Standard Method of Test for

Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

AASHTO Designation: T 350-14[1]

AASHTO

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1. SCOPE

1.1. This test method covers the determination of percent recovery and nonrecoverable creep compliance of asphalt binders by means of the Multiple Stress Creep Recovery (MSCR) test. The MSCR test is conducted using the Dynamic Shear Rheometer (DSR) at a specified temperature. It is intended for use with residue from T 240 (Rolling Thin-Film Oven Test (RTFOT)).

1.2. The percent recovery value is intended to provide a means for determining the elastic response and stress dependence of polymer modified and unmodified asphalt binders.

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

1.4. *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. *AASHTO Standards*:

- M 320, Performance-Graded Asphalt Binder
- M 332, Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
- 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)
- T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

2.2. *ASTM Standard*:

- D8, Standard Terminology Relating to Materials for Roads and Pavements

3. TERMINOLOGY

3.1. *Definitions*:

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

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

3.2.1. *creep and recovery*—a standard rheological test protocol whereby a specimen is subjected to a constant load for a fixed time period and then allowed to recover at a constant zero load for a fixed time period.

3.2.2. *nonrecoverable creep compliance (J_{nr})*—the residual strain in a specimen after a creep and recovery cycle divided by the stress applied, kPa^{-1}.

4. SUMMARY OF TEST METHOD

4.1. This test method is used to determine the presence of elastic response in an asphalt binder under shear creep and recovery at two stress levels at a specified temperature. For performance-graded (PG) asphalt binders, the specified temperature will typically be the PG high temperature as determined in accordance with M 332, Section 4. Refer to Note 3 in M 332 for additional guidance.

4.2. Asphalt binder is first conditioned using T 240 (RTFOT). A sample of the RTFO-conditioned asphalt is tested using T 315 (DSR). The 25-mm parallel plate geometry is used with a 1-mm gap setting. The sample is tested in creep at two stress levels followed by recovery at each stress level. The stress levels used are 0.1 kPa and 3.2 kPa. The creep portion of the test lasts for 1 s, which is followed by a 9-s recovery. Ten creep and recovery cycles are tested at each stress level.

5. SIGNIFICANCE AND USE

5.1. This method is designed to identify the presence of elastic response in a binder and the change in elastic response at two different stress levels while being subjected to ten cycles of creep stress and recovery. Nonrecoverable creep compliance has been shown to be an indicator of the resistance of an asphalt binder to permanent deformation under repeated load.

6. APPARATUS

6.1. Use the apparatus as specified in T 315.

7. PROCEDURE

7.1. *Conditioning*—Condition the asphalt binder in accordance with T 240 (RTFOT).

7.2. *Sample preparation*—The sample for the MSCR test is prepared the same as samples for T 315 using 25-mm plates. The temperature control will also follow the T 315 requirements.

7.2.1. This test may be performed on the same sample that was previously used to determine the DSR properties of the RTFO residue as specified in M 320. When using the previously tested sample to perform this test, a 1-min relaxation period between the tests is required before running this test. When using a new sample to perform this test, the 1-min relaxation period is not required.

7.3. *Test protocol*—Perform the test at the selected temperature using a constant stress creep of 1.0-s duration followed by a zero stress recovery of 9.0-s duration. Perform the test at 0.1 kPa and 3.2 kPa. Run 20 cycles at the 0.1-kPa stress level followed by 10 cycles at the 3.2-kPa stress level for a total of 30 cycles. Use the first 10 cycles at 0.1 kPa for conditioning the specimen. There are no rest periods between creep and recovery cycles or changes in stress level. The total time required to complete the two-step creep and recovery test is 300 s.

Record the stress and strain at least every 0.1 s for the creep cycle and at least every 0.45 s for the recovery cycle on an accumulated basis. Record the data points at the peak strain at 1.0 s and the recovered strain at 10.0 s for each cycle's local time. Extrapolate prior data to determine the strain value at 1.00 s and 10.00 s if the DSR does not record the peak and recovered strain as specified. Extrapolated data shall include a measured data point no more than 0.1 s prior to the required time for a creep cycle and no more than 0.5 s prior to the required time for a recovery cycle.

7.4. *Equipment Control*—Achieve the full stress for each creep cycle within 0.03 s from the start of the creep cycle as certified by the equipment manufacturer.

7.5. *Analysis*—Analyze and record the creep and recovered percent strain for the 0.1-kPa and 3.2-kPa creep stress levels as follows:

7.5.1. For each of the last 10 cycles at the 0.1-kPa stress level and the ten cycles at the 3.2-kPa stress level, record the following:

7.5.1.1. The initial strain value at the beginning of the creep portion of each cycle. This strain shall be denoted as $\in_0$.

7.5.1.2. The strain value at the end of the creep portion (i.e., after 1.0 s) of each cycle. This strain shall be denoted as $\in_c$.

7.5.1.3. The adjusted strain value at the end of the creep portion (i.e., after 1.0 s) of each cycle ($\in_1$), which is calculated as follows:

$$\in_1 = \in_c - \in_0$$

7.5.1.4. The strain value at the end of the recovery portion (i.e., after 10.0 s) of each cycle. This strain shall be denoted as $\in_r$.

7.5.1.5. The adjusted strain value at the end of the recovery portion (i.e., after 10.0 s) of each cycle ($\in_{10}$), which is calculated as follows:

$$\in_{10} = \in_r - \in_0$$

7.5.2. For each of the last 10 cycles, calculate the following at the creep stress level of 0.1 kPa:

7.5.2.1. Percent recovery $\in_r(0.1, N)$ for $N = 1$ to 10:

$$\in_r\left(0.1, N\right) = \frac{\left(\in_1 - \in_{10}\right) \times 100}{\in_1}$$

7.5.3. For each of the 10 cycles, calculate the following at the creep stress level of 3.2 kPa:

7.5.3.1. Percent recovery $\in_r(3.2, N)$ for $N = 1$ to 10:

$$\in_r\left(3.2, N\right) = \frac{\left(\in_1 - \in_{10}\right) \times 100}{\in_1}$$

8. CALCULATION

8.1. Using the results obtained in Sections 7.5.2.1 and 7.5.3.1, determine the average percent recovery for the asphalt binder at creep stress levels of 0.1 kPa and 3.2 kPa as shown in the following equations:

8.1.1. Calculate average percent recovery at 0.1 kPa:

$$R_{0.1} = \frac{SUM\left[\epsilon_r\left(0.1, N\right)\right]}{10} \text{ for } N = 11 \text{ to } 20$$

8.1.2. Calculate average percent recovery at 3.2 kPa:

$$R_{3.2} = \frac{SUM\left[\epsilon_r\left(3.2, N\right)\right]}{10} \text{ for } N = 1 \text{ to } 10$$

8.2. Using the results obtained in Sections 7.5.2.1 and 7.5.3.1, determine the nonrecoverable creep compliance between 0.1 kPa and 3.2 kPa as shown in the following equations:

8.2.1. For each of the 10 cycles at a creep stress of 0.1 kPa, calculate the nonrecoverable creep compliance using the last 10 cycles, $J_{nr}(0.1, N)$, kPa^{-1}, as strain/stress:

$$J_{nr}\left(0.1, N\right) = \frac{\epsilon_{10}}{0.1}$$

8.2.2. For each of the 10 cycles at a creep stress of 3.2 kPa, calculate the nonrecoverable creep compliance, $J_{nr}(3.2, N)$, kPa^{-1}, as strain/stress:

$$J_{nr}\left(3.2, N\right) = \frac{\epsilon_{10}}{3.2}$$

8.2.3. Calculate the average nonrecoverable creep compliance at 0.1 kPa, $J_{nr0.1}$, kPa^{-1}:

$$J_{nr0.1} = \frac{SUM\left[J_{nr}\left(0.1, N\right)\right]}{10} \text{ for } N = 11 \text{ to } 20$$

8.2.4. Calculate the average nonrecoverable creep compliance at 3.2 kPa, $J_{nr3.2}$, kPa^{-1}:

$$J_{nr3.2} = \frac{SUM\left[J_{nr}\left(3.2, N\right)\right]}{10} \text{ for } N = 1 \text{ to } 10$$

8.2.5. Calculate the percent difference in nonrecoverable creep compliance between 0.1 kPa and 3.2 kPa, J_{nrdiff}:

$$J_{nrdiff} = \frac{\left[J_{nr3.2} - J_{nr0.1}\right] \times 100}{J_{nr0.1}}$$

9. REPORT

9.1. *Report the following information*:

9.1.1. Sample identification;

9.1.2. PG grade and test temperature, to the nearest 0.1°C;

9.1.3. Average percent recovery at 0.1 kPa, $R_{0.1}$;

9.1.4. Average percent recovery at 3.2 kPa, $R_{3.2}$;

9.1.5. Nonrecoverable creep compliance at 0.1 kPa, $J_{nr_{0.1}}$, to two significant digits, kPa^{-1};

9.1.6. Nonrecoverable creep compliance at 3.2 kPa, $J_{nr_{3.2}}$, to two significant digits, kPa^{-1}; and

9.1.7. Percent difference between nonrecoverable creep compliance at 0.1 kPa and 3.2 kPa, $J_{nr_{diff}}$, to the nearest 0.1 percent.

10. PRECISION AND BIAS

10.1. *Precision*—The research required to develop precision estimates has not been conducted.

10.2. *Bias*—The research required to establish the bias has not been conducted.

11. KEYWORDS

11.1. Asphalt binders; creep and recovery; creep compliance; Dynamic Shear Rheometer (DSR); elastomer identification; Multiple Stress Creep and Recovery (MSCR) Test; percent recovery; polymer modification.

APPENDIXES

(Nonmandatory Information)

X1. SAMPLE CALCULATIONS

X1.1. A typical test data plot consisting of 10 cycles of creep and recovery at 0.1-kPa creep stress is shown in Figure X1.1. The plot for 3.2-kPa creep stress is similar to Figure X1.1 and will not be shown here. Test data from cycle number 9 are plotted in Figure X1.2 for further clarification.

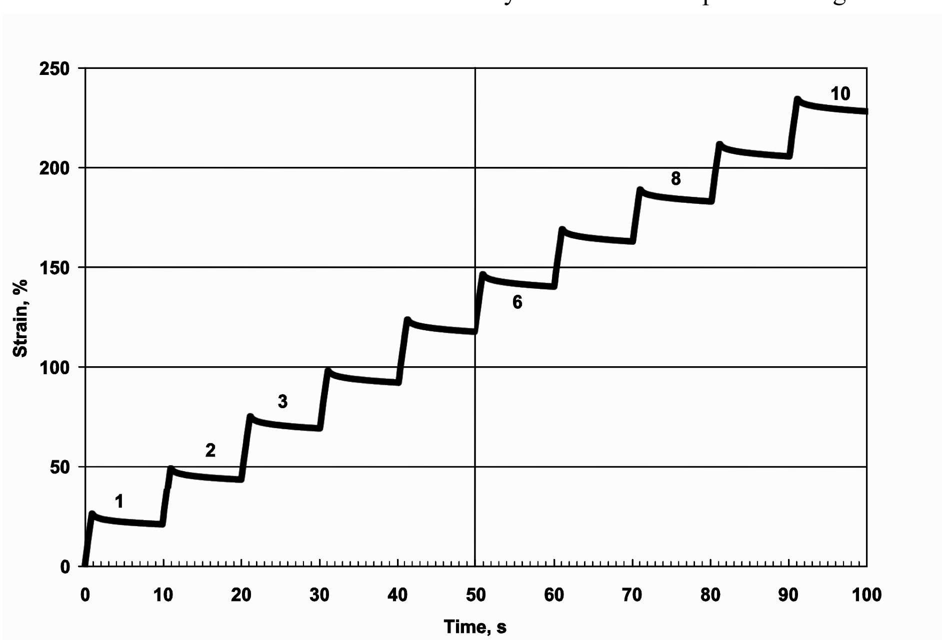

Figure X1.1—Test Data Plot Showing Typical 10 Cycles of Creep and Recovery at Creep Stress of 0.1 kPa

X1.2. *Sample Calculations*:

X1.2.1. Calculation of percent recovery for cycle number 9 (see Figure X1.2):

1. Determine strain at the start (initial strain): $\in_0 = 183\%$
2. Determine strain at 1-s creep end time point: $\in_c = 212\%$
3. Determine adjusted creep end strain at 1-s point: $\in_1 = (\in c - \in_0) = (212 - 183)\ \% = 29\%$
4. Determine strain at 10-s recovery end time point: $\in_r = 206.0\%$
5. Determine adjusted recovery end strain at 10-s point: $\in_{10} = (\in_r - \in_0) = (206 - 183)\ \% = 23\%$
6. Determine percent recovery for cycle number 9 at 0.1-kPa creep stress, $\in_r\ (0.1, 9)$:

$$\in_r \left(0.1, N\right) = \frac{\left(\in_1 - \in_{10}\right) \times 100}{\in_1}$$

X1.2.2. For cycle number 9 at a creep stress level of 0.1 kPa, the percent recovery will be:

$$\frac{(29 - 23) \times 100}{29.0} = 21\%$$

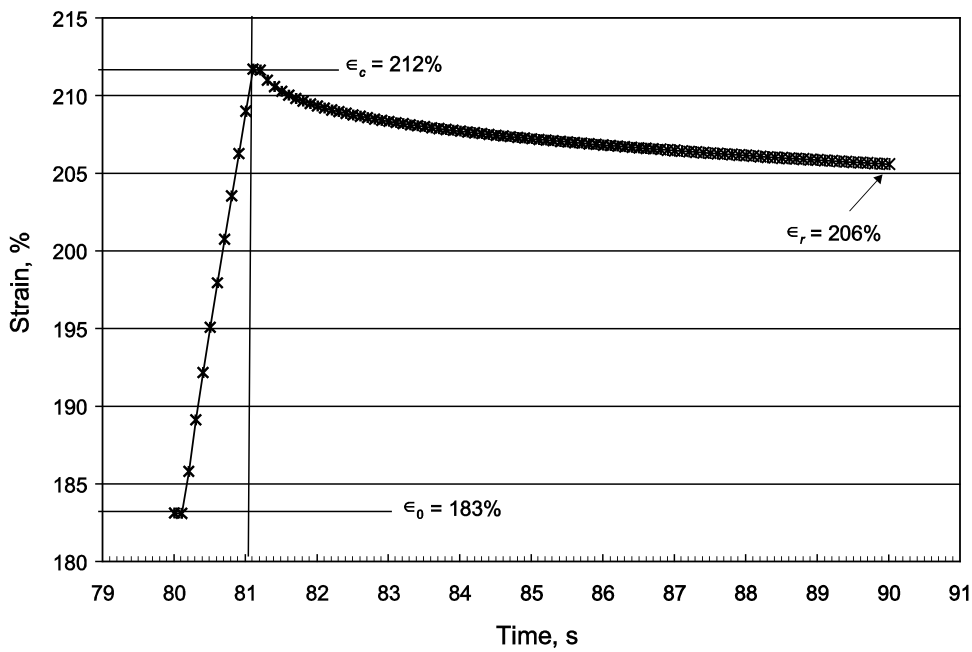

Figure X1.2—Test Cycle No. 9 Data Plot Showing Creep and Recovery at Creep Stress of 0.1 kPa

X1.3. Follow the above example to calculate percent recoveries for all 10 cycles for both creep stress levels of 0.1 kPa and 3.2 kPa.

[1] Formerly AASHTO Provisional Standard TP 70. First published as a full standard in 2014.