content the compactive effort to be used should be determined experimentally.

7.2 Plant Mixed, Laboratory Compacted Specimens - Obtain HMA samples in accordance with T168. Prepare three replicate hot mix asphalt beam specimens, from slab(s) or beam(s) compacted in accordance with TP38 or ASTM D3202. (Notes 1 and

2)

7.3 Roadway Specimens - Obtain compacted HMA samples from the roadway in accordance with ASTM D5361.

7.4 Saw at least 6 mm from both sides of each test specimen to provide smooth, parallel (saw-cut) surfaces for mounting the measurement gages. The final required dimensions, after sawing, of the specimens are 380 ± 6 mm in length, 50 ± 6 mm in height and 63 ± 6 mm in width.

8. Procedure

8.1 Specimen Measurement - Measure the height and width of the specimen to the nearest 0.01 mm at three different points along the middle 100 mm of the specimen length in accordance with applicable sections of ASTM D3549. Determine the average of the three measurements for each dimension and record the averages to the nearest 0.1 mm.

8.2 Epoxying Nut to Neutral Axis of Specimen - Locate the center of a specimen side. Apply epoxy in a circle around this center point and place the nut on the epoxy such that the center of the nut is over the center point. Avoid applying epoxy such that it fills the center of the nut. Allow the epoxy to cure before moving the specimen. (Figure 2 illustrates a nut epoxied to the neutral axis of the specimen.)

8.3 Place the specimen in an environment which is at $20.0 \pm 0.5^\circ\text{C}$ for 2 hours to ensure the specimen is at the test temperature prior to beginning the test.

8.4 Open the clamps and slide the specimen into position. (Figures 3, 4 and 5) Use the jig to ensure proper horizontal spacing of the clamps, 119 mm center-to-center. When the specimen and clamps are in the proper positions, close the outside clamps by applying sufficient pressure to hold the specimen in place. Next, close the inside clamps by applying sufficient pressure to hold the specimen in place.

8.5 Attach the LVDT block to the specimen by screwing the screw into the nut epoxied on the specimen. (Figure 4 illustrates the connection of the screw/nut/block assembly and the LVDT such that beam deflections at the neutral axis will be measured.) Clamp the LVDT into position such that the LVDT probe rests on top of the block and the LVDT is reading close to zero.

8.6 Select the desired initial strain (250 to 750 microstrain) and loading frequency, and the load cycle intervals at which test results are recorded and computed and enter them into the recording and control component's test program. Set the loading frequency within a range of 5 to 10 Hz.

Note 3 -- Selection of load cycle intervals at which test results are computed and recorded may be limited by the amount of memory available for storing data.

8.7 Apply 50 load cycles at a constant strain of 250 to 750 microstrain. Determine the specimen stiffness at the 50th load cycle. This stiffness is an estimate of the initial stiffness which is used as a reference for determining specimen failure.

8.8 Select a deflection level (strain level) such that the specimen will undergo a minimum of 10000 load cycles before its stiffness is reduced to 50 percent or less of the initial stiffness. A stiffness reduction of 50 percent or more represents specimen failure. A minimum of 10000 load cycles ensures that the specimen does not decrease in stiffness too rapidly.

8.9 After selecting the appropriate test parameters, begin the test. Activate the recording and control components so that the test results at the selected load cycle intervals are monitored and recorded, ensuring that the test system is operating properly. When the specimen has experienced greater than 50 percent reduction in stiffness, terminate the test.

9. Calculations

9.1 Perform the following calculations at the operator-specified load cycle intervals:

9.1.1 Maximum Tensile Stress, Pa:

$$\sigma_t = (0.357P)/(bh^2) \quad (1)$$

where,

P = load applied by actuator, in Newtons
b = average specimen width, in meters
h = average specimen height, in meters

9.1.2 Maximum Tensile Strain, m/m:

$$\epsilon_t = (12\delta h)/(3L^2 - 4a^2) \quad (2)$$

where,

δ = maximum deflection at center of beam, in meters
a = space between inside clamps, 0.357/3 meters, (0.119 meters)
L = length of beam between outside clamps, 0.357 meters

9.1.3 Flexural Stiffness, Pa:

$$S = \sigma_t/\epsilon_t \quad (3)$$

9.1.4 Phase Angle, deg:

$$\phi = 360fs \quad (4)$$

where,

f = load frequency, in Hz
s = time lag between P_{max} and δ_{max} , in seconds

Note 4 -- When automated testing software is used in the recording and control component of the test system, ϕ is approximated by an algorithm contained in the automated testing software.

9.1.5 Dissipated Energy (J/m^3) per cycle:

$$D = \pi\sigma_t\epsilon_t\sin(\phi) \quad (5)$$

9.1.6 Cumulative Dissipated Energy, J/m^3 :

$$\sum_{i=1}^{i=n} D_i \quad (6)$$

where,

$D_i = D$ for the i^{th} load cycle

Note 5 -- It may not be possible to calculate dissipated energy (D) for every load cycle due to memory limitations of the recording and control component. Therefore, dissipated energy may be plotted against load cycles for the particular load cycles at which data was collected (i.e., the load cycles selected by the operator) up to the load cycle of interest. The area under the curve represents the cumulative dissipated energy.

See Figure 5 for a typical dissipated energy versus load cycle plot.

9.1.7 Initial Stiffness, Pa - The initial stiffness is determined by plotting stiffness (S) against load cycles (n) and best-fitting the data to an exponential function of the form shown in equation 7. Figure 7 presents a typical plot of stiffness versus load cycles. The constant A represents the initial stiffness.

$$S = Ae^{bn} \quad (7)$$

where,

e = natural logarithm to the base e

A = constant

b = constant

9.1.8 Cycles to Failure - Failure is defined as the point at which the specimen stiffness is reduced to 50 percent of the initial stiffness. The load cycle at which failure occurs is computed by solving for n from equation 7, or simply:

$$n_{f,50} = [\ln(S_{f,50}/A)]/b \quad (8)$$

where,

$S_{f,50}$ = stiffness, 50 percent of initial stiffness, in Pa

$S_{f,50}/A = 0.5$, by definition

9.1.9 Cumulative Dissipated Energy to Failure (J/m^3):

$$\sum_{i=1}^{i=N_{f,50}} D_i \quad (9)$$

Note 6 -- It is not necessary to measure the dissipated energy for every load cycle; however the automated testing software used to control the fatigue test systematically determines the dissipated energy at specified load cycles during the test. The total dissipated energy to failure is summarized as part of the output.

10. Report

10.1 Hot Mix Asphalt Description - Report the binder type, binder content, aggregate gradation, and air void percentage.

10.2 Specimen Dimensions - Report the specimen length, average specimen height and average specimen width in meters, to 4 significant figures.

Note 7 - See R 11 for information on determination of significant figures in calculations.

10.3 Report the average test temperature to the nearest 0.2°C.

10.4 Report the test results listed in Table 2 for each load cycle interval selected by the operator to 3 significant figures.

10.5 Report the initial flexural stiffness in Pascals.

10.6 Report the cycles to failure.

10.7 Prepare a plot of stiffness versus load cycles as shown in Figure 7.

10.8 Prepare a plot of dissipated energy versus load cycles as shown in Figure 6.

11. Precision and Bias

11.1 Precision - The research required to develop precision values has not been conducted.

11.2 Bias - The research required to establish the bias of this method has not been conducted.

12. **Keywords** - fatigue life, flexural bending, hot mix asphalt fatigue, hot mix asphalt flexural testing, hot mix asphalt tensile testing, hot mix asphalt stiffness, hot mix asphalt energy dissipation.