Designation: D7405 − 15

Standard Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer[1,2]

This standard is issued under the fixed designation D7405; 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 the determination of percent recovery and non-recoverable creep compliance of asphalt binders by means of Multiple Stress Creep and Recovery (MSCR) testing. The MSCR test is conducted using the Dynamic Shear Rheometer (DSR) at a specified temperature.

1.2 This standard is appropriate for unaged material, material aged in accordance with Test Method D2872 (RTFO), material aged in accordance with Practice D6521 (PAV), and material aged in accordance with both Test Method D2872 and Practice D6521.

NOTE 1—The majority of development work on this test method was performed on material aged in accordance with Test Method D2872 (RTFO).

1.3 The percent recovery is intended to provide a means to determine the presence of elastic response and stress dependence of polymer modified and unmodified asphalt binders.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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:*[3]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D8 Terminology Relating to Materials for Roads and Pavements

D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)

D5801 Test Method for Toughness and Tenacity of Bituminous Materials

D6084 Test Method for Elastic Recovery of Asphalt Materials by Ductilometer

D6373 Specification for Performance Graded Asphalt Binder

D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer

2.2 *AASHTO Standards:*[4]

M 332 Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test

T 350 Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

3. Terminology

3.1 *Definitions*—For definitions of general terms used in this standard, refer to Terminology D8.

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

3.1.2 *non-recoverable creep compliance* (J_{nr}), *n*—the residual strain in a specimen after a creep and recovery cycle divided by the stress applied in kPa.

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

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.44 on Rheological Tests.

Current edition approved Dec. 1, 2015. Published January 2016. Originally approved in 2008. Last previous edition approved in 2010 as D7405 – 10a. DOI: 10.1520/D7405-15.

[2] This test method is based on a work product of the Federal Highway Administration. A similar standard is published as AASHTO TP 70.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

performance grade (PG) binders, the specified temperature will typically be the PG high temperature without grade bumping as determined in Specification D6373 or AASHTO M 332. Sample preparation and apparatus are in accordance with Test Method D7175 using the 25-mm parallel plate geometry with a 1-mm gap setting. The sample is loaded at constant stress for 1 s then allowed to recover for 9 s. Twenty creep and recovery cycles are run at 0.100 kPa creep stress followed by ten creep and recovery cycles at 3.200 kPa creep stress.

5. Significance and Use

5.1 This test method is used to identify the presence of elastic response in a binder and the change in elastic response at two different stress levels. Non-recoverable creep compliance has been shown to be an indicator of the resistance of an asphalt binder to permanent deformation under repeated load.

5.2 This test method is also useful as a surrogate for other test methods used to measure elasticity in asphalt binders such as Test Method D5801 (Toughness and Tenacity), Test Method D6084 (Elastic Recovery), and Test Method D7175 (DSR phase angle).

6. Apparatus

6.1 *Dynamic Shear Rheometer (DSR)*—A dynamic shear rheometer as described in the Apparatus section of Test Method D7175 and associated materials as described in the Materials section of Test Method D7175. The rheometer shall run in stress control mode.

7. Preparation of Test Specimen

7.1 Prepare the test specimen in accordance with the Preparing Test Specimens section of Test Method D7175.

NOTE 2—This test may be run on a specimen previously tested in dynamic shear in accordance with the Test Procedure section of Test Method D7175.

8. Procedure

8.1 Allow the specimen to reach thermal equilibrium at the desired test temperature in accordance with the Test Procedure section of Test Method D7175. If the specimen has previously been tested in dynamic shear, allow the specimen to remain unloaded for at least 1 min before starting the creep and recovery test.

8.2 *Creep and Recovery Cycle*—Load the specimen at a constant creep stress for 1.00 s duration creep and follow with a zero stress recovery of 9.00 s duration. The commanded full torque for each creep cycle shall be achieved within 0.003 s from the start of the creep cycle as certified by the equipment manufacturer. Record the stress and strain at least every 0.10 s for the creep cycle and at least every 0.45 s for the recovery cycle on a running accumulated time such that, in addition to other data points, data points at 1.00 s and 10.00 s for each cycle's local time are explicitly recorded. If the DSR does not record the strain at exactly 1.00 and 10.00 s then the DSR software shall extrapolate prior data to determine the strain value at the required time. Extrapolation data shall include a measured data point no more than 0.10 s prior to the required time for a creep cycle, no more than 0.50 s prior to the required time for a recovery cycle.

NOTE 3—If the creep and recovery curves will be used for modeling, more frequent data points may be required.

8.3 Allowing no rest period between cycles, perform 20 creep and recovery cycles at a creep stress of 0.100 kPa. The first 10 cycles are for conditioning the specimen. The second 10 cycles are for data collection and analysis.

8.4 Allowing no rest period following 8.3 and no rest period between cycles, perform 10 creep and recovery cycles at a creep stress of 3.200 kPa. The total time required to complete 8.3 and 8.4 is 300 s.

8.5 For each of the last 10 cycles at the 0.100 kPa stress level and the 10 cycles at the 3.200 kPa stress level record the following:

8.5.1 Initial strain value at the beginning of the creep portion of each cycle. This strain shall be denoted as ε_0.

8.5.2 The strain value at the end of the creep portion (that is, after 1.0 s) of each cycle. This strain shall be denoted as ε_c.

8.5.3 The adjusted strain value at the end of the creep portion (that is, after 1.0 s) of each cycle, ε_1, calculated as:

$$\varepsilon_1 = \varepsilon_c - \varepsilon_0 \tag{1}$$

8.5.4 The strain value at the end of the recovery portion (that is, after 10.0 s) of each cycle. This strain shall be denoted as ε_r.

8.5.5 The adjusted strain value at the end of the recovery portion (that is, after 10.0 s) of each cycle, ε_{10}, calculated as:

$$\varepsilon_{10} = \varepsilon_r - \varepsilon_0 \tag{2}$$

9. Calculation

9.1 Using the results obtained in 8.5 determine the average percent recovery and non-recoverable creep compliance for the asphalt binder at creep stress levels of 0.100 kPa and 3.200 kPa as follows:

9.1.1 For each of the last 10 cycles at a creep stress of 0.100 kPa calculate the percent recovery, $\varepsilon_r(0.1, N)$, for N = 1 to 10:

$$\varepsilon_r(0.1, N) = \frac{(\varepsilon_1 - \varepsilon_{10}) \cdot 100}{\varepsilon_1} \tag{3}$$

9.1.1.1 If $\varepsilon_r(0.1, N) < 0$ then record $\varepsilon_r(0.1, N)$ as zero.

NOTE 4—The measured percent recovery can be affected by characteristics such as inertia and data sampling. These effects are more pronounced when the recovery is small, as with many unmodified asphalt binders, and can result in a negative measured recovery. For the scope of this test method a negative recovery can be considered to be zero.

9.1.2 For each of the 10 cycles at a creep stress of 3.200 kPa calculate the percent recovery, $\varepsilon_r(3.2, N)$, for N = 1 to 10:

$$\varepsilon_r(3.2, N) = \frac{(\varepsilon_1 - \varepsilon_{10}) \cdot 100}{\varepsilon_1} \tag{4}$$

9.1.2.1 If $\varepsilon_r(3.2, N) < 0$ then record $\varepsilon_r(3.2, N)$ as zero.

9.1.3 Calculate average percent recovery at 0.100 kPa:

$$R0.1 = \frac{\mathrm{SUM}(\varepsilon_r(0.1,N))}{10} \text{ for } N = 11 \text{ to } 20 \tag{5}$$

9.1.4 Calculate average percent recovery at 3.200 kPa:

$$R3.2 = \frac{\mathrm{SUM}(\varepsilon_r(3.2,N))}{10} \text{ for } N = 1 \text{ to } 10 \tag{6}$$

9.1.5 Calculate percent difference in recovery between 0.100 kPa and 3.200 kPa:

$$R_{diff} = \frac{((R0.1 - R3.2) \cdot 100)}{R0.1} \tag{7}$$

9.1.6 For each of the last 10 cycles at a creep stress of 0.100 kPa calculate the non-recoverable creep compliance, $J_{nr}(0.1, N)$, for N = 1 to 10:

$$J_{nr}(0.1,N) = \frac{\varepsilon_{10}}{0.1} \tag{8}$$

9.1.6.1 If $\varepsilon_r(0.1, N)$ was less than zero then calculate $J_{nr}(0.1, N)$ as:

$$J_{nr}(0.1,N) = \frac{\varepsilon_{1}}{0.1} \tag{9}$$

NOTE 5—If $\varepsilon_r(0.1, N)$ is negative then the adjusted creep strain at 1.0 s is the more appropriate strain value to use as there is no recovery.

9.1.7 For each of the 10 cycles at a creep stress of 3.200 kPa calculate the non-recoverable creep compliance, $J_{nr}(3.2, N)$, for N = 1 to 10:

$$J_{nr}(3.2\ ,\quad N) = \frac{\varepsilon_{10}}{3.2} \tag{10}$$

9.1.7.1 If $\varepsilon_r(3.2, N)$ was less than zero then calculate $J_{nr}(3.2, N)$ as:

$$J_{nr}(3.2\ ,\quad N) = \frac{\varepsilon_{1}}{3.2} \tag{11}$$

9.1.8 Calculate average non-recoverable creep compliance at 0.100 kPa:

$$J_{nr}0.1 = \frac{\mathrm{SUM}(J_{nr}(0.1,N))}{10} \text{ for } N = 11 \text{ to } 20 \tag{12}$$

9.1.9 Calculate average non-recoverable creep compliance at 3.200 kPa:

$$J_{nr}3.2 = \frac{\mathrm{SUM}(J_{nr}(3.2,\ N))}{10} \text{ for } N = 1 \text{ to } 10 \tag{13}$$

9.1.10 Calculate percent difference in non-recoverable creep compliance between 0.100 kPa and 3.200 kPa:

$$J_{nrdiff} = \frac{(J_{nr}3.2 - J_{nr}0.1)\cdot 100}{J_{nr0.1}} \tag{14}$$

10. Report

10.1 Report the following information:

10.1.1 Sample identification;

10.1.2 Test temperature, to the nearest 0.1°C;

10.1.3 Average percent recovery at 0.100 kPa for the last 10 cycles, $R_{0.1}$, to the nearest 0.1 %;

10.1.4 Average percent recovery at 3.200 kPa, $R_{3.2}$, to the nearest 0.1 %;

10.1.5 Percent difference between average recovery at 0.100 kPa and 3.200 kPa, R_{diff}, to the nearest 0.1 %;

10.1.6 Non-recoverable creep compliance at 0.100 kPa for the last 10 cycles, $J_{nr0.1}$, to three significant figures;

10.1.7 Non-recoverable creep compliance at 3.200 kPa, $J_{nr3.2}$, to three significant figures; and

10.1.8 Percent difference between non-recoverable creep compliance at 0.100 kPa and 3.200 kPa, J_{nrdiff}, to nearest 0.1 %.

11. Precision and Bias

11.1 *Precision*—Criteria for judging the acceptability of results obtained by the Multiple Stress Creep and Recovery (MSCR) method are given in Table 1.

11.2 *Single-Operator Precision (Repeatability)*—the figures in Column 2 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results, expressed as a percent of their mean, exceeds the values given in Column 2.

11.3 *Multilaboratory Precision (Reproducibility)* —the figures in Column 3 of Table 1 are the coefficients of variation that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories, should not be considered suspect unless the difference in the two results, expressed as a percent of their mean, exceeds the values given in Column 3.

11.4 *Bias*—No information can be presented on the bias of the procedure because no material having an accepted reference value is available.

12. Keywords

12.1 asphalt binder; creep and recovery; DSR; dynamic shear rheometer; elastic recovery; MSCR; non-recoverable creep compliance; polymer modified asphalt

TABLE 1 Estimated Repeatability and Reproducibility

NOTE 1—The precision estimates in this table are based on the analysis of test results from eight laboratories for eight asphalt binders. The analysis included five binder grades: PG 64-22, PG 64-34, PG 70-28, PG 70-34, and PG 76-22. Average J_{nr} results varied from 0.061 to 2.498 kPa^{-1}. Average Recovery results varied from 0 to 88.3%.

Condition	Coefficient of Variation (1s%)[A]	Acceptable Range of Two Test Results (d2s%)[A]
Single-Operator Precision:		
$R_{0.1}$ (%)	2.4%	6.7%
$R_{3.2}$ (%)	3.0%	8.5%
$J_{nr0.1}$ (kPa^{-1})		
>1.00	4.6%	12.8%
0.26 - 1.00	5.4%	15.2%
0.10 - 0.25	13.7%	38.3%
< 0.10[B]	n/a	n/a
$J_{nr3.2}$ (kPa^{-1})		
>1.00	5.7%	16.0%
0.26 - 1.00	5.5%	15.3%
0.10 - 0.25	9.5%	26.6%
< 0.10[B]	n/a	n/a
Multilaboratory Precision:		
$R_{0.1}$ (%)	5.4%	15.0%
$R_{3.2}$ (%)	6.5%	18.1%
$J_{nr0.1}$ (kPa^{-1})		
>1.00	9.1%	25.6%
0.26 - 1.00	12.7%	35.6%
0.10 - 0.25	16.7%	46.8%
< 0.10[B]	n/a	n/a
$J_{nr3.2}$ (kPa^{-1})		
>1.00	7.9%	22.0%
0.26 - 1.00	13.9%	39.0%
0.10 - 0.25	15.2%	42.6%
< 0.10[B]	n/a	n/a

[A] These limits represent the 1s% and d2s% limits described in Practice C670.

[B] For J_{nr} values below 0.1 kPa^{-1} high variability is likely due to the very low strain values that are measured. If an asphalt binder has a J_{nr} value below 0.1 kPa^{-1} at a specified temperature, then consideration should be given to testing at a temperature that is 6°C higher.