Standard Test Method for Dynamic Modulus of Asphalt Mixtures[1]

This standard is issued under the fixed designation D 3497; 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 covers procedures for preparing and testing asphalt mixtures to determine dynamic modulus values. The procedure described covers a range of both temperature and loading frequency. The minimum recommended test series consists of testing at 41, 77, and 104°F (5, 25, and 40°C) at loading frequencies of 1, 4, and 16 Hz for each temperature.

1.2 This method is applicable to asphalt paving mixtures similar to mixes 3A, 4A, 5A, 6A, and 7A, as defined by Specification D 3515.

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 617 Practice for Capping Cylindrical Concrete Specimens

D 3496 Method for Preparation of Bituminous Mixture Specimens for Dynamic Modulus Testing

D 3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures

3. Terminology

3.1 *Definitions:*

3.1.1 *dynamic modulus*—the absolute value of the complex modulus that defines the elastic properties of a linear viscoelastic material subjected to a sinusoidal loading, $|E^*|$

3.1.2 *complex modulus*—a complex number that defines the relationship between stress and strain for a linear viscoelastic material, E^*.

3.1.3 *linear material*—a material whose stress to strain ratio is independent of the loading stress applied.

4. Summary of Test Method

4.1 A sinusoidal (haversine) axial compression stress is applied to a specimen of asphalt concrete at a given temperature and loading frequency. The resulting recoverable axial strain response of the specimen is measured and used to calculate dynamic modulus.

5. Significance and Use

5.1 The values of dynamic modulus can be used for both asphalt paving mixture design and asphalt pavement thickness design.

6. Apparatus

6.1 *Testing Machine*—An electro-hydraulic testing machine with a function generator capable of producing a haversine wave form has proven to be most suitable for use in dynamic modulus testing. The testing machine should have the capability of applying the loads over a range of frequencies from 0.1 to 20 Hz and stress levels up to 100 psi (690 kPa).

6.2 *Temperature-Control System*—The temperature-control system should be capable of a temperature range from 32 to 120 ± 1°F (0 to 50 ± 0.5°C). The temperature chamber should be large enough to hold six specimens.

6.3 *Measurement System*—The measurement system consists of a two-channel recorder, stress- and strain-measuring devices, a suitable signal amplification, and excitation equipment. The measurement system should have the capability for determining loading up to 3000 lbf (13.3 kN) from a recording with a minimum sensitivity of 2 % of the test load per millimetre of chart paper. This system should also be capable for use in determining strains over a range of full-scale recorder outputs from 300 to 5000 micro units of strain. At the highest sensitivity setting, the system should be able to display 4 micro strain units or less per millimetre on the recorded chart.

6.3.1 *Recorder*—The recorder amplitude should be independent of frequency for tests conducted up to 20 Hz.

6.3.2 *Strain Measurement*—The values of axial strain are measured by bonding two wire strain gages[3] at mid-height opposite each other on the specimens. The gages are wired in a Wheatstone Bridge circuit with two active gages on the test specimen and two temperature-compensating gages on an

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road Paving Materials and is the direct responsibility of Subcommittee D04.26 on Fundamental/Mechanistic Tests.

Current edition approved Oct. 26, 1979. Published December 1979. Originally approved in 1976. Last previous edition approved in 1995 as D 3497 – 79 (1995).

[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] The Baldwin-Lima-Hamilton SR-4 Type A-1S 13 strain gage has been found satisfactory for this purpose.

unstressed specimen exposed to the same environment as the test specimen. The temperature-compensating gages should be at the same position on the specimen as the active gages. The sensitivity and type of measurement device should be selected to provide the strain readout required in 6.3.

6.3.3 *Load Measurements*—Loads are measured with an electronic load cell meeting requirements for load and stress measurements in 6.3.

6.4 *Hardened Steel Disk*—A hardened steel disk with a diameter equal to that of the test specimen is required to transfer the load from the testing machine to the specimen.

7. Test Specimens

7.1 *Laboratory Molded Specimens*—Prepare the laboratory molded specimens in accordance with Method D 3496. The specimens should have a height-to-diameter ratio of 2 to 1, a minimum diameter of 4 in. (101.6 mm) and a diameter four or more times the maximum nominal size of aggregate particles. A minimum of three specimens is required for testing.

7.2 *Pavement Cores*—A minimum of six cores from an in-service pavement is required for testing. Obtain cores having a minimum height-to-diameter ratio of 2 to 1 and with diameters not less than two times the maximum nominal size of an aggregate particle. Select cores to provide a representative sample of the pavement section being studied.

7.3 *Specimen Preparation*—Cap all specimens with a sulfur mortar in accordance with the requirements of Method C 617 prior to testing. Bond the strain gages with epoxy cement[4] to the sides of the specimen near mid-height in position to measure axial strains (Note 1). Wire the strain gages as required in 6.3.2 and attach suitable lead wires and connectors.

NOTE 1—On specimens with large-size aggregate, care must be taken so that the gages are attached over areas between the aggregate faces.

8. Procedure

8.1 Place the test specimens in a controlled temperature cabinet and bring them to the specified test temperature.

NOTE 2—A dummy specimen with a thermocouple in the center can be used to determine when the desired test temperature is reached.

8.2 Place the specimen into the loading apparatus and connect the strain gage wires to the measurement system. Put the hardened steel disk on top of the specimen and center both under the loading apparatus. Adjust and balance the electronic measuring system as necessary.

8.3 Apply haversine loading to the specimen without impact and with loads varying between 0 and 35 psi (241 kPa) for each load application for a minimum of 30 s and not exceeding 45 s at temperatures of 41, 77, and 104°F (5, 25, and 40°C) and at loading frequencies of 1, 4, and 16 Hz for each temperature.

NOTE 3—If excessive deformation (greater than 2500 micro units of strain) occurs, reduce the maximum loading stress level to 17.5 psi (121 kPa).

8.4 For pavement-cored specimens, test six specimens at each temperature and frequency condition once. Start at the lowest temperature and run the three frequencies from fastest to slowest. Bring specimens to specified temperature before each test. Repeat for next highest temperature.

8.5 For laboratory-molded specimens, test three specimens at each temperature and frequency condition twice. Conduct tests in same order as pavement cores (8.4). Run the replicate tests before the temperature is changed for the three frequencies. Bring the specimens to the specified test temperature before each test.

8.6 Monitor both the loading stress and axial strain during the test. Increase the recorder chart speed such that 1 cycle covers 10 to 20 mm of chart paper for five to ten repetitions before the end of the test.

8.7 Complete the loading for the test within 2 min from the time specimens are removed from the temperature-control cabinet.

NOTE 4—The 2-min testing time limit may be waived if loading is conducted within a temperature-control cabinet meeting requirements in 6.2.

9. Calculations

9.1 Measure the average amplitude of the load and the strain over the last three loading cycles to the nearest 0.5 mm (see Fig. 1).

9.2 Calculate the loading stress, σ_o, as follows:

$$\sigma_o = (H_1 \times L)/(H_2 \times A) \quad (1)$$

where:
H_1 = measured height of load, in. (or mm) (see Fig. 1),
H_2 = measured chart height, in. (or mm) (see Fig. 1),
L = full-scale load amplitude determined by settings on the recording equipment, lbf (or N), and
A = cross-sectional area of the test specimen, in.^{2}(or m^2).

9.3 Calculate the recoverable axial strain, ϵ_o, as follows:

$$\epsilon_o = (H_3 \times S)/H_4 \quad (2)$$

where:
H_3 = measured height of recoverable strain, in. (or mm) (see Fig. 1),
H_4 = measured chart height, in. (or mm) (see Fig. 1), and
S = full-scale strain amplitude determined by settings on the recording equipment, in./in. (or m/m).

9.4 Calculate dynamic modulus, $|E^*|$; as follows:

$$\text{Dynamic modulus} = \sigma_o/\epsilon_o \quad (3)$$

where:
σ_o = axial loading stress, psi (or kPa), and
ϵ_o = recoverable axial strain, in./in. (or m/m).

10. Report

10.1 Report the average dynamic modulus at temperatures of 41, 77, and 104°F (5, 25, and 40°C) for 1, 4, and 16-Hz loading frequencies at each temperature.

11. Precision

11.1 This test method shall not be used for Specification purposes.

[4] Baldwin-Lima-Hamilton EPY 150 Epoxy Cement has been found satisfactory for this purpose.

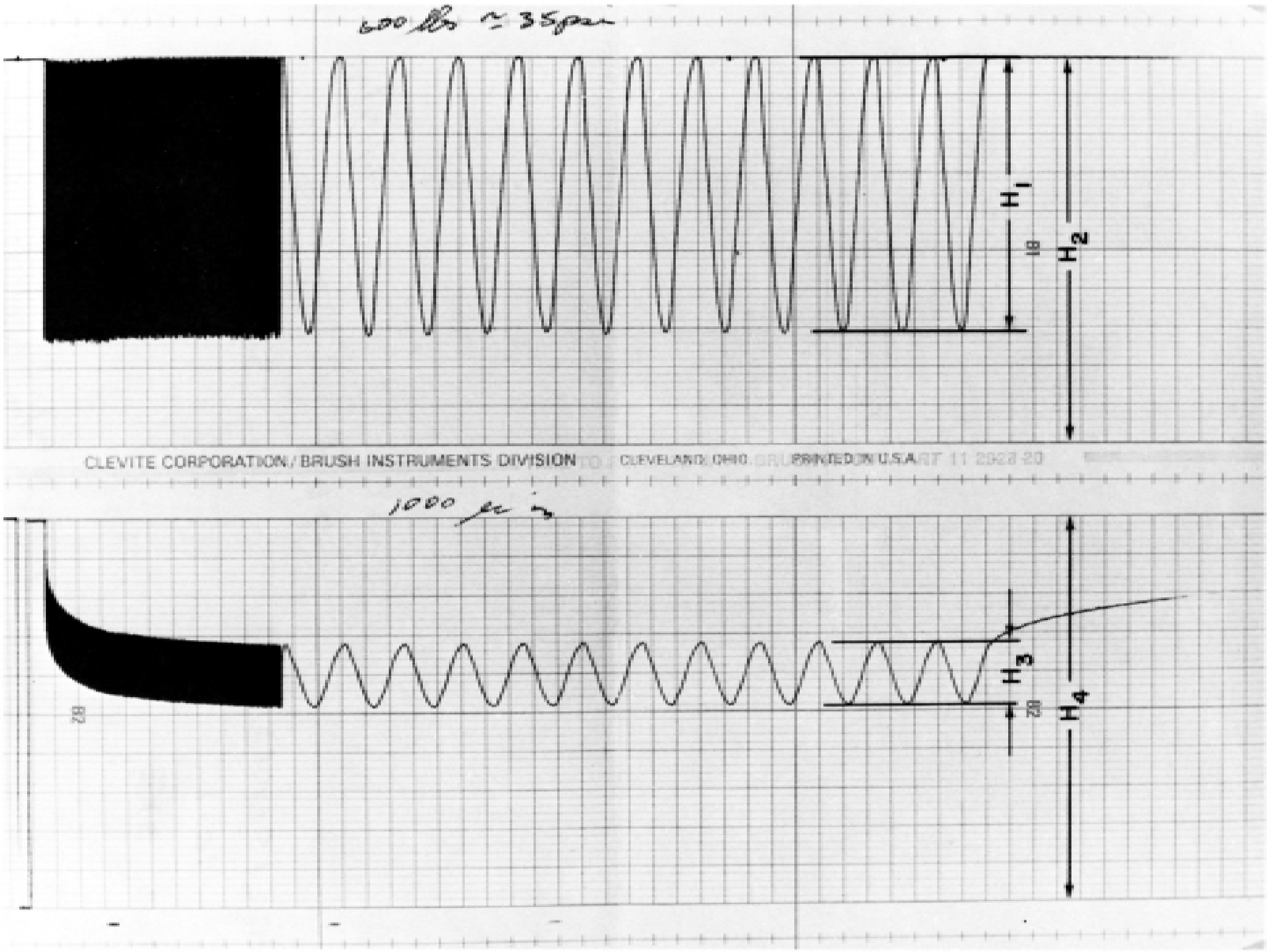

FIG. 1 Recording of Load and Strain