
Standard Method of Test for

**Determining the Damage
Characteristic Curve and Failure
Criterion Using the Asphalt Mixture
Performance Tester (AMPT) Cyclic
Fatigue Test**

AASHTO Designation: TP 107-18 (2020)¹

**Technical Subcommittee: 2d, Proportioning
of Asphalt–Aggregate Mixtures**

Release: Group 3 (July)



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Standard Method of Test for

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1. SCOPE

- 1.1. This test method covers procedures for preparing and testing asphalt concrete mixtures to determine the damage characteristic curve and failure criterion via direct tension cyclic fatigue tests in the Asphalt Mixture Performance Tester (AMPT).
- 1.2. This standard is applicable to laboratory prepared specimens of mixtures with nominal maximum size aggregate less than or equal to 25.0 mm (0.98 in.). Mixtures with a nominal maximum aggregate size greater than or equal to 25.0 mm (0.98 in.) may experience lower success rates.
- 1.3. *This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all 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:*
 - R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
 - R 38, Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)
 - R 62, Developing Dynamic Modulus Master Curves for Asphalt Mixtures
 - R 84, Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
 - T 342, Determining Dynamic Modulus of Hot Mix Asphalt (HMA)
 - T 378, Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
- 2.2. *ASTM Standard:*
 - E4, Standard Practices for Force Verification of Testing Machines

- 2.3. *Other Documents:*
- Kim, Y. R., et al. *Development of Asphalt Mixture Performance Related Specifications*, Final Report, FHWA Project DTFH61-08-H-00005, 2018.
 - *National Cooperative Highway Research Report 629: Ruggedness Testing of the Dynamic Modulus and Flow Number Tests with the Simple Performance Tester*, Appendix E, Final Version of the SPT Equipment Specifications. NCHRP, Transportation Research Board, 2008.

3. TERMINOLOGY

- 3.1. *alpha term (α)*—value corresponding to the maximum slope of the relaxation modulus master curve which is used in the accumulation of damage with time.
- 3.2. *average rate of dissipated pseudo strain energy per cycle (G^R)*—parameter used in the failure criterion for fatigue performance which is generated from a pseudo strain energy density function relating pseudo strain and damage.
- 3.3. *complex modulus (E^*)*—a complex number that defines the relationship between stress and strain for a linear viscoelastic material.
- 3.4. *cyclic pseudo secant modulus (C^*)*—the secant modulus in stress–pseudo strain space for a single cycle. This pseudo modulus differs from C because it is computed using a steady-state assumption and is used only with cycle-based data.
- 3.5. *damage (S)*—the internal state variable that quantifies microstructural changes in asphalt concrete.
- 3.6. *damage characteristic curve (C versus S curve)*—the curve formed when plotting the damage on the x -axis and the pseudo secant modulus on the y -axis. It defines the unique relationship between the structural integrity and amount of damage in a given mixture.
- 3.7. *dynamic modulus ($|E^*|$)*—the norm of the E^* , which is calculated by dividing the peak-to-peak stress by the peak-to-peak axial strain measured during the steady-state period.
- 3.8. *dynamic modulus ratio (DMR)*—the ratio between the dynamic modulus fingerprint and the dynamic modulus value from a master curve construction, both evaluated at the same temperature and frequency condition. This value is also used to characterize specimen-to-specimen variability.
- 3.9. *failure cycle (N_f)*—the cycle in which the measured phase angle drops sharply after a stable increase during cyclic loading.
- 3.10. *fatigue analysis coefficients (K_1, K_2, K_3)*—fitting coefficients to describe the classical stress (or strain) versus cycles to failure relationship.
- 3.11. *phase angle (ϕ)*—the angle, expressed in degrees, between an applied sinusoidal stress and the resulting sinusoidal strain measured during the steady-state period.
- 3.12. *pseudo strain (ϵ_R)*—a quantity that is similar to strain but does not include time effects. Pseudo strain is calculated by solving the convolution integral of the strain and $E(t)$.
- 3.13. *pseudo secant modulus (C)*—the secant modulus in stress–pseudo strain space.
- 3.14. *relaxation modulus ($E(t)$)*—the quotient of the stress response of a material with time to a constant step amplitude of strain.

4. SUMMARY OF METHOD

- 4.1. An actuator displacement-controlled and repeated cyclic loading is applied to a cylindrical asphalt concrete specimen until failure. The applied stress and on-specimen axial strain response are measured and used to calculate the necessary quantities. The relationship between the damage (S) and the pseudo secant modulus (C) is determined and expressed as the damage characteristic curve. It is important to consider this document pertains to direct tension testing in an AMPT. Test procedures will differ if using other machinery and it is recommended more specialized procedures be developed for these loading machines.

5. SIGNIFICANCE AND USE

- 5.1. The damage characteristic curve represents the fundamental relationship between damage and material integrity for asphalt concrete mixtures. This property is independent of temperature, frequency, and mode of loading. Combined with the linear viscoelastic properties of asphalt concrete, the damage characteristic curve can be used to analyze the fatigue characteristics of asphalt concrete mixtures.
- 5.2. Damage characteristic curves can also be combined with the failure criterion and additional pavement response models to predict the fatigue behavior of in-service asphalt concrete mixtures.

6. APPARATUS

- 6.1. *Asphalt Mixture Performance Tester*—An AMPT or system meeting or exceeding the requirements of Equipment Specifications for the Simple Performance Test System, NCHRP Report 629, Appendix E, with the additional capability to conduct direct tension testing, as shown in Figure 1. The minimum requirements of the accuracy and resolution of the equipment measurement system are summarized in Table 1.

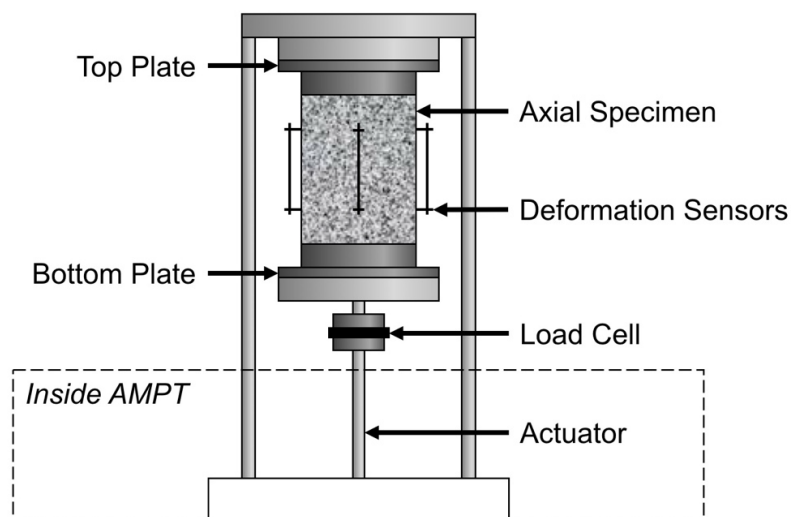


Figure 1—General Schematic of Direct Tension Test Setup

Table 1—Accuracy and Resolution of Equipment Measurement System

Measurement	Range	Accuracy	Resolution
Load	0.12 to 13.5 kN (27.0 to 3034.9 lb)	Error $\leq 1.0\%$	≤ 0.0012 kN (0.2698 lb)
Machine deformation	At least 12 mm (0.47 in.)	Error ≤ 0.03 mm (0.001 in.)	≤ 0.0025 mm (9.843E-5 in.)
On-specimen deformation	Not specified ^a	Error $\leq 1.0\%$	Not specified ^b

^a A range of about 7000 μe is recommended.

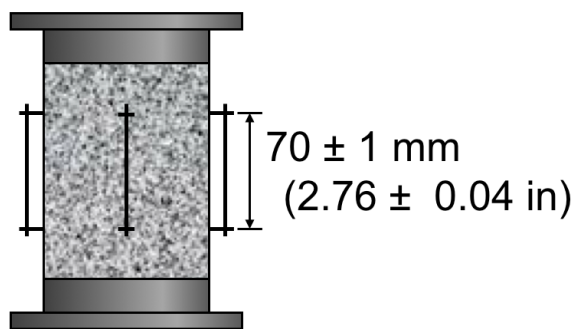
^b A resolution less than 7.5 μe is recommended.

6.2. *External Conditioning Chamber (optional)*—An environmental chamber for conditioning the test specimens to the desired testing temperature. The chamber shall be capable of controlling the temperature of the specimen over a temperature range of 5 to 25°C (41 To 77°F) to within $\pm 0.5^\circ\text{C}$ ($\pm 1^\circ\text{F}$). The chamber shall be large enough to accommodate at least a single test specimen and a “dummy” specimen with a thermocouple or other calibrated temperature-measuring devices mounted at the center for temperature verification.

6.3. *Axial Deformation Measurement System*—Axial deformations shall be measured in the middle 70 mm (2.76 in.) of the specimen using sensors mounted between gauge points that are glued to the specimen, an example of which is shown in Figure 2. The deformations shall be measured at three locations 120 degrees apart, or four locations 90 degrees apart.

Note 1—If gauge-head type (spring-loaded) linear variable differential transducers (LVDTs) are chosen, care should be taken to ensure that the spring force is not so strong (less than 1 N or 0.22 lb) as to force the gauge points apart. This effect can be measured by monitoring the deformation of a specimen that is lying on its side and is conditioned to the appropriate temperature measured using a spring-loaded LVDT that has been attached to the specimen.

Note 2—The reliability of sensors should be verified with the supplier or manufacturer.

**Figure 2**—General Schematic of Gauge Points (Not to Scale)

6.4. *Loading Platens*—Are required above and below the specimen to transfer the load from the testing machine to the specimen. The diameter of the loading platens shall be not less than 100 mm (3.94 in.) and not greater than 105 mm (4.13 in.). It is recommended that the diameter of platens is closer to the target specimen diameter of 100 mm (3.94 in.), as this improves centering of the specimen. Generally, these platens should be made of hardened or plated steel, or anodized high strength aluminum. Softer materials will require more frequent replacement. Materials that have linear elastic modulus properties and hardness properties lower than that of 6061-T6 aluminum shall not be used. The face of each load platen shall be grooved to provide better adhesion between the glue and plate. The top loading platen shall be designed so that it can be mated to the test machine without inducing loading eccentricity. For machines using a three-point attachment

configuration, the platens should simply be tightened into the machine using screws and a torque wrench.

Note 3—Users may also place a ball bearing between the platens and the top loading platform in an attempt to account for loading eccentricity. Extra care should be taken using the ball bearing since it could have a negative effect if screws are overtightened.

Note 2—It is recommended the grooves in the end plates be approximately 0.6 mm (0.024 in.) deep and spaced laterally by a distance of approximately 1.9 mm (0.075 in.). The grooving pattern can be either concentric circles or a spiral pattern. A V-shaped groove or a cross-hatched groove is suggested. The 60-degree point threading bit has been used successfully for making the grooves.

- 6.5. *End Plate Gluing Apparatus*—Should be available for gluing the end plates to the asphalt concrete specimen. The device should ensure that the end plates and specimen are all centered, that the two platens are held parallel, and that the specimen is standing perpendicular to the plates. The weight resting on the specimen during curing of the adhesive shall not exceed 0.045 kN (10 lb), otherwise it shall be possible to clamp or otherwise hold the gluing apparatus at a fixed height for a period of at least 4 h. Figure 3 shows a gluing jig that has been used successfully. If no jig is available, the specimen can be glued directly in the test machine. To do this, the gluing should be performed with the machine in load control. The applied compressive load should not be greater than 0.045 kN (10 lb).



Figure 3—End Plate Gluing Apparatus

7. HAZARDS

- 7.1. Standard laboratory safety precautions must be observed when preparing and testing asphalt concrete specimens.

8. TESTING EQUIPMENT CALIBRATION

- 8.1. The guidelines provided in T 378 shall be followed to ensure that the test equipment and on-specimen measurement devices are properly calibrated.
- 8.2. If any of the verifications yield data that do not comply with the accuracy specified, the problem shall be corrected prior to further testing.
- 8.3. The hydraulic machine shall be properly tuned in displacement control mode, to enable use of the strain selection guidance in this standard. In displacement control mode, the tuning shall be such that there is a sinusoidal actuator deformation shape and the actuator displacement returns close to the initial position on the first cycle, as this will ensure the cycles are uniform and the input strain closely matches the output strain. If the machine is not tuned properly, the strain selection guidance may need to be adjusted for the specific machine.

9. TEST SPECIMENS

- 9.1. Direct tension testing shall be performed on test specimens cored and cut from larger Superpave gyratory compacted specimens, prepared in accordance with R 83, with the exception of the allowance for 130-mm-height specimens. Meeting the height requirements for both the gyratory compacted specimens (from R 83, 180 mm) and final test specimens will minimize unwanted end failure of the test specimen due to an uneven air void distribution. The average height of the test specimens shall be between 127.5 and 132.5 mm (5.0 and 5.2 in.), respectively.
- Note 3**—The specimen height that should be used and the cutting scheme will depend on the air void gradient produced by the specific compactor and the capabilities of the sawing equipment. For specimens compacted to a height of 180 mm (7.1 in.), it has been found that 25 mm (0.98 in.) should first be cut from the bottom face of the specimen (the face which was at the bottom of the gyratory compaction mold). Then, the remaining length should be cut so that the final specimen height is between 127.5 and 132.5 mm (5.0 and 5.2 in.).
- 9.2. *Aging*—Laboratory-prepared mixtures shall be temperature-conditioned in accordance with the 4-h, short-term oven-conditioning procedure outlined in R 30. Field mixtures need not be aged prior to testing.
- 9.3. Prepare at least three test specimens at the target air void content ± 0.5 percent. Depending on mixture characteristics and operator experience, additional specimens may be necessary. For pavement performance analysis, it is strongly recommended to perform four successful tests to improve accuracy.
- 9.4. *Replicates*—One specimen should be tested at each input condition.
- 9.5. *Specimen storage*—Store the test specimen, until tested, on its end on a flat shelf in a room with the temperature controlled between 15 and 27°C (59.0 to 80.6°F).
- Note 6**—Definitive research concerning the effects of test specimen aging on the results of this test has not been completed. Some users enclose specimens in plastic or minimize specimen storage time to two weeks, or both.

10. TEST SPECIMEN INSTRUMENTATION PROCEDURE

- 10.1. Attach the mounting studs for the axial sensors to the sides of the specimen using epoxy cement. Take care to avoid placing mounting studs directly in-line with screw holes in the end plates, which will be used to attach the specimen to the testing machine. A spacing fixture may be used to facilitate the mounting of the axial deformation measuring hardware.