TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, Industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Pavement Technology

FHWA-HIF-11-038

April 2011

THE MULTIPLE STRESS CREEP RECOVERY (MSCR) PROCEDURE

This Technical Brief provides an overview of the intent of the Superpave MSCR procedure to evaluate asphalt binder and its relation to asphalt pavement performance.

Rationale for MSCR Procedure

The Multiple Stress Creep Recovery (MSCR) test is the latest improvement to the Superpave Performance Graded (PG) Asphalt Binder specification. This new test and specification – listed as AASHTO TP70 and AASHTO MP19 – provide the user with a new high temperature binder specification that more accurately indicates the rutting performance of the asphalt binder and is blind to modification. A major benefit of the new MSCR test is that it eliminates the need to run tests such as elastic recovery, toughness and tenacity, and force ductility, procedures designed specifically to indicate polymer modification of asphalt binders. A single MSCR test can provide information on both performance and formulation of the asphalt binder.

Overview

So what exactly is the MSCR test? The MSCR test uses the well-established creep and recovery test concept to evaluate the binder's potential for permanent deformation. Using the Dynamic Shear Rheometer (DSR), the same piece of equipment used today in the existing PG specification, a one-second creep load is applied to the asphalt binder sample. After the 1-second load is removed, the sample is allowed to recover for 9 seconds. Figure 1 shows typical data for a polymer modified binder. The test is started with the application of a low stress (0.1 kPa) for 10 creep/recovery cycles then the stress in increased to 3.2 kPa and repeated for an additional 10 cycles.

The material response in the MSCR test is significantly different than the response in the existing PG tests. In the PG system, the high temperature parameter, $G^*/\sin\delta$, is measured by applying an oscillating load to the binder at very low strain. Due to the low strain level, the PG high temperature parameter doesn't accurately represent the ability of polymer modified binders to resist rutting.

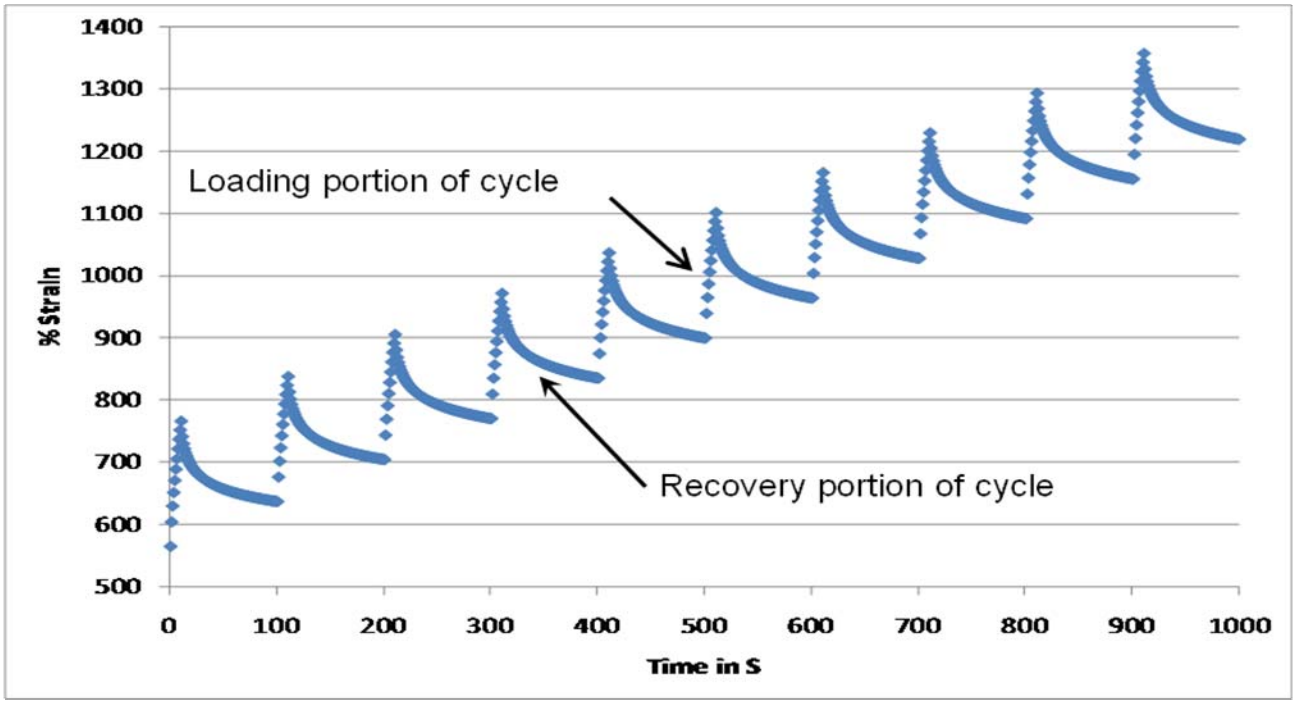
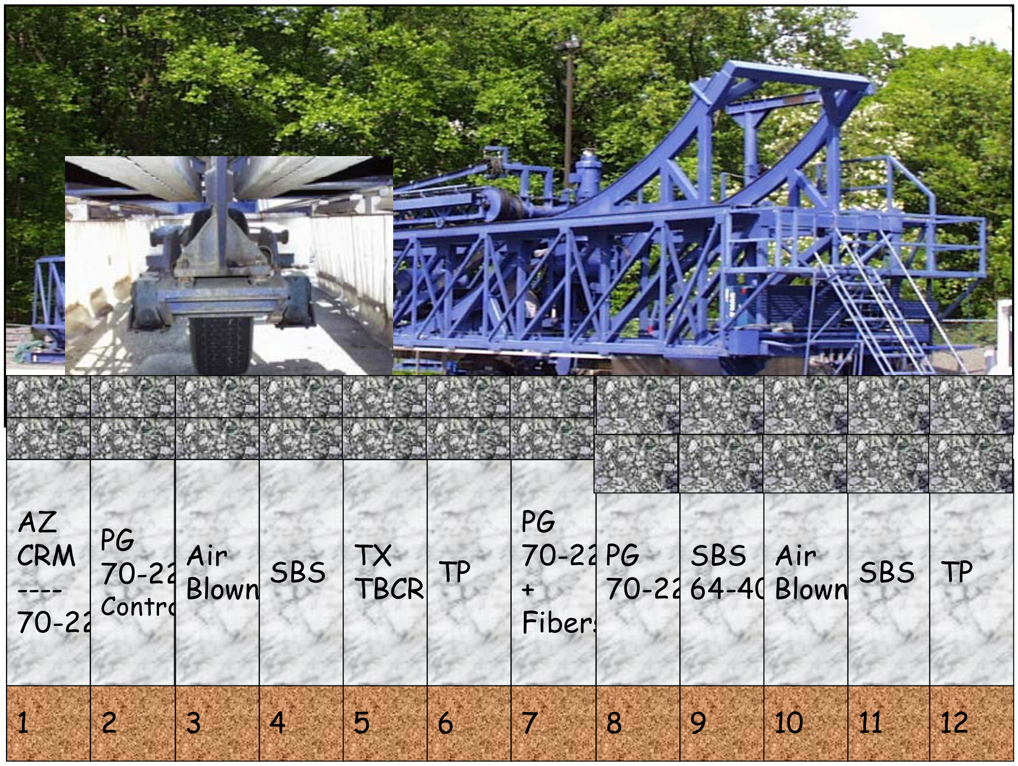


Figure 1: Examples of Modified Asphalt Binder Response to Repeated Loading.

Under the very low levels of stress and strain present in dynamic modulus testing, the polymer network is never really activated. In the existing PG specification the polymer is really only measured as a filler that stiffens the asphalt. In the MSCR test, higher levels of stress and strain are applied to the binder, better representing what occurs in an actual pavement. By using the higher levels of stress and strain in the MSCR test, the response of the asphalt binder captures not only the stiffening effects of the polymer, but also the delayed elastic effects (where the binder behaves like a rubber band).

Rutting Criteria

The relationship of the MSCR test specification parameter " J_{nr}" to actual rutting has been extensively evaluated. At the Federal Highway Administration's (FHWA) Accelerated Loading Facility (ALF), full scale testing of test sections constructed with multiple neat and modified binders (Figure 2) clearly showed the improved performance relationship of the MSCR test over the standard Superpave PG high temperature binder criteria, $G^*/\sin\delta$. The ALF test sections included neat, air-blown, SBS-modified, crumb rubber-modified and Elvaloy-modified binders. The sections were then heated to 64°C and trafficked with a super-single tire loaded to 10,000 lbs. Rutting of the test sections was compared to both the PG high temperature parameter (G*/sin δ) and also the MSCR high temperature parameter (J_{nr}).



ALF test sections

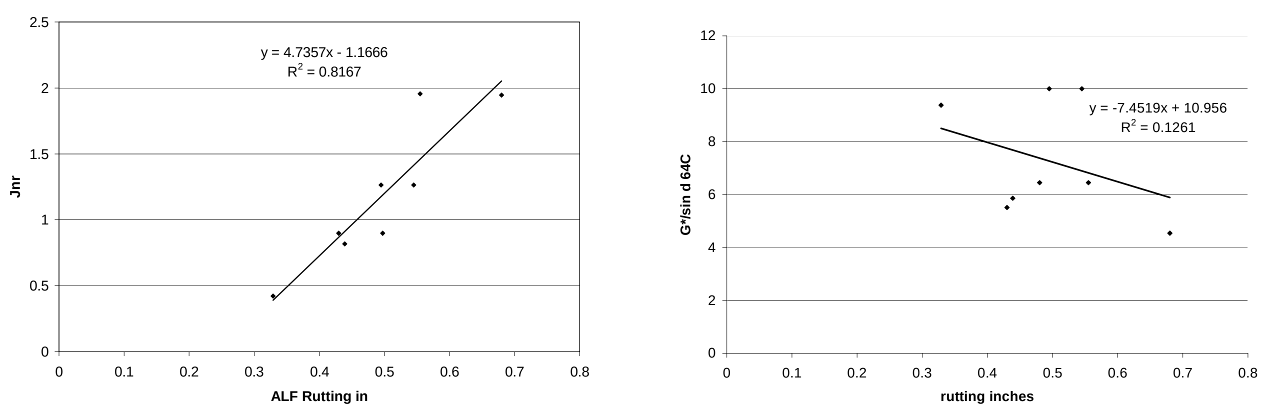


Figure 2: Various Asphalt Binder Evaluated with the ALF and G*/sin δ as Compared with the MSCR.

The findings from the FHWA ALF study indicated that the existing Superpave high temperature parameter actually did not do a very good job of correlating with rutting. The correlation of G*/sin δ at 64°C to rutting only provided an R^2 value of only 0.13. The relationship of J_{nr} to rutting was significantly better, with an R^2 value of 0.82. The findings indicated that J_{nr} could identify the rutting performance of the modified as well as the non-modified binders used at the ALF, accurately ranking the rutting potential in all the test sections.

The relationship between rutting and the results from MSCR testing was also verified with test sections on I-55 in Mississippi. In 1996, Mississippi DOT built several test sections on I-55. Multiple modifiers were used in the sections, including SBS, SB, SBR, and crumb rubber, with a control section of unmodified (neat) asphalt binder. Rutting was monitored for six years. The findings from this study again indicated that the MSCR parameter, J_{nr}, correlated much better to rutting then the PG parameter, G*/sin δ, shown in Figure 3.

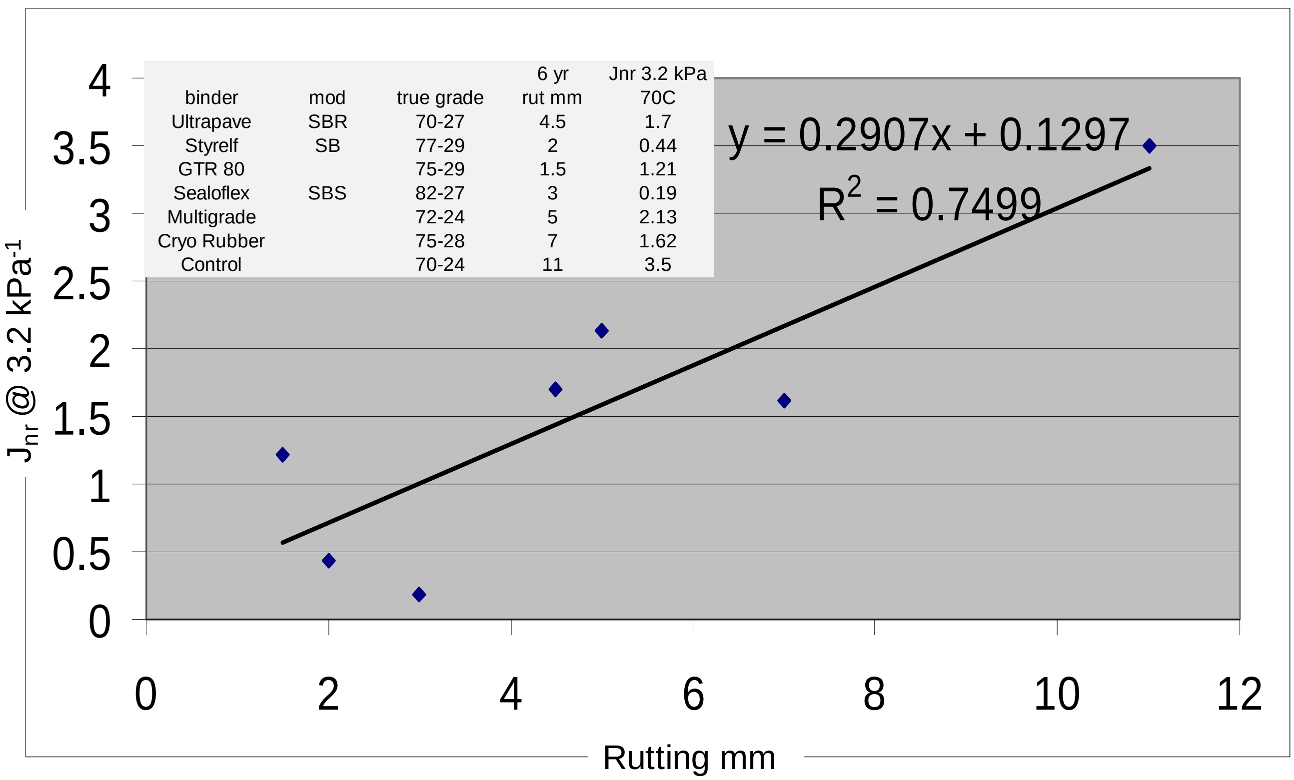


Figure 3: Rutting on I-55 Mississippi vs J_{nr}.

Grade Bumping

A major difference between the new MSCR specification and the old Superpave high temperature spec is how grade bumping is done. In the old Superpave spec grade bumping was done by increasing the test temperature for the binder and keeping the required test results the same. Under the old system, if the standard grade is a PG64 based on climate and due to heavy traffic, and the agency wants 2 grade bumps they would specify a PG 76. This required testing at 76°C for a 76-22 binder in a 64°C climate. In truth, the pavement will never see this high temperature; it is just an artificial way of requiring a stiffer binder by testing at a higher temperature. When using modified binders, this can provide some very misleading information. Many polymer systems soften very quickly at high temperatures. With the new MSCR specification, the binder testing is done at the high environmental temperature that the pavement is expected to experience. If the climate grade is a PG 64 or PG58, you would do all high temperature testing at 64°C or 58°C. If heavy traffic is expected the specification requirement is changed, i.e. a lower J_{nr} value is required to reflect the increased stress the pavement will actually experience, but testing is still done at say 64°C for a PG 64 climate. For example the MSCR spec for standard fast moving traffic J_{nr} requirement is 4.0 kPa^{-1} and for slow moving or higher traffic the required J_{nr} value would be 2.0 or 1.0 to require a more rut resistant material instead of testing at a higher temperature and high temperature testing for each S, H, V or E grades would be done at the same pavement climate temperature of say 58°C or 64°C. This allows for accurate evaluation of the binder at the expected operating temperature. A section of the AASHTO specification is shown below, where grade bumping is done by changing the required specification value for standard, heavy, very heavy or extreme traffic, not by changing temperature shown in Table 1 below.

Table 1: The MSCR gradings reflect the current grade bumping limits.

Standard S grade	traffic < 3 million ESAL's
Heavy H grade	traffic > 3 million ESAL's
Very Heavy V grade	traffic > 10 million ESAL's
Extreme E grade	traffic > 30 million ESAL's

Performance Grade	PG 64					
	10	16	22	28	34	40
Average 7-day max pavement design temp, °C						
Min pavement design temp, °C	>–10	>–16	>–22	>–28	>–34	>–40
Original Binder						
Flash point temp, T 48, min °C	230					
Viscosity, T 316: max 3 Pa·s, test temp, °C	135					
Dynamic shear, T 315: G*/sinδ, min 1.00 kPa test temp @ 10 rad/s, °C	64					
Rolling Thin-Film Oven Residue (T 240)						
Mass change, max, percent	1.00					
MSCR, TP 70: Standard Traffic "S" Grade $J_{nr3.2}$, max 4.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	64					
MSCR, TP 70: Heavy Traffic "H" Grade $J_{nr3.2}$, max 2.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	64					
MSCR, TP 70: Very Heavy Traffic "V" Grade $J_{nr3.2}$, max 1.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	64					
MSCR, TP 70: Extremely Heavy Traffic "E" Grade $J_{nr3.2}$, max 0.5 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	64					
Pressurized Aging Vessel Residue (R 28)						
PAV aging temp, °C	100					
Dynamic shear, T 315: "S" Grade G* sinδ, max 5000 kPa test temp @ 10 rad/s, °C	31	28	25	22	19	16
Dynamic shear, T 315: "H, "V", "E" Grades G* sinδ, max 6000 kPa test temp @ 10 rad/s, °C	31	28	25	22	19	16
Creep stiffness, T 313: *S*, max 300 MPa *m*-value, min 0.300 test temp @ 60 s, °C	0	–6	–12	–18	–24	–30

SHRP + Criteria

The MSCR test does a better job of identifying the rut resistance of both neat and polymer modified binders, but some highway agencies still want to make sure polymer is in the binder for other purposes such as crack resistance and durability. Here the MSCR test provides great improvements over the existing tests like the elastic recovery and toughness and tenacity. Data from the exact same sample from the MSCR test that was used to do high temperature grading provides information on the polymer modification as well. The one test provides the high temperature grade and quality of polymer modification eliminating the need to run additional tests like elastic recovery on additional samples. The compliance value J_{nr} from the MSCR test provides the rut resistance and the amount of recovered strain from the test identifies the presence of polymer and also the quality of the blending of the polymer in the binder shown in Figure 4 below.

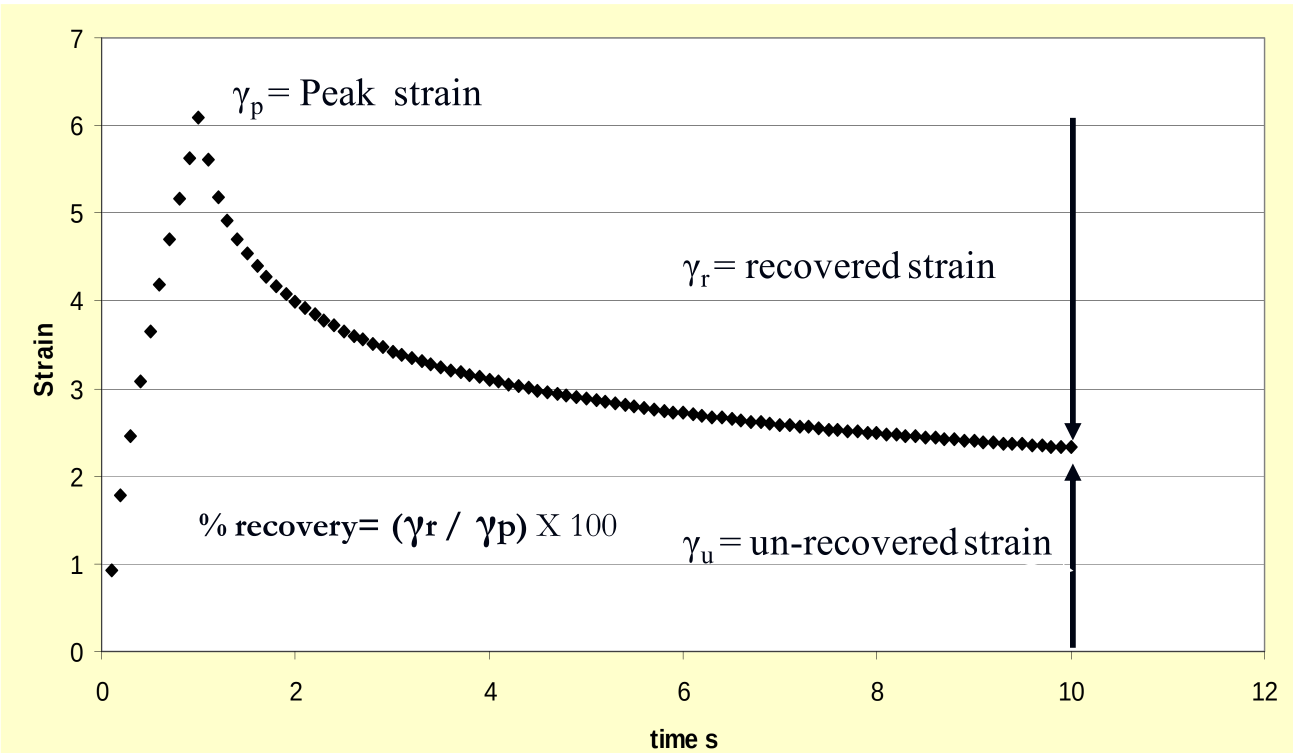


Figure 4. Plot showing the determination of the % Recovery in the MSCR test.

An experiment was conducted to demonstrate the improved ability of the MSCR test to identify the presence of polymer and quality of blending. Two samples were produced by adding 4% SBS polymer to the same base binder but using different blending techniques. One sample was produced with a linear SBS, not the optimum for the base asphalt, and it did not undergo high shear mixing. The other binder was produced with a radial SBS polymer, optimum for the base binder and mixed in with high shear. The existing Superpave specification indicates the binders have almost the exact same high temperature grade, however, the new MSCR parameter indicates that there is a significant difference between the binders. The MSCR indicates the binder with the optimum polymer mixed with high shear is much more rut resistant. The Elastic Recovery Test (ER) ranks the two binders as almost the same, but the % recovery from the MSCR test shows that the binders are very different. The binder made without high shear mixing and not the optimum polymer only had an MSCR % recovery of only 19%. The binder made with the optimum polymer and high shear mixing had an MSCR % recovery of 40%. In this case, both binders had 4% polymer, however, one was made to optimize performance by cross-linking the SBS and one was made to simply meet the Superpave PG specifications. The MSCR, in one simple test, clearly shows that the two binders, even though they both have 4 % SBS and the same base, are very different and will provide different performance, which the ER and G*/sinδ could not show. The actual test data is shown in table 2 below.

Table 2: Comparison of data for SHRP criteria and new MSCR criteria

Comparison of binders with the same base and different polymers and mixing process.					
Continuous Grade	Polymer	Temp °C	J_{nr} 3.2kPa^{-1}	ER	% Recovery 3.2kPa^{-1}
66.7-24.1		64	3.12	5	0
75.7-22.3	4% SBS	70	1.85	73.8	19.2
76.6-25.2	4% SBS	70	1.18	86	40.3

AASHTO currently does not have a specification on items such as Elastic Recovery or any of the currently used SHRP + tests. In keeping with their current practice no actual specification was developed for the % Recovery in the MSCR test. Recommendations on minimum MSCR % Recovery are part of the TP 70 test procedure for MSCR. This can be used in graphical form or as a table shown below in Table 3.

Table 3: Minimum % Recovery values from the MSCR test for ranges of J_{nr} values to evaluate for delayed elastic response.

Minimum % Recovery for Measured Jnr values	
Jnr @ 3.2 kPa	Minimum % Recovery
2.0 - 1.01	30%
1.0 - 0.51	35%
0.50 - 0.251	45%
0.25 - 0.125	50%

Summary

The Multi-Stress Creep and Recovery Test were developed to replace the existing RTFOT DSR high temperature Superpave requirement. It has been to shown to be far more discriminating in identifying the rutting potential of both modified and neat binders. The MSCR has been used to test and successfully rank neat, SBS, SB, Elvaloy, CRM, latex and chemically modified binders. The same simple test procedure to determine the high temperature test can also be used to evaluate the presence of polymer modification in the binder eliminating the need to run other time consuming, less discriminating test methods. The MSCR test provides the next major improvement in our ability to provide performance-related specifications for highway materials.

Contact—For information related to Superpave binder testing and MSCR, please contact the following Federal Highway Administration engineers:

John Bukowski - john.bukowski@dot.gov (Office of Pavement Technology)
Jack Youtcheff - jack.youtcheff@dot.gov (Office of Infrastructure R&D)
Tom Harman – tom.harman@dot.gov (Pavement & Materials Technical Service Team)

This **TechBrief** was developed as part of the Federal Highway Administration's (FHWA's) Asphalt Pavement Technology Program.

Distribution—This **TechBrief** is being distributed according to a standard distribution. Direct distribution is being made to the Resource Centers and Divisions.