Designation: D 4123 – 82 (Reapproved 1995)

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures[1]

This standard is issued under the fixed designation D 4123; 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 laboratory-fabricated or field-recovered cores of bituminous mixtures to determine resilient modulus values using the repeated-load indirect tension test. The procedure described covers a range of temperatures, loads, loading frequencies, and load durations. The recommended test series consists of testing at 41, 77 (Note 1), and 104°F (5, 25 (Note 1), and 40°C) at one or more loading frequencies, for example, at 0.33, 0.5, and 1.0 Hz for each temperature. This recommended series will result in nine test values for one specimen which can be used to evaluate the overall resilient behavior of the mixture.

NOTE 1—Ambient laboratory temperature may be substituted as appropriate.

1.2 *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:*

D 1559 Test Method for Resistance to Plastic Flow of Bituminous Mixture Using Marshall Apparatus[2]

D 1561 Practice for Preparation of Bituminous Mixture Test Specimens by Means of California Kneading Compactor[2]

D 3387 Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)[2]

D 3496 Method for Preparation of Bituminous Mixture Specimens for Dynamic Modulus Testing[2]

D 3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures[2]

3. Summary of Test Method

3.1 The repeated-load indirect tension test for determining resilient modulus of bituminous mixtures is conducted by applying compressive loads with a haversine or other suitable waveform. The load is applied vertically in the vertical diametral plane of a cylindrical specimen of asphalt concrete (Fig. 1). The resulting horizontal deformation of the specimen is measured and, with an assumed Poisson's ratio, is used to calculate a resilient modulus. A resilient Poisson's ratio can also be calculated using the measured recoverable vertical and horizontal deformations.

3.2 Interpretation of the deformation data (Fig. 2) has resulted in two resilient modulus values being used. The instantaneous resilient modulus is calculated using the recoverable deformation that occurs instantaneously during the unloading portion of one cycle. The total resilient modulus is calculated using the total recoverable deformation which includes both the instantaneous recoverable and the time-dependent continuing recoverable deformation during the unloading and rest-period portion of one cycle.

4. Significance and Use

4.1 The values of resilient modulus can be used to evaluate the relative quality of materials as well as to generate input for pavement design or pavement evaluation and analysis. The test can be used to study effects of temperature, loading rate, rest periods, etc. Since the procedure is nondestructive, tests can be repeated on a specimen to evaluate conditioning as with temperature or moisture. This test method is not intended for use in specifications.

5. Apparatus

5.1 *Testing Machine*—The testing machine should have the capability of applying a load pulse over a range of frequencies, load durations, and load levels.

NOTE 2—An electrohydraulic testing machine with a function generator capable of producing the desired wave form has been shown to be suitable for use in repeated-load indirect tension testing. Other commercially available or laboratory constructed testing machines such as those using pneumatic repeated loading can also be used. However, these latter machines may not have the load capability to handle larger specimens at the colder testing temperatures.

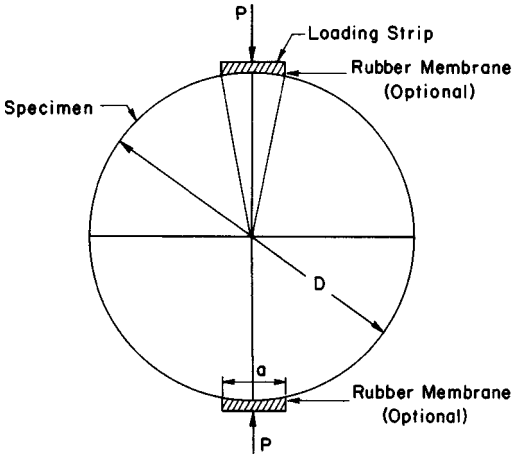
5.2 *Temperature-Control System*—The temperature-control system should be capable of control over a temperature range from 41 to 104°F (5 to 40°C) and within ±2°F (±1.1°C) of the specified temperature within the range. The system should include a temperature-controlled cabinet large enough to hold at least three specimens for a period of 24 h prior to testing.

---

[1] This test method is under the jurisdiction of ASTM Committee D-4 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.26 on Fundamental/Mechanistic Tests.

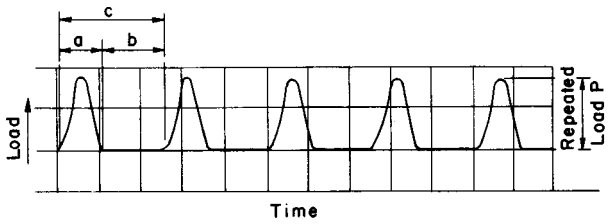
Current edition approved April 30, 1982. Published June 1982.

[2] *Annual Book of ASTM Standards*, Vol 04.03.



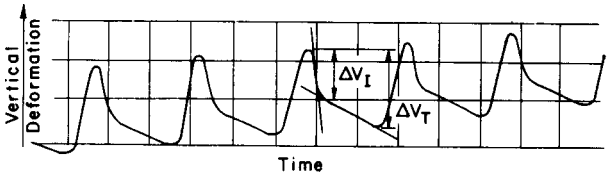
P = applied load
t = thickness of specimen
D = diameter of specimen
a = width of loading strip
= 0.5 in. (13 mm) for 4-in. (102-mm) diameter specimen
= 0.75 in. (19 mm) for 6-in. (152-mm) diameter specimen

FIG. 1 Indirect Tension Test

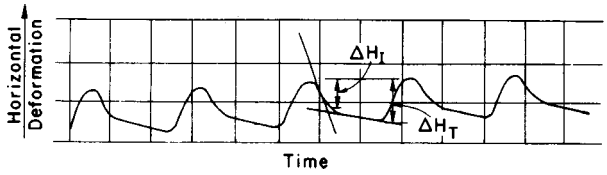


(*a*) Load-Time Pulse

a = duration of loading during one load cycle
b = recovery time
c = cycle time



(*b*) Vertical Deformation Verses Time



(*c*) Horizontal Deformation Verses Time

FIG. 2 Typical Load and Deformation Versus Time Relationships for Repeated-Load Indirect Tension Test

5.3 *Measurement and Recording System*—The measurement and recording system should include sensors for measuring and recording horizontal and vertical deformations. When Poisson's ratio is to be assumed, only a measurement system for horizontal deformation is required. The system should be capable of measuring horizontal deformations in the range of 0.00001 in. (0.00025 mm) of deformation. Loads should be measured and recorded or accurately calibrated prior to testing.

5.3.1 *Recorder*—The measuring or recording devices should be independent of frequency for tests conducted up to 1.0 Hz.

5.3.2 *Deformation Measurement*—The values of vertical and horizontal deformation can be measured by linear variable differential transducers (LVDTs) or other suitable devices. LVDTs should be at midheight opposite each other on the specimen's horizontal diameter. The sensitivity and type of measurement device should be selected to provide the deformation readout required in 5.3. A positive contact by spring loading or gluing attachments to the specimen should be provided if direct contact between the measuring device and sample is required.

NOTE 3—The Trans-TEX Model 350-000 LVDT[3] and Statham UC-3[4]transducers have been found satisfactory for this purpose. If the transducers are temperature-sensitive, such as Statham UC-3, the testing machine should be placed in a controlled temperature chamber. The gages should be wired to preclude the effects of eccentric loading so as to give the algebraic sum of the movement of each side of the specimen. Alternatively, each gage can be read independently and the results summed independently.

5.3.3 *Load Measurement*—Loads should be measured with an electronic load cell capable of satisfying the specified requirements for load measurements in 5.3.

5.4 *Loading Strip*—A metal loading strip with a concave surface having a radius of curvature equal to the nominal radius of the test specimen is required to apply load to the specimen. Specimens will normally be either a nominal 4 or 6 in. (102 or 152 mm) in diameter. The load strip shall be 0.5 or 0.75 in. (13 or 19 mm) wide for these diameters, respectively. Edges should be rounded by grinding to remove the sharp edge in order not to cut the sample during testing. For specimens with rough textures, a thin hard rubber membrane attached to the loading strip has been found effective in reducing stress concentration effects, but should be used only when vertical deformations are not measured.

6. Specimens

6.1 *Laboratory-Molded Specimens*—Prepare the laboratory-molded specimens in accordance with acceptable procedures such as Methods D 1561, D 1559, D 3496, and D 3387. The specimens should have a height of at least 2 in. (51 mm) and a minimum diameter of 4 in. (102 mm) for aggregate up to 1 in. (25 mm) maximum size, and a height of at least 3 in. (76 mm) and a minimum diameter of 6 in. (152 mm) for aggregate up to 1.5 in. (38 mm) maximum size.

6.2 *Core Specimens*—Cores should have relatively smooth, parallel surfaces and conform to the height and diameter requirements specified for laboratory specimens.

7. Procedure

7.1 Place the test specimens in a controlled-temperature cabinet and bring them to the specified test temperature. Unless the temperature is monitored, and the actual temperature

[3] Available from Trans-tek Inc., Route 83, Ellington, CT 06029.
[4] Available from Gould-Statham, 2230 Statham Blvd., Oxnard, CA 93033.

known, the specimens should remain in the cabinet at the specified test temperature for at least 24 h prior to testing.

NOTE 4—A dummy specimen with a thermocouple in the center can be used to determine when the desired test temperature is reached.

7.2 Place a specimen into the loading apparatus and position the loading strips to be parallel and centered on the vertical diametral plane. Adjust and balance the electronic measuring system as necessary.

7.3 Precondition the specimen by applying a repeated haversine or other suitable waveform load to the specimen without impact for a minimum period sufficient to obtain uniform deformation readout. Depending upon the loading frequency and temperatures, a minimum of 50 to 200 load repetitions is typical; however, the minimum for a given situation must be determined so that the resilient deformations are stable (Note 5). Resilient modulus evaluation will usually include tests at three temperatures, for example, 41 ± 2, 77 ± 2, and 104 ± 2°F (5, 25, and 40 ± 1°C), at one or more loading frequencies, for example, 0.33, 0.5, and 1.0 Hz for each temperature. The recommended load range is that to induce 10 to 50 % of the tensile strength (Note 6). Tensile strength can be determined from a destructive test on a specimen and the equation of 8.3 (Note 7).

NOTE 5—As few as five repetitions have been found to be sufficient for loads such as 5 to 25 lbf.

NOTE 6—Loads as low as 10 lbf have been used.

NOTE 7—Load duration is the more important variable and it is recommended that the duration be held to some minimum which can be recorded. The recommended time for the load duration is 0.1 to 0.4 s, with 0.1 s being more representative of transient pavement loading. Recommended frequencies are 0.33, 0.5, and 1 Hz. Instead of tensile strength data, load ranges from 4 to 200 lbf/in. (4 to 35 N/mm) of core or specimen thickness can be used.

7.4 Monitor the horizontal and, if measured, the vertical deformations during the test. If total cumulative vertical deformation greater than 0.001 in. (0.025 mm) occurs during the test, reduce the applied load, the test temperature, or both.

NOTE 8—A typical load pulse-deformation trace is shown in Fig. 2, along with notations indicating the load-time terminology.

7.5 Each resilient modulus determination should be completed within 4 min from the time the specimens are removed from the temperature-control cabinet. The 4-min testing time limit is waived if loading is conducted within a temperature-control cabinet meeting the requirements in 5.2.

7.6 Test each specimen for resilient modulus twice: Following the first test, replace the sample in the temperature-control cabinet for 10 min, continue by rotating the specimen approximately 90°, and repeat the test. Three laboratory fabricated specimens or three cores are recommended for a given test series with variables of temperature, load duration, and load frequency. In order to reduce permanent damage to the specimen, testing should begin at the lowest temperature, shortest load duration, and smallest load. Subsequent testing on the same specimen should be for conditions producing progressively lower moduli. Bring the specimens to the specified temperature before each test.

7.7 Measure the average recoverable horizontal and vertical deformations over at least three loading cycles (see Fig. 2) after the repeated resilient deformation has become stable. The vertical deformation measurements can be omitted when Poisson's ratio is not to be determined.

8. Calculations

8.1 Calculate the resilient modulus of elasticity, E, in pounds-force per square inch (or megapascals), and Poisson's ratio, ν as follows:

$$E_{RI} = P(\nu_{RI} + 0.27)/t\Delta H_I \quad (1)$$

$$E_{RT} = P(\nu_{RT} + 0.27)/t\Delta H_T \quad (2)$$

$$\nu_{RI} = 3.59\ \Delta H_I/\Delta V_I - 0.27 \quad (3)$$

$$\nu_{RT} = 3.59\ \Delta H_T/\Delta V_T - 0.27 \quad (4)$$

where:

E_{RI} = instantaneous resilient modulus of elasticity, psi (or MPa),
E_{RT} = total resilient modulus of elasticity, psi (or MPa),
ν_{RI} = instantaneous resilient Poisson's ratio,
ν_{RT} = total resilient Poisson's ratio,
P = repeated load, lbf (or N),
t = thickness of specimen, in. (or mm),
ΔH_I = instantaneous recoverable horizontal deformation, in. (or mm),
ΔV_I = instantaneous recoverable vertical deformation, in. (or mm),
ΔH_T = total recoverable horizontal deformation, in. (or mm), and
ΔV_t = total recoverable vertical deformation, in. (or mm).

8.2 If Poisson's ratio is assumed, the vertical deformations are not required. A value of 0.35 for Poisson's ratio has been found to be reasonable for asphalt mixtures at 77°F (25°C).

8.3 Calculate the tensile strength, S_T, approximately as follows:

$$S_T = 2\ P_{ult}/\pi tD \quad (5)$$

where:

P_{u1t} = ultimate applied load required to fail specimen, lbf (or N),
t = thickness of specimen, in. (or mm), and
D = diameter of specimen, in. (or mm)

9. Report

9.1 Report the average resilient modulus at temperatures of 41, 77, and 104°F (5, 25, and 40°C) and load duration for each load and frequency used in the test.

10. Precision

10.1 The precision of this test method has not been established.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.