Standard Method of Test for

Yield Energy of Asphalt Binders Using the Dynamic Shear Rheometer

AASHTO Designation: T XXX-09

1. SCOPE

1.1. This test method covers the indication of asphalt binders' resistance yield-type failure under monotonic constant shear-rate loading. The Binder Yield Energy test (BYET) is conducted using the Dynamic Shear Rheometer at the intermediate temperature performance grade (PG Grade) of the asphalt binder. The test method can be used with material aged using AASHTO T 240 (RTFOT) and/or AASHTO 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, Standard Specification for Performance Graded Asphalt Binder
T 240, Effect of Heat and Air on Rolling Film of Asphalt (Rolling Thin-Film Oven Test)
R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

2.2. *ASTM Standards*:
D 8, Standard Terminology Relating to Materials for Roads and Pavements
D 2872, Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
D 6521, Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
D 7175, Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer

3. TERMINOLOGY

3.1 Definitions

3.1.1 Definitions of terms used in this practice may be found in Terminology D 8 determined from common English usage, or combinations of both.

4. SUMMARY OF TEST METHOD

4.1 Asphalt binder is first aged using Test Method AASHTO T 240 (ASTM D 2872) (RTFOT) to represent short-term aging of asphalt pavements, or the material may be further aged using AASHTO R 28 (ASTM D 6521-08) prior to testing in order to simulate long-term aging of asphalt pavements. A sample is prepared consistent with Test Method AASHTO T 315 (ASTM D 7175-05) (DSR) using the 8-mm parallel plate geometry with a 2-mm gap setting. The sample is tested in monotonic shear using a constant shear rate to continuously load the sample until peak shear strength is achieved and the sample has yielded.

5. SIGNIFICANCE AND USE

5.1. This method is intended to evaluate the amount of energy required to cause yielding in asphalt binder. The "yield energy" of the material can be used to identify the relative performance of different materials, and the stress-strain response curve can be useful in identifying the presence of polymer modifiers in the material.

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 BYET is prepared following T 315 for 8-mm plates. The temperature control also follows the T 315 requirements.

6.2.1. 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* – The binder yield energy test is run at the selected temperature and applies a constant shear rate of 1% strain per second. 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 3,600% strain (60 minutes).

7. CALCULATION AND INTERPRETATION OF RESULTS

7.1. 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

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

7.1.2. For subsequent data points, the area under the curve is calculated as the sum of the trapeziodal 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, which is calculated using the formula below:

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

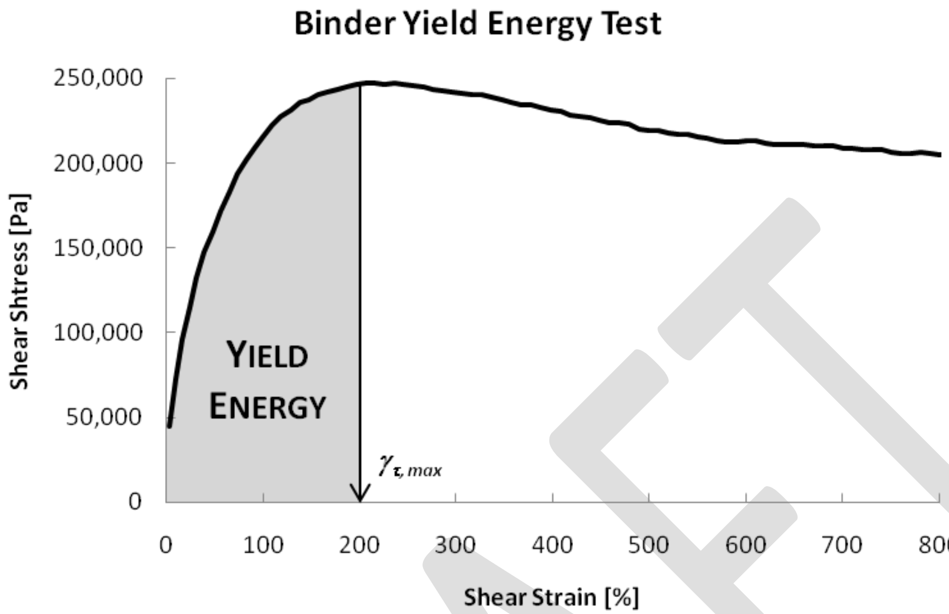

FIGURE 7.1 – Visual representation of Binder Yield Energy Test parameters.

8. REPORT

8.1. *Report the following, if known*:

8.1.1. Sample identification,

8.1.2. PG 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, $\gamma_{\tau,max}$, %.

8.1.5. Yield Energy, MPa.

9. PRECISION AND BIAS

9.1.

10. KEYWORDS

10.1. Asphalt binder, shear strength, yield energy, DSR.

11. REFERENCES

11.1.

[1] The numbers in parentheses refer to the list of references at the end of this standard.

APPENDIX

X1. SAMPLE CALCULATIONS

X1.1. Example data from the BYET is given in Table X1.1.

Table X1.1 – Example data output from BYET

Shear Strain	Shear Stress
[%]	[Pa]
2	31,081
4	44,824
6	53,874
8	61,042
10	67,072
12	72,496
14	77,216

X1.2. *Sample calculations:*

X1.2.1. The first data point is used to calculate A_{i-1} as described in Section 7.1.1.:

$A_{i-1} = (\tau_{i-1})(\gamma_{i-1}) / 2 = (31{,}081) \times (2\%) = 311$ Pa.

X1.2.2. The following data points are used to determine the incremental energy areas as described in Section 7.1.2.:

$$Yield\ Energy_i = \left(\frac{\tau_i + \tau_{i-1}}{2}\right)(\gamma_i - \gamma_{i-1}) = \left(\frac{44{,}824+31{,}081}{2}\right)(4\% - 2\%) = 759 \text{ Pa.}$$

X1.2.3. This procedure is repeated, giving the results shown in Table X1.2. The values shown in the incremental energy column are summed only to the (τ_{max}, $\gamma_{\tau,max}$) boundary to calculate Yield Energy.

Table X1.2 – Example data output and energy calculations from the BYET

Shear Strain	Shear Stress	Incremental Energy
[%]	[Pa]	[Pa]
2	31,081	311
4	44,824	759
6	53,874	987
8	61,042	1,149
10	67,072	1,281
12	72,496	1,396
14	77,216	1,497