
Standard Method of Test for

Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

AASHTO Designation: T 378-22¹

Technically Revised: 2022

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



**American Association of State Highway and Transportation Officials
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1. SCOPE

- 1.1. This standard describes test methods for measuring the dynamic modulus and flow number for asphalt mixtures using the Asphalt Mixture Performance Tester (AMPT). This practice is intended for dense- and gap-graded mixtures with nominal-maximum aggregate sizes up to 37.5 mm.
- 1.2. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.3. *The quality of the results produced by this standard 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 R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
 - < M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - < R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - < R 83, Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)
- 2.2. *ASTM Standards:*
 - < E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
 - < E879, Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
 - < E1137/E1137M, Standard Specification for Industrial Platinum Resistance Thermometers

- 2.3. *International Electrotechnical Commission Standard:*
< IEC 60751: 2008 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors
- 2.4. *NCHRP Publications:*
< NCHRP. Equipment Specification for the Simple Performance Test System, Version 3.0, Prepared for National Cooperative Highway Research Program (NCHRP), Transportation Research Board, Washington, DC, October 16, 2007. Information regarding the final version of the SPT Equipment Specifications is available online as Appendix E of NCHRP Report 629 at <https://www.trb.org/Publications/Blurbs/160512.aspx>.
< NCHRP. *National Cooperative Highway Research Program Report 702: Precision of the Dynamic Modulus and Flow Number Tests Conducted with the Asphalt Mixture Performance Tester*. National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2011

3. TERMINOLOGY

- 3.1. *Definitions:*
- 3.1.1. *confining pressure*—the stress applied to all surfaces in a confined test.
- 3.1.2. *deviatoric stress*—the difference between the total axial stress and the confining pressure in a confined test.
- 3.1.3. *dynamic modulus*, $|E^*|$ —the absolute value of the complex modulus calculated by dividing the peak-to-peak stress by the peak-to-peak strain for a material subjected to a sinusoidal loading.
- 3.1.4. *flow number*—the number of load cycles corresponding to the minimum rate of change of permanent axial strain during a repeated-load test.
- 3.1.5. *phase angle*, δ —the angle in degrees between a sinusoidally applied stress and the resulting strain in a controlled stress test.
- 3.1.6. *permanent deformation*—the nonrecovered deformation in a repeated-load test.

4. SUMMARY OF METHOD

- 4.1. This test method describes procedures for measuring the dynamic modulus and flow number for asphalt mixtures.
- 4.2. In the dynamic modulus procedure, a specimen at a specific test temperature is subjected to a controlled sinusoidal (haversine) compressive stress of various frequencies. The test may be conducted with or without confining pressure. The applied stresses and resulting axial strains are measured as a function of time and used to calculate the dynamic modulus and phase angle.
- 4.3. In the flow number procedure, a specimen at a specific test temperature is subjected to a repeated haversine axial compressive load pulse of 0.1 s every 1.0 s. The test may be conducted with or without confining pressure. The resulting permanent axial strains are measured as a function of the load cycles and numerically differentiated to calculate the flow number. The flow number is defined as the number of load cycles corresponding to the minimum rate of change of permanent axial strain.

5. SIGNIFICANCE AND USE

- 5.1. The dynamic modulus is a performance-related property that can be used for mixture evaluation and for characterizing the stiffness of asphalt mixtures for mechanistic-empirical pavement design.
- 5.2. The flow number is a property related to the resistance of asphalt mixtures to permanent deformation. It can be used to evaluate and design asphalt mixtures with specific resistance to permanent deformation.

6. APPARATUS

- 6.1. *Specimen Fabrication Equipment*—For fabricating dynamic modulus test specimens as described in R 83.
- 6.2. *Dynamic Modulus Test System*—Meeting the requirements of the equipment specification for the Simple Performance Test (SPT) System, Version 3.0, except for the following provisions: In the referenced equipment specification, Sections 10.7 and 11.3 shall require a temperature sensor range of 0 to 75°C (32 to 167°F) and Section 11.1 shall require a temperature control range from 4 to 70°C (39 to 158°F).
- 6.3. *Conditioning Chamber*—An environmental chamber for conditioning the test specimens to the desired testing temperature. The environmental chamber shall be capable of controlling the temperature of the specimen over a temperature range from 4 to 70°C to an accuracy of $\pm 0.5^\circ\text{C}$. The chamber shall be large enough to accommodate the number of specimens to be tested plus a “dummy” specimen with a temperature sensor mounted in the center for temperature verification. A thermometer for measuring environmental chamber temperature shall meet the requirements of M 339M/M 339 with a temperature range of at least 0 to 80°C, and an accuracy of $\pm 0.13^\circ\text{C}$.
- Note 1**—The temperature range required for the Dynamic Modulus Test System and the Conditioning Chamber is a function of the anticipated test temperature. The temperature control range provided in Sections 6.2 and 6.3 is intended to be inclusive of all areas of the U.S. In many climatic regions, it may not be necessary to have equipment capable of controlling the temperature up to 70°C. Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Special order; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Special order.
- 6.4. *TFE-Fluorocarbon Sheet*—0.25 mm thick, to be used as a friction reducer between the specimen and the loading platens in the dynamic modulus test.
- 6.5. *Latex Membranes*—100-mm diameter by 0.3 mm thick, for use in confined tests and for manufacturing “greased double latex” friction reducers to be used between the specimen and the loading platens in the dynamic modulus and flow number tests.
- 6.6. *Silicone Grease*—Dow Corning “Stopcock Grease” or equivalent, for manufacturing greased double latex friction reducers.
- 6.7. *Balance*—Capable of determining mass to the nearest 0.01 g. The balance is used to determine the mass of silicone grease during fabrication of greased double latex friction reducers.

7. HAZARDS

- 7.1. This practice and associated standards involve handling of hot asphalt binder, aggregates, and asphalt mixtures. It also includes the use of sawing and coring machinery and servo-hydraulic

testing equipment. Use standard safety precautions, equipment, and clothing when handling hot materials and operating machinery.

8. STANDARDIZATION

8.1. *Verification with Proving Ring:*

- 8.1.1. Verify the normal operation of the AMPT weekly or at the beginning of a new testing program using the manufacturer-provided proving ring and following the proving ring manufacturer's use instructions. Perform a dynamic modulus test on the proving ring using a target strain of 100 microstrain at 1.0 Hz. The dynamic modulus of the proving ring should be within ± 3 percent of the value obtained on the proving ring for the same testing conditions during the last calibration.

8.2. *Calibration:*

- 8.2.1. The following systems on the AMPT shall be calibrated annually, when the AMPT system is moved, or when any of its components are changed:

- < Load Measuring System
- < Actuator Displacement Measuring System
- < Specimen-Mounted Deformation Measuring System
- < Confining Pressure Measuring System
- < Temperature Measuring System

Methods for calibration of each of these systems are included in Annex B.

9. PROCEDURE A—DYNAMIC MODULUS TEST

9.1. *Test Specimen Fabrication:*

- 9.1.1. Testing shall be performed on 100-mm diameter by 150-mm tall test specimens fabricated in accordance with R 83.

- 9.1.2. Prepare at least two test specimens at the target air void content ± 0.5 percent and with the aging condition in accordance with R 83.

Note 2—The number of specimens to test depends on the desired accuracy of the analysis. Refer to Table 4 for guidance on the reproducibility of dynamic modulus and phase angle measurements.

9.2. *Test Specimen Instrumentation (Standard Glued-Gauge-Point System):*

- 9.2.1. Attach the gauge points to the specimen in accordance with the manufacturer's instructions.
- 9.2.2. Confirm that the gauge length is 70 mm $\pm$ 1 mm, measured center-to-center of the gauge points.

9.3. *Loading Platens and End-Friction Reducers:*

- 9.3.1. For the dynamic modulus test, the top platen shall be free to rotate.
- 9.3.2. Either greased double latex or TFE fluorocarbon end-friction reducers can be used in the dynamic modulus test.
- 9.3.2.1. Teflon end-friction reducers are made from 0.25-mm thick TFE fluorocarbon sheet, cut to a size slightly larger than the loading platen.

- 9.3.2.2. Greased double latex friction reducers are fabricated from 0.3-mm thick latex membranes as described in Annex A.
- 9.4. *Procedure:*
- 9.4.1. *Unconfined Tests:*
- 9.4.1.1. Place the specimens to be tested in the environmental chamber with the “dummy” specimen and monitor the temperature of the dummy specimen to determine when testing can begin.
- 9.4.1.2. Place platens and friction reducers inside the testing chamber. Turn on the AMPT, set the temperature control to the desired testing temperature, and allow the testing chamber to equilibrate at the testing temperature for at least 1 h.
- 9.4.1.3. When the dummy specimen and the testing chamber reach the target temperature, open the testing chamber. Remove a test specimen from the conditioning chamber and quickly place it in the testing chamber.
- 9.4.1.4. Assemble the specimen to be tested with platens in the following order from bottom to top: bottom loading platen, bottom friction reducer, specimen, top friction reducer, and top loading platen.
- 9.4.1.5. Install the specimen-mounted deformation measuring system on the gauge points per the manufacturer’s instructions. Ensure that the deformation measuring system is within its calibrated range. Ensure that the top loading platen is free to rotate during loading.
- 9.4.1.6. Close the testing chamber and allow the chamber temperature to return to the testing temperature.
- 9.4.1.7. Procedures in Sections 9.4.1.3 through 9.4.1.6, including the return of the test chamber to the target temperature, shall be completed in 5 min.
- 9.4.1.8. Enter the required identification and control information into the dynamic modulus software.
- 9.4.1.9. Follow the software prompts to begin the test. The AMPT will automatically unload when the test is complete and will display the test data and data quality indicators.
- 9.4.1.10. Review the data quality indicators as discussed in Section 9.5. Retest specimens with data quality indicators above the values specified in Section 9.5.
- 9.4.1.11. Once acceptable data have been collected, open the test chamber and remove the tested specimen.
- 9.4.1.12. Repeat procedures in Sections 9.4.1.3 through 9.4.1.11 for the remaining test specimens.
- 9.4.2. *Confined Tests:*
- 9.4.2.1. Assemble each specimen to be tested with the platens and membrane as follows: place the bottom friction reducer and the specimen on the bottom platen. Stretch the membrane over the specimen and bottom loading platen. Install the lower O-ring seal. Place the top friction reducer and top platen on top of the specimen and stretch the membrane over the top platen. Install the upper O-ring seal. When performing confined tests, the specimen must be vented to atmospheric pressure through the drainage lines. Ensure that the friction reducers have holes to allow air to be vented from inside the membrane.
- 9.4.2.2. Encase the “dummy” specimen in a membrane.

- 9.4.2.3. Place the specimen and platen assembly in the environmental chamber with the dummy specimen and monitor the temperature of the dummy specimen to determine when testing can begin.
- 9.4.2.4. Turn on the AMPT, set the temperature control to the desired testing temperature, and allow the testing chamber to equilibrate at the testing temperature for at least 1 h.
- 9.4.2.5. When the dummy specimen and the testing chamber reach the target temperature, open the testing chamber. Remove a test specimen and platen assembly and quickly place it in the testing chamber. When performing confined tests, the specimen must be vented to atmospheric pressure through the drainage lines. Properly connect the drainage lines to the loading platens, and ensure that they are vented to atmospheric pressure through the bubble chamber to identify leaks.
- 9.4.2.6. Install the specimen-mounted deformation measuring system outside the membrane on the gauge points per the manufacturer's instructions. Ensure that the deformation measuring system is within its calibrated range. Ensure that the top loading platen is free to rotate during loading.
- 9.4.2.7. Close the testing chamber, and allow the chamber temperature to return to the testing temperature.
- 9.4.2.8. Procedures in Sections 9.4.2.5 through 9.4.2.7, including the return of the test chamber to the target temperature, shall be completed in 5 min.
- 9.4.2.9. Enter the required identification and control information into the dynamic modulus software.
- 9.4.2.10. Follow the software prompts to begin the test. The AMPT will automatically unload when the test is complete and will display the test data and data quality indicators.
- 9.4.2.11. Review the data quality indicators as discussed in Section 9.5. Retest specimens with data quality indicators above the values specified in Section 9.5.
- 9.4.2.12. Once acceptable data have been collected, open the test chamber and remove the tested specimen.
- 9.4.2.13. Repeat procedures in Sections 9.4.2.3 through 9.4.2.12 for the remaining test specimens.
- 9.5. *Computations and Data Quality:*
- 9.5.1. The calculation of dynamic modulus, phase angle, and the data quality indicators is performed automatically by the AMPT software.
- 9.5.2. Accept only test data meeting the data quality statistics given in Table 1. Table 2 summarizes actions that can be taken to improve the data quality statistic. Repeat tests as necessary to obtain test data meeting the data quality statistics requirements.

Table 1—Data Quality Statistics Requirements

Data Quality Statistic	Limit
Deformation drift	In direction of applied load
Peak-to-peak strain	75 to 125 microstrain for unconfined tests 85 to 115 microstrain for confined tests
Load standard error	10%
Deformation standard error	10%
Deformation uniformity	30%
Phase uniformity	3 degrees

Note 3—The data quality statistics in Table 1 are reported by the AMPT. If a dynamic modulus test system other than the AMPT is used, refer to the equipment specification for the Simple