INTERNATIONAL

**Designation: D8237 – 21**

# Standard Test Method for Determining Fatigue Failure of Asphalt-Aggregate Mixtures with the Four-Point Beam Fatigue Device[1]

This standard is issued under the fixed designation D8237; 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 for determining a fatigue curve that is developed using three or more strain levels. The resulting data can be used in the fatigue models for mechanistic-empirical pavement design (that is, Pavement ME). Failure points are determined for estimating the fatigue life of 380 mm long by 50 mm thick by 63 mm in breadth (width) asphalt mixture beam (rectangular prism) specimens sawed from laboratory or field-compacted asphalt mixture, which are subjected to repeated flexural bending.

1.2 The largest nominal maximum aggregate size (NMAS) recommended for beams 50 mm thick is 19 mm. Beams made with an NMAS greater than 19 mm might significantly interfere with the material response, thereby affecting the repeatability of the test.

1.3 The text of this standard 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 standard.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard, with the exception of degrees (°) where angle is specified in accordance with IEEE/ASTM SI 10.

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
D75/D75M Practice for Sampling Aggregates
D140/D140M Practice for Sampling Asphalt Materials
D979/D979M Practice for Sampling Bituminous Paving Mixtures
D2041/D2041M Test Method for Theoretical Maximum Specific Gravity and Density of Asphalt Mixtures
D2726/D2726M Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Asphalt Mixtures
D3203/D3203M Test Method for Percent Air Voids in Compacted 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
D7981 Practice for Compaction of Prismatic Asphalt Specimens by Means of the Shear Box Compactor
D8079 Practice for Preparation of Compacted Slab Asphalt Mix Samples Using a Segmented Rolling Compactor
E4 Practices for Force Verification of Testing Machines
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E2309/E2309M Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines
IEEE/ASTM SI 10 American National Standard for Metric Practice

2.2 *AASHTO Standard:*[3]

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

[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.

Current edition approved July 1, 2021. Published July 2021. Originally approved in 2018. Last previous edition approved in 2018 as D8237 – 18. DOI: 10.1520/D8237-21.

[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. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 $\sigma_{p-p}$, *n*—peak-to-peak stress amplitude at load cycle *i*.

3.1.2 $\sigma_t$, *n*—maximum tensile stress at the fiber of the beam.

3.1.3 $\varepsilon_{p-p}$, *n*—peak-to-peak tensile strain at load cycle *i*.

3.1.4 $\varepsilon_t$, *n*—maximum tensile strain at the bottom fiber of the beam.

3.1.5 $\delta_{p-p}$, *n*—peak-to-peak displacement as determined in Fig. 1.

3.1.6 *S, n*—flexural beam stiffness, which is the stress divided by the strain.

3.1.7 $S_i$, *n*—the initial beam stiffness determined at 50 load cycles.

3.1.8 *failure point, n*—the number of cycles to failure, $N_f$, which corresponds to the maximum or peak normalized beam stiffness × normalized cycles when plotted versus number of cycles (9.9).

3.1.9 *normalized stiffness × normalized cycles, n*—see Rowe and Bouldin (**1**).[4]

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

## 4. Summary of Test Method

4.1 The four-point flexural bending test method is conducted on compacted beam specimens to evaluate the fatigue properties of viscoelastic asphalt mixtures using a fixed reference point bending beam fixture. A cyclic sinusoidal loading pattern is initiated having no rest periods from the start location. A fully executed peak-to-peak displacement ($\delta_{p-p}$) at the articulating H-frame third points of the beam is induced. The outer third points are held in an articulating fixed position about the neutral axis of the beam. The frequency rate has a default frequency of 10 Hertz (Hz) and a test temperature of 20 °C. This produces a constant bending moment over the center third (L/3, length between outside clamps divided by 3) span of 119 mm ± 0.5 mm (distance may vary between manufacturers; check with manufacturers' specifications) between the H-frame contact points on the beam specimen. The level of desired strain is pre-calculated and an input value for the equipment peak-to-peak deflection. The peak-to-peak deflection at mid-length position (L/2, length between outside frames divided by 2) of a beam specimen is regulated by the closed-loop control system measured from the mid-height position (neutral axis). The peak-to-peak deflection is measured relative to a fixed reference point located at the outer articulating fixed position.

NOTE 1—Caution should be applied when using frequencies above 10 Hz, Pronk (**2**).

## 5. Significance and Use

5.1 The laboratory fatigue life determined by this standard for beam specimens has been used to estimate the fatigue life of asphalt mixture pavement layers under repeated traffic loading. Although the field performance of asphalt mixtures is impacted by many factors (traffic variation, loading rate, and wander; climate variation; rest periods between loads; aging; etc.), it has been more accurately predicted when laboratory properties are known along with an estimate of the strain level induced at the layer depth by the traffic wheel load traveling over the pavement.

NOTE 2—The quality of the results produced by this standard are

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.



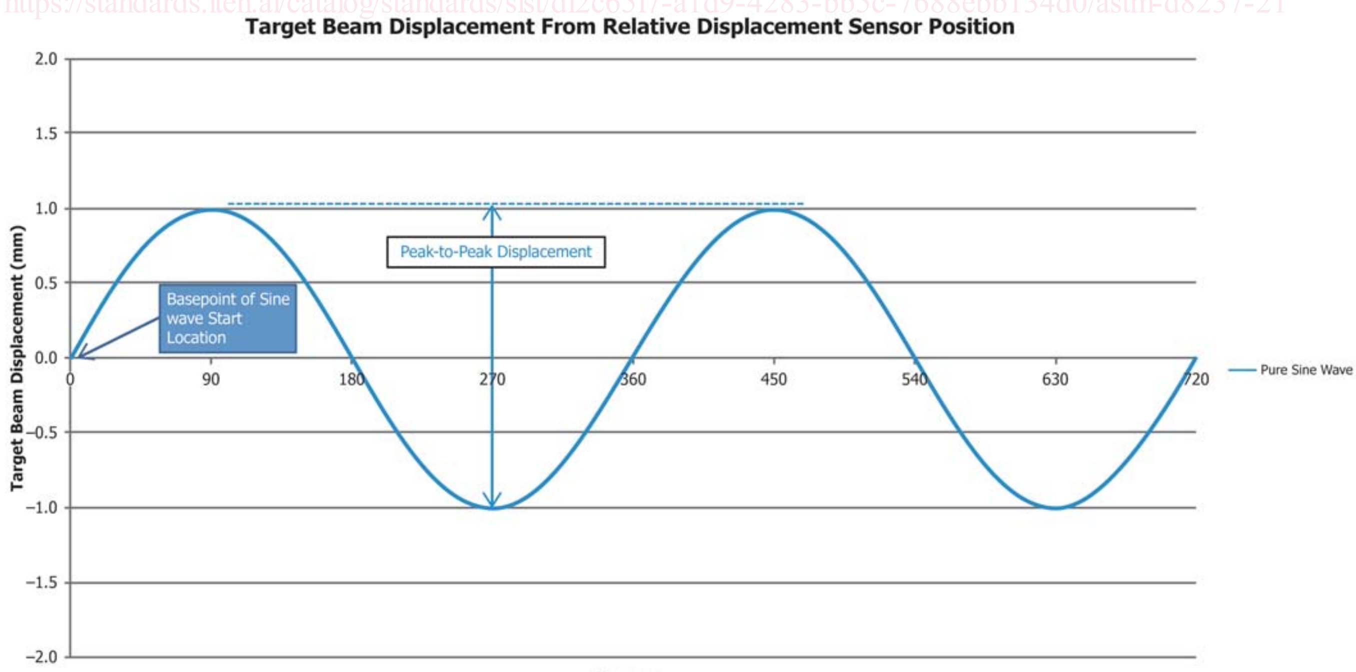


FIG. 1 Illustration of Actuator Response of Repeated Sinusoidal Peak-to-Peak Defection

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 standard are cautioned that compliance with Specification D3666 alone does not completely ensure reliable results. Reliable results 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 shall consist of a load frame, an environmental chamber (temperature control system), and a closed-loop control and data acquisition system. 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 controlled maximum deflection (and resulting strain) during each load cycle. The test system shall meet the minimum requirements specified in Table 1.

NOTE 3—Test system unit calibrations are performed in mm for displacement and kN for load measurements (Practices E4 and E2309/E2309M). Unit conversions will need to be made when applying to calculations in Section 10.

6.1.1 *Loading Device*—The loading device shall be capable of: (*1*) providing repeated sinusoidal loading at a frequency range of 5 to 25 Hz, and (*2*) subjecting specimens to four-point bending with free rotation and horizontal translation at all clamped load and reaction points as shown in Figs. 2 and 3. Floating reference point bending beam fixtures are not recognized by this standard.

NOTE 4—The fundamental equations are more viable with dual controlling displacement sensors. The on-specimen displacement sensor controls the peak-to-peak displacement for the waveform loading of the maximum deflection value at the L/2 location, and the frame-mounted displacement sensor controls the H-frame point of origin location. An even better approach is the use of four displacement sensors. Two dual controlling sensors, as listed previously in this note, and two recording the L/6 and 5L/6 locations to better understand the deflections between each of the frames.

6.1.2 *Environmental Chamber (Temperature Control System)*—The environmental chamber shall enclose the entire specimen and maintain the specimen at the default test temperature of 20 °C. The temperature shall be within ±0.5 °C throughout the conditioning and testing times.

NOTE 5—Replacing an incandescent, florescent, or halogen light bulb with light emitting diode (LED) for your environmental chamber reduces the heat signature and improves the chamber's ability to control within ±0.5 °C. Globe-style bulb design improves illumination of fixture and inside of chamber.

6.1.3 *Control and Data Acquisition System*—During each load cycle, the control and data acquisition system shall be capable of measuring the peak-to-peak 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. Minimum data capture rate and sampling intervals are listed in Table 2. The minimum number of data samples for each load cycle is 200.

6.2 *Miscellaneous Apparatus and Materials*—Means or tools for targeting the displacement sensor to the neutral axis of the specimen and proper glue (cyanoacrylate) are required for attaching the target to the specimen. A saw suitable for cutting the beams with parallel faces to the proper dimensions of 380 mm ± 3 mm in length, 50 mm ± 2 mm in height, and 63 mm ± 2 mm in breadth (width). A clamp alignment gauge is required for setting the proper clamp spacing between the frames, ensuring parallelism and perpendicularity. A rigid material beam having the dimensions specified in 6.2 and tolerance of 0.254 mm across the beam (measured using a straightedge and feeler gauge) will be the required beam gauge for setting the proper clamping height. Yearly verification is required for the beam gauge to be in compliance.

NOTE 6—Hard, high-strength 7075 aluminum is found to be adequate for the beam gauge. The aluminum bar off the shelf will require being cut to a length of 380 mm (McMaster – Carr Item #9055K31).

## 7. Hazards

7.1 Observe standard laboratory safety precautions when preparing and testing asphalt mixture specimens.

## 8. Sampling and Test Specimen Preparation

8.1 *Laboratory-Mixed and Compacted Specimens*—Sample asphalt binder in accordance with Practice D140/D140M, and sample aggregate in accordance with Practice D75/D75M. If a complete fatigue curve is desired, prepare six to nine replicate asphalt mixture beam specimens, compacted in accordance with Practice D7981 or D8079, or active AASHTO compaction standards for slab(s) or beam(s). Otherwise, prepare as many specimens as desired for individual beam test results. Laboratory-prepared mixtures are conditioned with a short-term oven aging (STOA) process, such as defined in Section 7.2 of AASHTO R 30 (condition loose mixture for 4 h at 135 °C). Determine the theoretical maximum specific gravity in accordance with Test Method D2041/D2041M. Determine the bulk specific gravity in accordance with Test Method D2726/D2726M. Calculate the percent air voids in accordance with Test Method D3203/D3203M. Test at least six replicate asphalt mixture beam specimens at different strain levels in

**TABLE 1 Test System Minimum Requirements**

| | |
|---|---|
| Load Measurement and Control | Range: ±5 kN<br>Resolution: 0.005 N<br>Accuracy: 0.01 N |
| Displacement Measurement and Control | Range: ±2.5 mm<br>Resolution: 2.5 µm<br>Accuracy: 5 µm |
| Frequency Measurement and Control | Range: 5 to 25 Hz<br>Resolution: 0.005 Hz<br>Accuracy: 0.01 Hz |
| Temperature Measurement and Control | Range: 5 to 25 °C<br>Resolution: 0.25 °C<br>Accuracy: ±0.5 °C |
| Displacement Sensor | Linear variable differential transducer (LVDT), extensometer, or similar device |

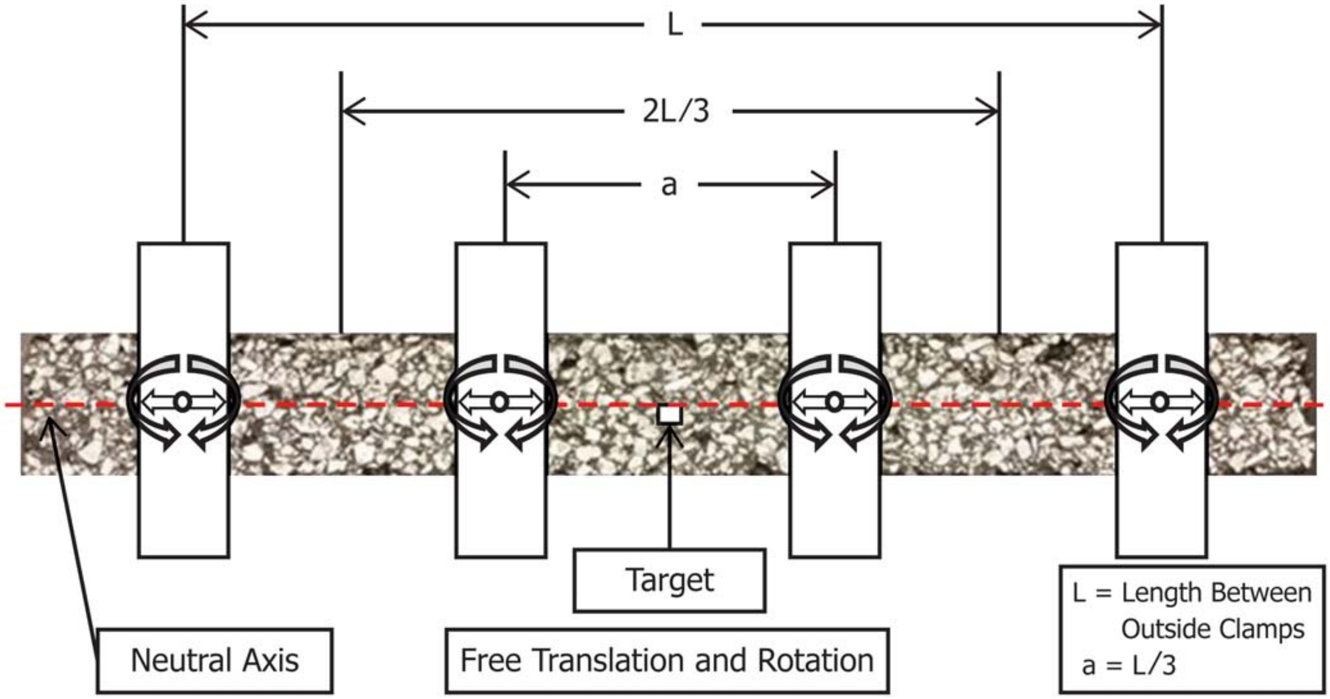


FIG. 2 Specimen Articulation and Dimensioning



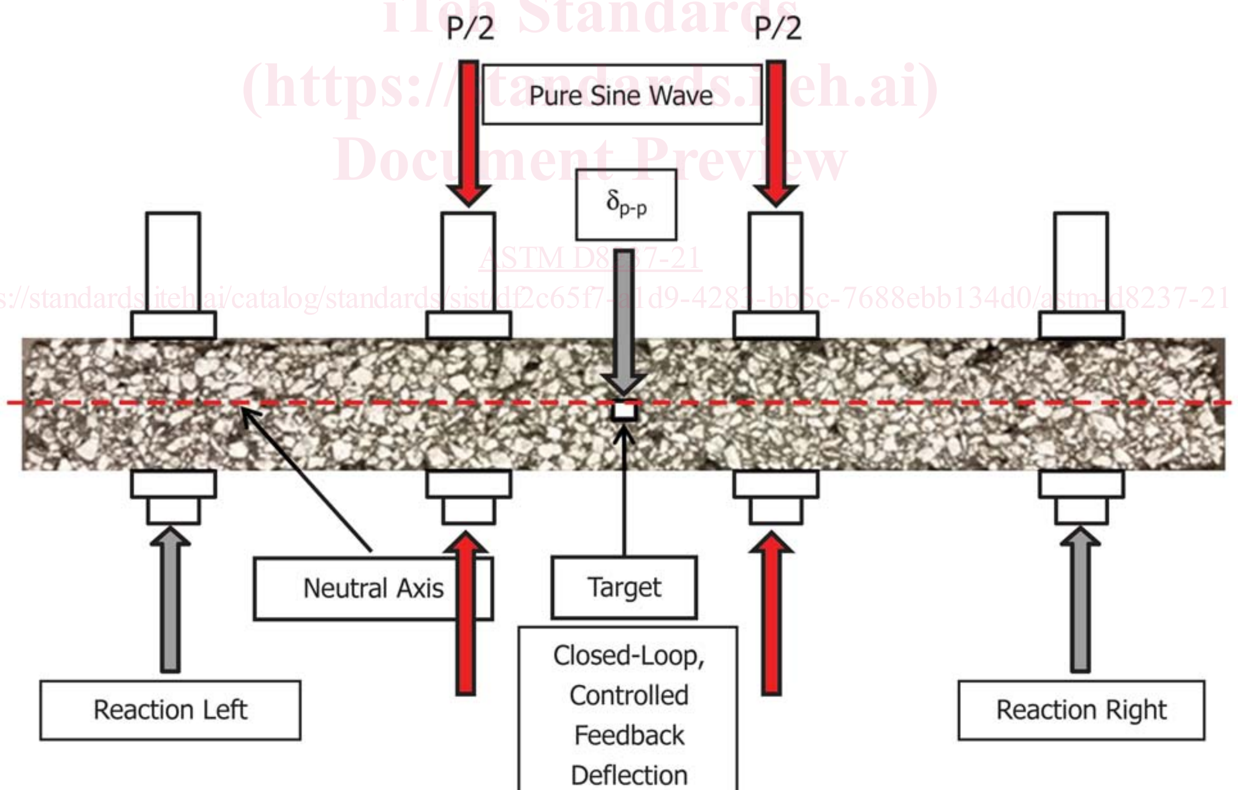


FIG. 3 Load Characteristics of Fatigue Test Apparatus Illustrated as Pure Sine Wave

order to develop a fatigue curve, as shown in Fig. 4. The extra specimens may also be tested as desired if the data appears to include an outlier or if a beam failure occurs directly at a clamp. A linear relationship on a log-log plot exists between $N_f$ and the level of tensile strain (με, microstrain = strain × $10^6$).

**TABLE 2 Minimum Data Capture Rate and Sampling Intervals**

| Repetitions | Intervals (Spaced equally within each range) | Cycles at each collection points (Included in average reported) |
|---|---|---|
| 0 to 10 | 1–10 | Report individual cycles |
| 10 to 1000 | 10 | 5 |
| 1000 to 10 000 | 90 | 5 |
| 10 000 to 100 000 | At least one every 1000 repetitions | 5 |
| 100 000 to end of test | At least one every 10 000 repetitions | 5 |

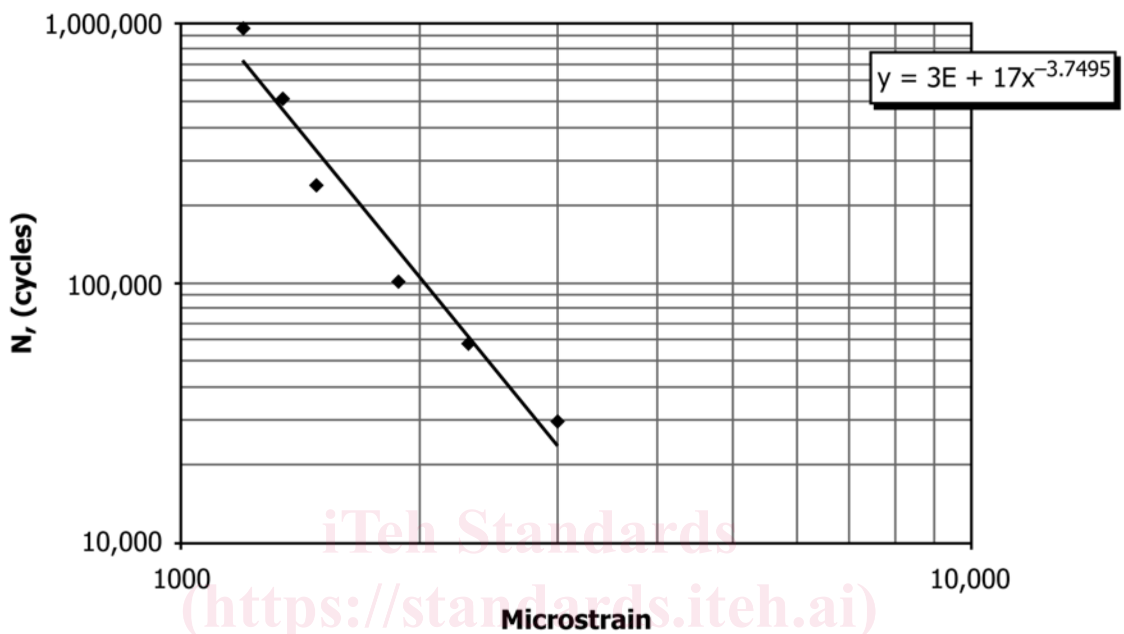


**FIG. 4 Example Fatigue Curve**



NOTE 7—AASHTO R 30 also contains additional information on long-term oven aging (LTOA) of compacted specimens for five days at 85 °C. In addition, new research in Braham et al. (**3**) and NCHRP Report 871 (**4**) provides information on long-term aging loose mixture.

NOTE 8—The type of compaction device (linear kneading, rolling wheel, vibratory) may influence the test results relative to representing actual construction. Check with the manufacturer recommendations on compaction procedures or applicable ASTM or AASHTO standards.

8.2 *Plant-Mixed, Laboratory-Compacted Specimens*—Obtain asphalt mixture samples in accordance with Practice D979/D979M. If a complete fatigue curve is desired, prepare six to nine replicate asphalt mixture beam specimens, compacted in accordance with Practice D7981 or AASHTO active compaction standards for slab(s) or beam(s). Otherwise, prepare as many specimens as desired for individual beam test results. See Note 7 for long-term oven aging of specimens, if that is necessary. Determine the theoretical maximum specific gravity in accordance with Test Method D2041/D2041M. Determine the bulk specific gravity in accordance with Test Method D2726/D2726M. Calculate the percent air voids in accordance with Test Method D3203/D3203M. Test at least six replicate asphalt mixture beam specimens at different strain levels in order to develop a fatigue curve, as shown in Fig. 4. The extra specimens may also be tested as desired if the data appears to include an outlier or if a beam failure occurs directly at a clamp. A linear relationship on a log-log plot exists between $N_f$ and the level of tensile strain (με, microstrain = strain × $10^{-6}$).

8.3 *Roadway Specimens*—Obtain compacted asphalt mixture samples from the roadway in accordance with Practice D5361/D5361M. Determine the theoretical maximum specific gravity in accordance with Test Method D2041/D2041M. Determine the bulk specific gravity in accordance with Test Method D2726/D2726M. Calculate the percent air voids in accordance with Test Method D3203/D3203M.

8.4 *Specimen Trimming*—Saw at least 6 mm from all sides of each compacted slab edge to mitigate end effects and provide smooth, parallel (saw-cut) surfaces for mounting the neutral axis target. The final required dimensions of the test specimen, after sawing, are 380 mm ± 3 mm in length, 50 mm ± 2 mm in height, and 63 mm ± 2 mm in breadth (width). Measure the height and breadth of the specimen to the nearest 0.01 mm at three or more different points along the middle 100 mm of the specimen length in accordance with the applicable sections of Test Method D3549/D3549M. Determine the average of the measurements for each dimension and record the average to the nearest 0.01 mm. The allowed difference between maximum and minimum measured values of breadth and height is 1 mm. If the difference of the maximum and minimum values of either dimension exceeds 1 mm, then the beam shall be recut or discarded.

NOTE 9—Previous experience has shown that in order to minimize specimen variability, it is recommended that the beams be immediately labeled to ensure consistent orientation (top and sides) during testing, relative to the compaction process. Masad et al. (**5**) shows that the air voids at the compaction plate/compaction keys are lower than the air voids at the bottom of the sample.

8.5 *Specimen Storage*—The specimens should be stored on a 12.7-mm steel plate or similar material capable of supporting the beams, with a flatness of 0.508 mm across the surface of the shortest section of plate from end to end. This flat surface keeps the beam specimens from being pre-strained before testing. It is permissible to stack a second beam on top of the first beam on storage racks.

## 9. Procedure

9.1 *Attaching the Target to the Neutral Axis of Specimen*—Locate the center of a specimen on one of its 50-mm high lengthwise sides (that is, mid-height and mid-length of the beam). Place the beam so that the side having the target is face-up before gluing to counteract gravitational effects. Apply cyanoacrylate (super glue) or equivalent in a circle around this point and place the target on the glue such that the top of the target is at the center point and parallel to the neutral axis of the beam. Allow the glue to cure before moving the specimen. Fig. 5 illustrates the target attached to the neutral axis of the specimen.

9.2 Place the specimen on a stiff, flat surface in an environment holding the desired test temperature for 2 h to ensure that the specimen has equilibrated to the desired test temperature prior to beginning the test. Temperature (T) for this test method will have a default T = 20 °C. The temperature shall be within ±0.5 °C throughout the conditioning and testing times.

NOTE 10—Two hours is sufficient to equilibrate the temperature of a beam that was stored near room temperature to its testing environment.

NOTE 11—Previous experience has shown that agencies have modified the standard to bracket 10 °C ≤ T ≤ 20 °C. The selection of temperature is based on the climatic region for the geographical area and depth in the pavement structure.

9.3 *Fixture Alignment*—The beam gauge referenced in 6.2, or any other alignment tools, are used for setting the proper clamp height (point of origin) and correct spacing to prevent pre-straining the beam during the clamping procedure. This will ensure proper alignment of the beam fixture H-frame in reference to the articulating fixed-position outer frame clamps prior to testing. To complete the alignment and removal of the beam gauge, refer to the equipment manufacturer's detailed procedures.

NOTE 12—If the top and bottom faces of the beam test specimen are not parallel, it should not be an issue with the clamping. The saw cuts are



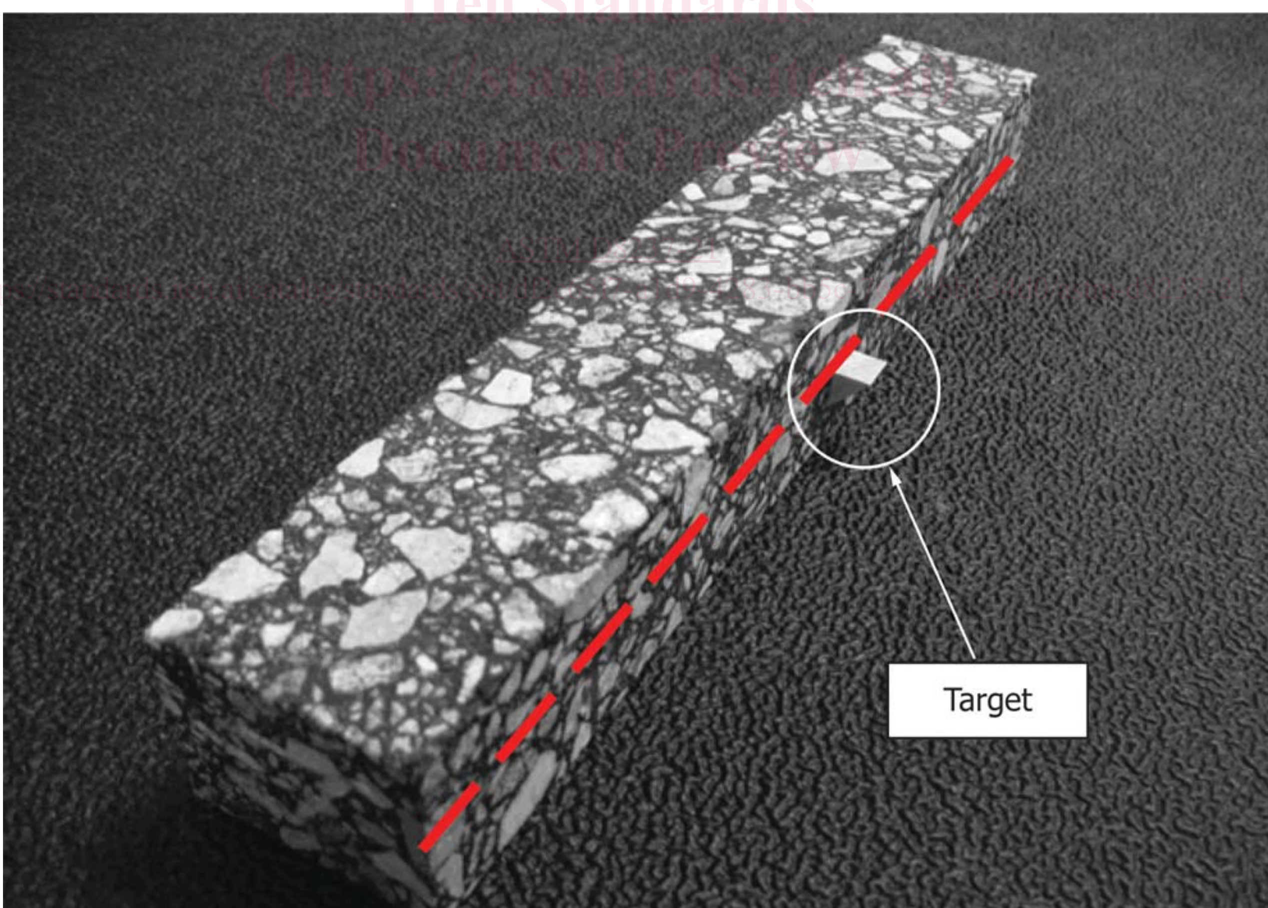


**FIG. 5 Target Attached to the Beam Neutral Axis (Mid-Height, Mid-Length)**

typically straight on all sides of the beam; even if these are not exactly parallel to each other, the top clamps will compensate for the lack of parallelism, since the clamps are all independent of each other.

NOTE 13—It is recommended that the clamps be flat and have the following minimum dimensions: 25 mm wide by 63 mm long, using a force of 600 to 1000 N to hold the beam in place while not causing any indentation.

9.4 Open the clamps and slide the specimen into horizontally centered position as shown in Figs. 6-8. When the specimen clamps are in the proper positions, apply the clamps in accordance with the manufacturer's clamping procedures. Check for adequate clamping pressure by toggling (lightly shaking) each frame with the spacing fixture in place and make sure that all clamps are seated properly, flat against the specimen.

9.5 Follow the manufacturer's procedure to correctly set up and position the on-specimen displacement sensor at the mid-height and L/2 location. Once the specimen has been mounted, allow 20 min for the temperature in the test chamber to equilibrate. Set the target peak-to-peak displacement to the desired strain rate in the test control software.

NOTE 14—Switching of the stroke actuator point of origin (start location) to the on-specimen displacement sensor for fixed reference displacement sensor fixture during the 20-min equilibrium time prior to starting the test will cause the H-frame attached to the actuator to creep upward at approximately the same displacement rate the specimen creeps downward between the two middle frames due to the mix's viscous nature for the specific mix design at the L/2 location. All mixtures flow at different rates due to the materials selected for the mix design.

NOTE 15—Previous experience has shown that vertical beam fixtures mitigate the creep between the clamping frames due to gravitational effects of the viscoelastic asphalt mixture beams in a horizontal orientation. Beams with the dimensions given in 8.4 do not flow as much when tested in a vertical configuration. Vertical beam fixtures have different orientation and require different fixture design to perform the test.

NOTE 16—Additional creep at the two middle frames on a horizontal beam fixture will increase due to gravitational effects from acceleration due to test frequency selection and friction induced by the energy applied to the specimen at the desired strain rate and resulting maximum peak-to-peak deflection that was calculated for the on-specimen displacement sensor at mid-height and the L/2 location.

9.6 Select the desired initial peak-to-peak strain (50 to 3000 με; typically 200 to 800 με for conventional asphalt mixtures; 50 to 150 με (endurance limit determination) for evaluating severely high-repetition but low-strain conditions; 1500 to 3000 με for some interlayer and bridge deck materials) and loading frequency, and the load cycle intervals at which test results are to be recorded and computed. The load cycle intervals shall be recorded at least as frequently as listed in Table 2. Enter these values into the specific template for this testing program in the control and data acquisition system.

9.7 Within the load cycles to be recorded, include an interval near the point of 50 cycles. Determine the specimen stiffness at the 50th load cycle; this stiffness is the recommended estimate of the initial beam stiffness.

9.8 Select a peak-to-peak displacement level (peak-to-peak strain level) near the mid-range initially for the specific material based on trial and error or experience, such that the specimen will undergo a minimum of 10 000 load cycles prior to failure. A minimum of 10 000 load cycles ensures that the specimen does not decrease in stiffness too rapidly. Adjust the peak-to-peak strain up and down on additional replicate beams to evaluate performance of the material over a range of peak-to-peak strain levels in order to establish a fatigue curve.

9.9 After selecting the appropriate test parameters, begin the test. Activate the control and data acquisition system so that the test results at the selected load cycle intervals are monitored and recorded, ensuring that the test system is operating properly. Ideally, the test should be terminated sometime after the normalized beam stiffness ($\hat{S}$) × normalized cycles ($\hat{N}$) peak value (failure point) has been achieved on a graphical plot of normalized beam stiffness × normalized cycles versus cycles



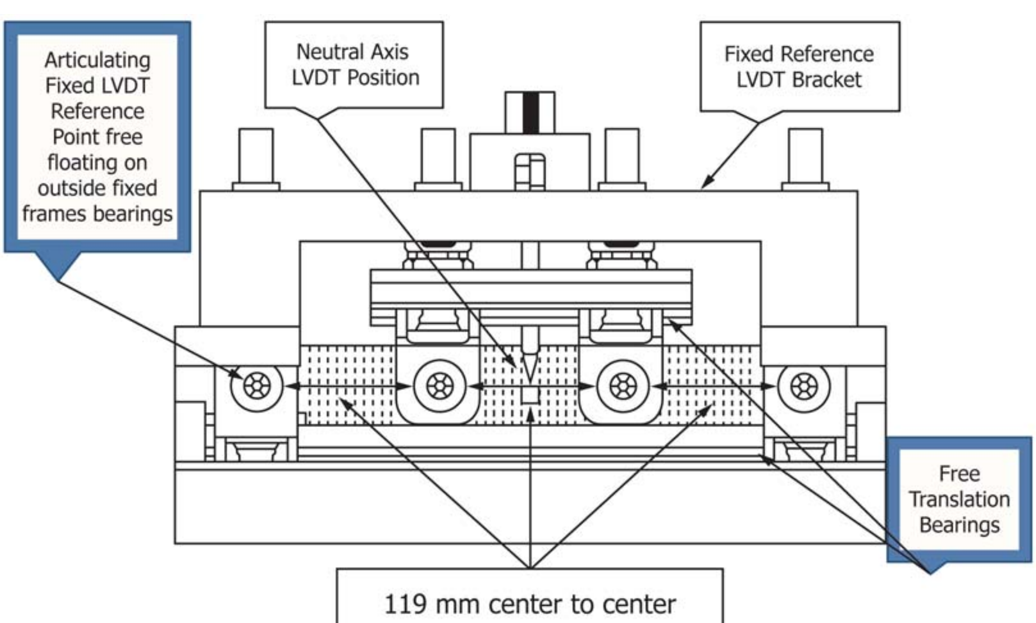


FIG. 6 Schematic of Fixed Reference Displacement Sensor of Flexural Beam Fatigue Test Apparatus (Side View)