
Standard Method of Test for Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test

AASHTO Designation: TP 127-22 (2024)¹

Technically Revised: 2022

Revised but Not Updated: 2024

Technical Subcommittee: 2b, Liquid Asphalt



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1. SCOPE
- 1.1.

This test method covers the determination of fracture energy density of asphalt binder by means of a direct tension test. For evaluation of relative cracking performance, it is recommended that this test procedure be used with asphalt binder aged using T 240 (RTFO) plus R 28 (PAV). However, this test can be used for determination of binder facture energy for any binder including any aged (RTFO plus PAV or PAV only) neat or modified binder and asphalt binder extracted and recovered from pavement. The test apparatus is designed for testing within the intermediate temperature range, from 0°C to 25°C.
- 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 procedure to establish appropriate safety and health practices and to determine the applicability of regularity limitations prior to use.

2. REFERENCED STANDARDS
- 2.1.

AASHTO Standards:
 - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
 - T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- 2.2.

ASTM Standards:
 - E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
 - E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
 - 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 Standards:
 - IEC 60584-1: 2013 Thermocouples - Part 1: EMF Specifications and Tolerances

3. TERMINOLOGY

3.1. *Definition:*

3.1.1. *asphalt binder*—an asphalt-based cement that is produced from petroleum residue either with or without the addition of particulate organic modifiers of size less than 250 μm .

3.2. *Description of Terms Specific to This Standard:*

3.2.1. *brittle*—type of failure in a direct tension test where the stress–strain curve is essentially linear up to the point of failure and the failure is sudden by rupture of the test specimen without appreciable reduction in cross-sectional area of the specimen.

3.2.2. *brittle–ductile*—type of failure in a direct tension test where the stress–strain curve is curvilinear and the failure is by the rupture of the test specimen. Limited reduction in the cross-section of the specimen occurs before rupture.

3.2.3. *ductile*—type of failure in a direct tension test where the specimen does not rupture but fails by flow at large strain.

3.2.4. *failure*—for specimens exhibiting a stress–strain curve with a single peak stress followed by a continuously increasing reduction in stress, failure is the point at which the tensile stress reaches a maximum value.

3.2.5. *failure strain*—the tensile strain corresponding to the failure stress.

3.2.6. *failure stress*—the tensile stress at the point associated with failure as defined in Section 3.2.4.

3.2.7. *fracture energy density*—maximum energy that can be stored in a unit volume of material without the occurrence of fracture.

3.2.8. *large strain formulation*—analysis, which includes changes in geometry due to excessively large strain.

3.2.9. *necking*—disproportionately large strain localized in a small region of the asphalt binder specimen which results in a prominent decrease in local cross-sectional area.

3.2.10. *tensile strain*—axial strain resulting from the application of a tensile load and calculated as the change in length of the effective gauge length caused by the application of the tensile load divided by the original unloaded effective gauge length.

3.2.11. *tensile stress*—axial stress resulting from the application of a tensile load and calculated as the tensile load divided by the original area of cross-section of the specimen.

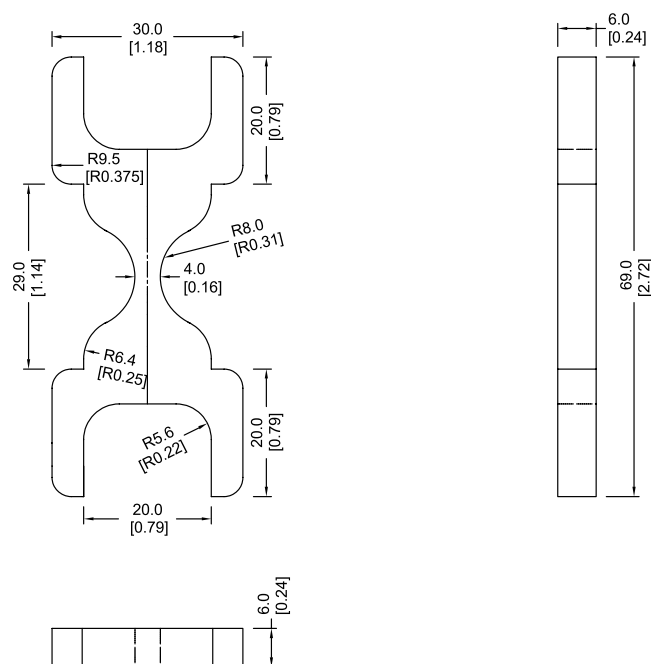
3.2.12. *true strain*—strain determined by accounting for reduction in cross-sectional area.

3.2.13. *true stress*—ratio of the applied load to the instantaneous cross-sectional area.

3.2.14. *true stress–true strain curve*—graphical representation of the relationship between true stress and true strain.

4. SUMMARY OF TEST METHOD

- 4.1. This method describes the procedure used to measure stress and strain on a fracture failure plane in an asphalt binder specimen pulled at a constant rate of displacement (displacement-control). Test specimens have a special geometry (Figure 1) and they are prepared using the specified mold. Two G10 phenolic end tabs are bonded to the asphalt binder, and they transfer the tensile load from the test machine to the asphalt binder.
- 4.2. This test method was developed for asphalt binders at intermediate temperatures where they exhibit brittle-ductile or brittle failure. The test is not applicable at temperature where failure is by ductile flow (necking).
- 4.3. A displacement transducer is used to measure the elongation of the test specimen as it is pulled in tension at a designated displacement rate. The load developed during the test is also measured. The tensile stress and strain from initial loading through failure are determined and used to calculate and report failure stress, failure strain, and fracture energy density.
- 4.4. Fracture energy density can be used to evaluate the relative resistance to fracture of different asphalt binders. In addition, characteristics of the resulting true stress-true strain curve can be used to identify the presence of polymer and/or rubber in the binder.



Notes:

- ^a All dimensions are in millimeters (inches in parentheses.)
- ^b Tolerances are as follows:
- | | |
|-----------|---------------|
| Fractions | ±1.6 (0.0625) |
| X.X | ±0.8 (0.03) |
| X.XX | ±0.25 (0.01) |
| X.XXX | ±0.12 (0.005) |
- ^c Remove all sharp edges.
- ^d Surface finish for machined surfaces equals $\sqrt{125}$ unless otherwise specified.

Figure 1—Specimen Geometry

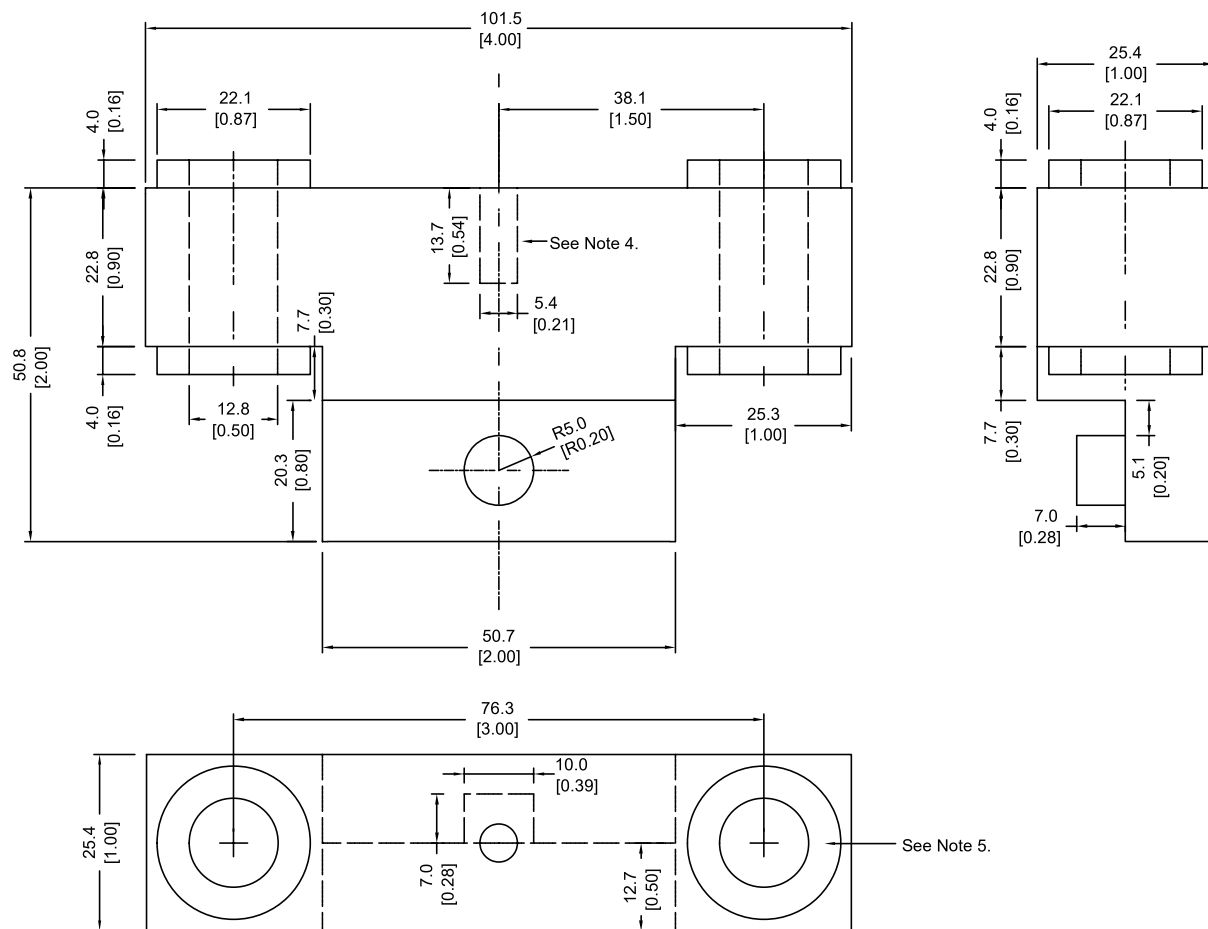
5. SIGNIFICANCE AND USE

- 5.1. The test is designed to measure fracture energy density of asphalt binder at intermediate temperatures. Fracture energy density has been shown to be an indicator of the resistance to fracture of an asphalt binder.
- 5.2. The test can be used to differentiate unmodified and modified binders by means of either the characteristics of the true stress–true strain curve or fracture energy density value. The test can also be used as an effective tool to screen new binders that may result in deficient performance.
- 5.3. For a given binder, fracture energy density as measured by this procedure has been determined to be independent of displacement rate and testing temperature. Although test temperatures may vary from 0°C to 25°C, 15°C was found to work well for a broad range of binders. Therefore, this temperature was recommended to determine fracture energy density.
- 5.4. Although the test displacement rate may vary from 100 mm/minute to 900 mm/minute, 500 mm/minute was found to work best for a broad range of binders. Therefore, this displacement rate is primarily used to determine binder fracture energy density at 15°C. Test outcomes at the 500 mm/minute rate may require an increase or decrease in this rate as specified in the test procedure, Section 11.3.1.

6. APPARATUS

- 6.1. A forced-air convection oven capable of reaching and maintaining $170 \pm 10^\circ\text{C}$ for heating asphalt. Oven(s) shall be capable of operation at the temperatures required, as corrected, if necessary, by standardization. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer for measuring the temperature of materials shall meet the requirements of M 339M/M 339 with a temperature range of at least 165 to 185°C, and an accuracy of $\pm 2.5^\circ\text{C}$ (see Note 1).
- Note 1**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E230/E230M thermocouple thermometer, Type J or K, Standard Class; or IEC 60584 thermocouple thermometer, Type J or K, Class 1 or Class 2.
- 6.2. A loading system capable of pulling a test specimen at constant loading rates ranging from 100 to 900 mm/minute.
- 6.2.1. Test chamber for temperature control and testing, which is capable of maintaining a temperature between 0°C to 25°C, $\pm 0.2^\circ\text{C}$. The thermometer for measuring the temperature of materials shall meet the requirements of M 339M/M 339 with a temperature range of at least -5 to 30°C, and an accuracy of $\pm 0.05^\circ\text{C}$ (see Note 2).
- Note 2**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer, special order; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, special order; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, special order.
- 6.2.2. Load cell capable of accurately measuring tensile load up to 448 N (100 lb) with a resolution of 0.01 lb.
- 6.2.3. Linear variable differential transducer (LVDT) with a resolution of 0.000001 in.
- 6.2.4. Load measuring and recording devices (data acquisition system) capable of acquisition rates of up to 1,000 samples per second, per channel.

- 6.3. Figure 2 illustrates a miniature loading frame with two (or more) parallel precision rods, which allows 1.2-in. travel length and applies an axial load minimizing any eccentricity to the BFE specimen.
- 6.4. Specimen mold assemblies.
 - 6.4.1. Specimen molds shall be manufactured from aluminum, with the exception of the end tabs.
 - 6.4.2. *The specimen molds include:*
 - 6.4.2.1. Two side plates (Figure 5a),
 - 6.4.2.2. One bottom plate (Figure 5b),
 - 6.4.2.3. Two G10 phenolic end tabs (Figure 6a), and
 - 6.4.2.4. Metal rings (Figure 6b).
 - 6.4.3. Binder clips (Figure 9).
 - 6.4.4. Trim knife (Section 10.6).
- 6.5. Demolding gauge (Figure 7).



Notes:

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- | | |
|-----------|----------------|
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| X.X | ± 0.8 (0.03) |
| X.XX | ± 0.25 (0.01) |
| X.XXX | ± 0.12 (0.005) |
| Angles | ± 30 degrees |
- ^c Surface finish for machined surfaces equals $\sqrt{125}$ unless otherwise specified.
- ^d Thread to accommodate load cell.
- ^e Drilled and reamed to dimension 0.5-in. frelon bearing or similar (Pacific bearing FL08).
- ^f Material: 300-series stainless steel or 6061-T6 aluminum.

Figure 2—Loading Frame Assemblies: Upper Loading Head

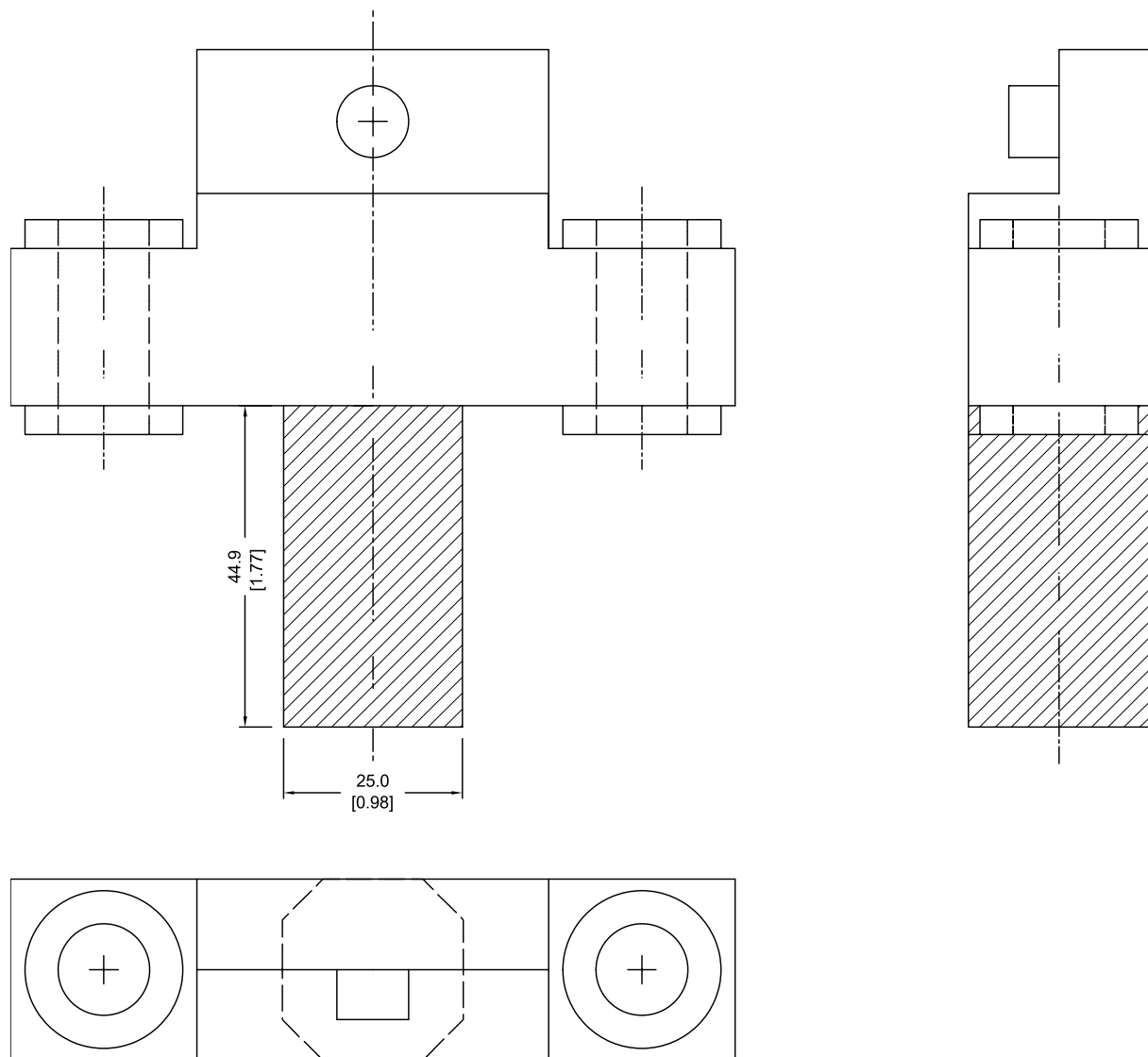


Figure 3—Loading Frame Assemblies: Lower Loading Head