Standard Method of Test for

Measuring Asphalt Binder Yield Energy and Elastic Recovery Using the Dynamic Shear Rheometer

AASHTO Designation: TP 123-16 (2020)[1]

AASHTO

Technical Subcommittee: 2b, Liquid Asphalt

Release: Group 3 (July)

1. SCOPE

1.1. This test method covers the Binder Yield Energy Test (BYET) for evaluation of asphalt binders' resistance to yield-type failure under monotonic constant shear-rate loading using the Dynamic Shear Rheometer (DSR). This test procedure can also be adapted for performing surrogate test procedure using the DSR in place of the conventional ductility test (T 51), and the Elastic Recovery test (ASTM D6084). The test method can be used with unaged material and material aged using T 240 (RTFOT) and/or R 28 (PAV) to simulate the estimated aging for in-service asphalt pavements.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard does not purport to address all of the safety problems, 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. *AASHTO Standards*:

- M 320, Performance-Graded Asphalt Binder
- T 51, Ductility of Asphalt Materials
- T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
- T 300, Force Ductility Test of Asphalt Materials
- T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

2.2. *ASTM Standards*:

- D8, Standard Terminology Relating to Materials for Roads and Pavements
- D6084, Standard Test Method for Elastic Recovery of Bituminous Materials by Ductilometer

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. Definitions of terms used in this practice may be found in Terminology D8, determined from common English usage, or combinations of both.

4. SUMMARY OF TEST METHOD

4.1. The binder is prepared either at an unaged condition or using T 240 (RTFOT) to represent short-term aging of asphalt pavements, or further conditioned using R 28 (PAV) to simulate long-term aging of asphalt pavements. The sample is prepared consistent with T 315 (DSR) using the 8-mm parallel plate geometry with a 2-mm gap setting.

4.2. For the binder yield energy procedure, the sample is tested in monotonic shear using a constant strain rate. The sample is continuously loaded until peak shear strength is achieved and the sample has yielded. The results can also be used to estimate ductility or forced ductility using the strain and stress at the peak of the yield curve.

4.3. For measuring the binder Elastic Recovery, after 2 min of monotonic shear using a constant strain rate, the sample is allowed to recover for 30 min before calculating the percent strain recovery.

5. SIGNIFICANCE AND USE

5.1. This method is intended to evaluate the performance of binders at intermediate temperatures in terms of resistance to yielding and in terms of elastic recovery. The "yield energy" of the sample can be used to identify the relative performance of different materials in terms of resistance to fatigue or extreme loading damage.

5.2. This method also provides a simple and more repeatable alternative to conducting the ductility test (T 51) and elastic recovery test (ASTM D6084), using a standard Dynamic Shear Rheometer and a small sample size. The stress–strain response curve from the yield test, as well as the strain recovery from the elastic recovery test, can be useful in identifying the presence of modifiers in binders and their potential benefits in improving ductile behavior of binders.

Note 1— It is to be noted that the relationship between ductility and elastic recovery to pavement performance is not known and there is no clear evidence that having higher ductility or higher elastic recovery improves pavement performance. The significance of this test is to replace the use of a ductilometer used for ductility, forced ductility, and elastic recovery with simpler and more repeatable tests in the DSR.

6. PROCEDURE

6.1. Condition the asphalt binder in accordance with T 240 (RTFOT) for short-term performance, or follow with R 28 (PAV) for long-term performance.

6.2. *Sample Preparation*—The sample for the test is prepared following T 315 for 8-mm plates. The temperature control also follows the T 315 requirements. This test may be performed on the same sample that was previously used to determine the rheological properties in the DSR on PAV residue as specified in M 320.

6.3. *Test Protocol*—Two variations of the BYET test protocols are hereby described: Method A describes the procedure for measuring the binder yield energy, and a surrogate test procedure for the conventional ductility test (T 51). Method B describes the Elastic Recovery test (ASTM D6084).

6.3.1. *Method A: Binder Yield Energy and Ductility*—The prepared sample is tested at the desired test temperature at which a constant strain rate of 2.315 % s^{-1} is applied to the sample. Both stress (τ, Pa) and strain (γ, %) are recorded at a sampling rate of one data point every two seconds. The test is concluded once the material achieves 4167% strain (30 min).

For estimation of the ductility the prepared sample is tested at the desired test temperature (usually 4 or 25°C) at which a constant strain rate of 2.315% s^{-1} is applied to the sample. Both stress (τ, Pa) and strain (γ, %) are recorded at a sampling rate of one data point every two seconds. The test can be concluded once the material achieves a strain of 2778% (1200 seconds) (Ref. 11.1). The strain at the peak stress can be used as a measure of the ductility.

6.3.2. *Method B: DSR- Elastic Recovery*—The prepared sample is tested at the desired test temperature (usually 25°C) at which a constant strain rate of 2.315 % s^{-1} is applied to the sample until a strain of 277.78 % is achieved. After this a recovery step is carried out by applying a 0.0 kPa shear stress to the sample for 30 min. Both stress (τ, Pa) and strain (γ, %) are recorded at a sampling rate of one data point every two seconds throughout the test (Ref. 11.2–11.3).

Note 2—The DSR strain rate is selected to be approximately equivalent to the 5 cm/min Ductilometer deformation rate used in T 51 and ASTM D6084 (Ref. 11.1–11.2)

Note 3—The applied strain rate can be proportionally adjusted if different equivalent ductilometer deformation rates are desired (e.g., a rate of 0.463% s^{-1} would be equivalent to 1 cm/min in the ductilometer).

Note 4—The strain limit of 2778% is chosen to be equivalent to the maximum elongation of 100 cm of the ductility sample (with an effective length of 36 mm) in the ductilometer following T 51.

7. CALCULATION AND INTERPRETATION OF RESULTS

7.1. *Method A: Binder Yield Energy—For the results of the binder yield energy test, the data should be analyzed as follows*:

7.1.1. For the first data point, (τ_{i-1}, γ_{i-1}), the area, A_{i-1}, under the stress–strain curve at that point is calculated as:

$$A_{i-1} = \frac{(\tau_{i-1})(\gamma_{i-1})}{2} \qquad (1)$$

7.1.2. For subsequent data points, the area under the curve is calculated as the sum of the trapezoidal areas between each data point, known as the incremental energy, until the point of maximum shear stress (τ_{max}, $\gamma_{\tau,max}$). The total area is recorded as the yield energy (Figure 1), which is calculated using the formula below:

$$\text{Yield Energy} = A_{i-1} + \sum_{i=1}^{N}\left(\frac{\tau_i + \tau_{i-1}}{2}\right)(\gamma - \gamma_{i-1}) \qquad (2)$$

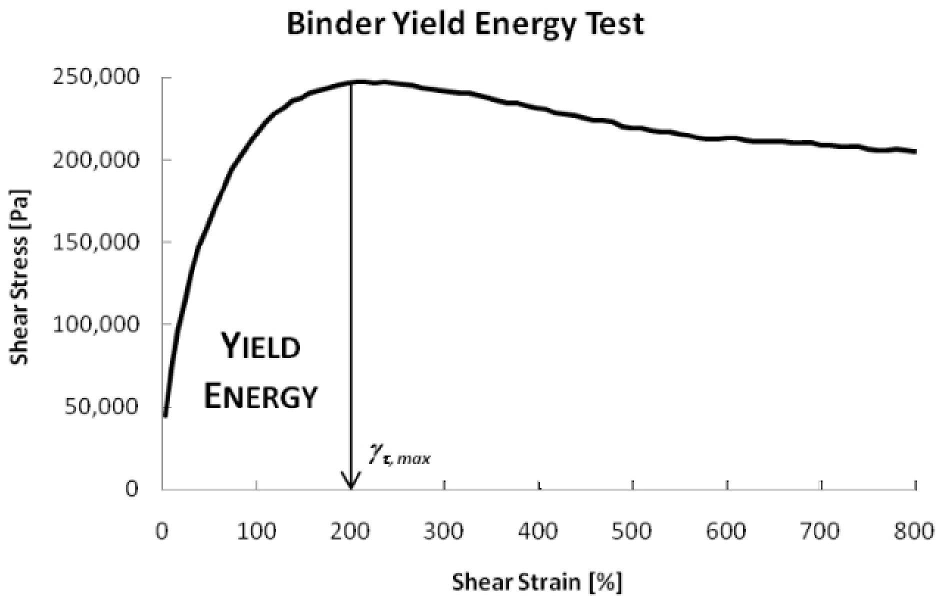

Figure 1—Visual Representation of Binder Yield Energy Test Parameters

7.2. *Method A—For the ductility test, the data should be analyzed as follows*:

7.2.1. Determine the maximum shear stress (τ_{max}) and the strain corresponding to the maximum shear stress, report this as ductility ($\gamma_{\tau,max}$).

Note 5—It is possible to analyze data to achieve parameters comparable to those reported for the force ductility test (T 300). For this the full shear stress vs. shear strain curve must be analyzed.

7.3. *Method B—For the elastic recovery test, the data should be analyzed as follows*:

7.3.1. Using the strain after 1800 seconds of recovery (γ_2) and the strain at the end of the loading step (γ_1 = 277.78%), the elastic recovery of the sample (Figure 2) is calculated using the formula below:

$$\text{Elastic Recovery} = \frac{\gamma_1 - \gamma_2}{\gamma_1} \times 100 \qquad (3)$$

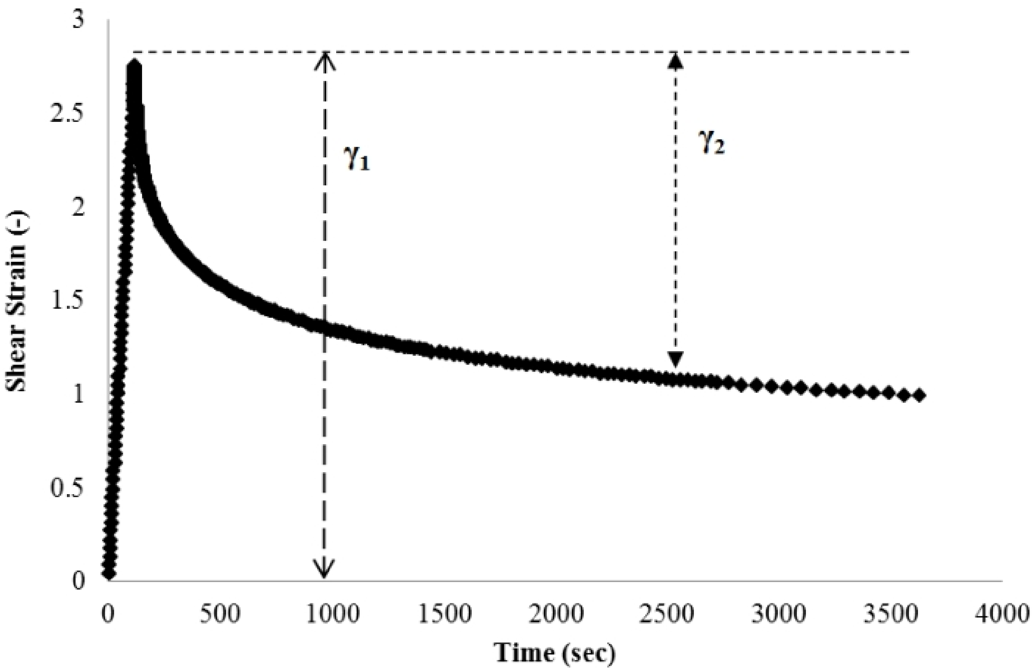

Figure 2—Typical γ(*t*) Curve for the Elastic Recovery Test in the DSR

8. REPORT

8.1. *For Method A (Binder Yield Energy and Ductility) report the following, if known*:

8.1.1. Sample identification.

8.1.2. Asphalt Binder Grade and test temperature, nearest 0.1°C.

8.1.3. Maximum shear stress, τ_{max}, kPa.

8.1.4. Shear strain at maximum shear stress, $\gamma_{\tau,max}$, percent.

8.1.5. Yield Energy, MPa.

8.2. *For Method B (DSR-Elastic Recovery) report the following, if known*:

8.2.1. Sample identification.

8.2.2. Asphalt Binder Grade and test temperature, nearest 0.1°C.

8.2.3. Shear strain at maximum shear stress, $\gamma_{\tau,max}$, percent.

8.2.4. Elastic Recovery, percent.

9. PRECISION AND BIAS

9.1. Two replicate tests are recommended for every material at each temperature tested.

9.2. Test precision and bias is to be determined upon results of inter-laboratory testing.

10. KEYWORDS

10.1. Asphalt binder; ductility; ductilometer; dynamic shear rheometer; elastic recovery; energy; yield.

11. REFERENCES

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11.2. Clopotel, C. S. and H. U. Bahia. "Importance of Elastic Recovery in the DSR for Binders and Mastics," *Engineering Journal*, Vol. 16, No. 4, 2012.

11.3. Daranga, C., C. S. Clopotel, and H. U. Bahia. Replacing the Elastic Recovery Test of Asphalt Binders with a DSR Test: Development of Protocol and Relationship to Binder Fatigue. Presentation made at the 89th Annual Meeting of the Transportation Research Board, Washington, DC, 2010.

[1] This provisional standard was first published in 2016.