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Update on rheological techniques for asphalt

By Arlis Kadrmas
BASF Corp.

Executive summary

Rheological techniques using the dynamic shear rheometer have been used since the introduction of the SuperPave binder specifications in the 1990s. The recent advancements of a multiple stress creep recovery (MSCR) procedure to determine the elastic properties of the modification of asphalt was established to take the place of traditional tests such as elastic recovery, forced ductility, and toughness and tenacity.

The current procedure will be described and how it is used in the development of specifications based on fatigue characteristics. The introduction into its use in asphalt emulsion residues is also developed. The data in the presentation will show the fit into testing parameters following a low temperature recovery for emulsion residues.

The use of the SHRP Superpave binder specifications to determine the appropriate grading of binders for environmental conditions since being implemented in the 1990s was a very important improvement to past grading techniques.

The specifications were found not to take into consideration the traffic loading effects that the binder would need to support in the asphalt mixtures. The Superpave specifications were revised to include elastic tests to determine the inclusion of polymer to the systems and were called in some areas, SHRP Plus specifications.

These specifications increased the high temperature of the grade to incorporate the stiffness the polymers added to the

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system, but this grade bumping provided additional complexity to the specifications. The recent development of the multiple stress creep recovery (MSCR) procedure has found a way to evaluate the elastic properties of the binder, while allowing the high temperature grade to remain at the climate conditions originally specified.

The following report shows the development of the MSCR procedure as well as giving a background of the evolution of the specification. It gives the reasons for the implementation of the test and the importance to the industry as it is being introduced in both the asphalt and asphalt emulsion products.

A map of the current SHRP binder specification, based on a 98-percent reliability, is shown in **Fig. 1**.

The specification shows the grades that should be specified based on the climate areas, but does not take into consideration the traffic conditions. An example of the nomenclature for the grading is shown based on a PG58-28 asphalt that is the predominant grade in the Ohio area:

PG 58-28

Performance Grade — **Average 7-day max pavement design temp** — **Min pavement design temp**

The PG stands for Performance Grade, the 58 is the average seven-day maximum pavement design temperature, which is meant to deal with rutting, and the -28 is the minimum design pavement temperature to define a temperature that would indicate thermal cracking. The specification, again, does not deal with traffic loads on the pavement.

Why add polymer, and how does that affect the specification?

The chart to the right shows a list of the Superpave grades and how the current refined oils to asphalts fit into the specification[1].

Low Temperature, °C \ High Temperature, °C	52	58	64	70	76
-16	52-16	58-16	64-16	70-16	76-16
-22	52-22	58-22	64-22	70-22	76-22
-28	52-28	58-28	64-28	70-28	76-28
-34	52-34	58-34	64-34	70-34	76-34
-40	52-40	58-40	64-40	70-40	76-40

= Crude Oil
= High Quality Crude Oil
= Modifier Required

As the chart shows, a combined temperature of 92 degrees would be a limit on what even the highest quality crudes for asphalt would be able to meet. Temperature ranges beyond that would require an addition of a polymer or other additive.

The process of "grade bumping," to increase the high temperature to adjust for traffic loads, increases this temperature range even further.

The addition of an elastic test, such as elastic recovery, forced ductility, toughness and tenacity, etc, is added to the specification to give evidence of the addition of a polymer. A picture of the elastic recovery test can be seen in **Fig. 2**.

An example of a "grade bumped" specification can be seen below:

PG 70-28 **(Plus Elastic Test)**

Performance Grade — **Average 7-day max pavement design temp (adjusted for traffic load)** — **Min pavement design temp**

This example shows a PG58-28 grade bumped to a PG70-28, with the addition of polymer, for a high traffic load pavement.

What is the multiple stress creep recovery test?

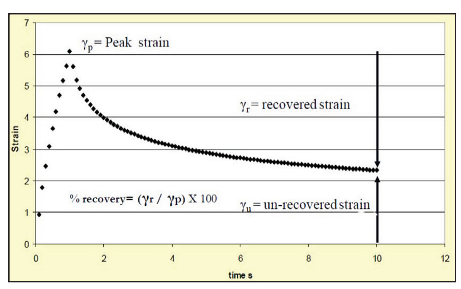
The MSCR test is designed as a fatigue test on the binder to take over for the elastic tests in the grade bump specifications. The test is done on the binder after the rolling thin film oven test at the Superpave grade map temperature for the climate area.

The test uses the dynamic shear rheometer and applies a one-second creep load at two different stress levels (100 Pa and 3200 Pa), followed by a nine-second recovery time for 10 cycles at each stress level. After 10 cycles at the 100 Pa stress level, it is followed by 10 cycles at the 3200 Pa stress level.

The first measurement from the MSCR test is the J_{nr} value, which is defined as the non-recoverable creep compliance. It is the measure of the amount of residual strain left in the specimen after repeated creep and recovery, relative to the amount of stress applied.

A graphic example of a run of the test is shown in **Fig. 3**[2]. The figure shows each load and recovery of the cycles that are done on the binder.

One issue with the J_{nr} value being used is that it gives more benefit to the stiffness of the binder than the elasticity of the binder at the test temperature. A percent recovery can be obtained from the MSCR testing, and that is shown below[2]:



This is a clip of one cycle that defines the percent recovery as the recovered

Fig. 3. A graphic example of a run of MSCR test.

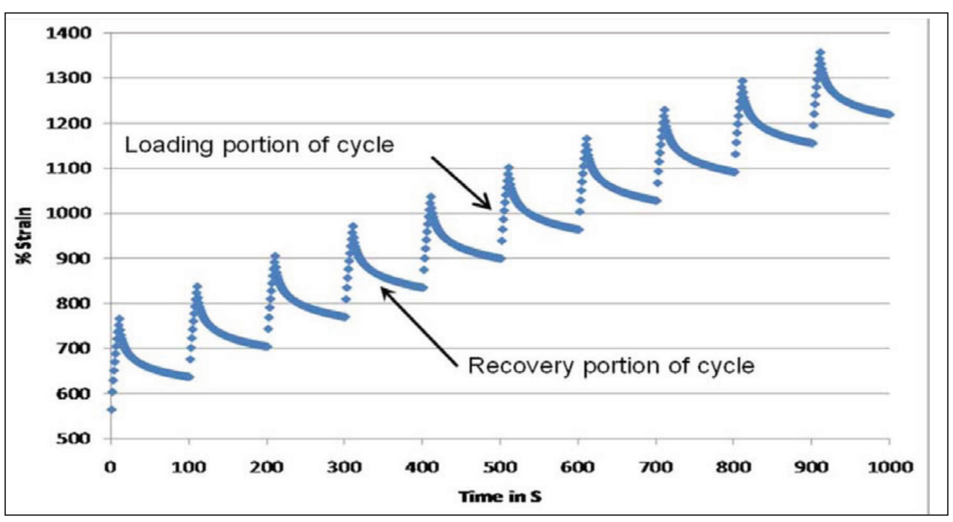


Fig. 2. Elastic recovery test.

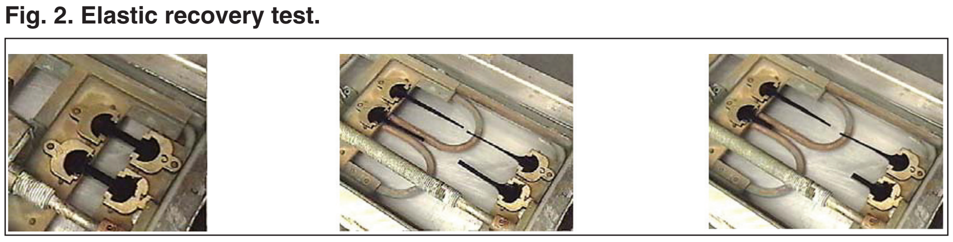
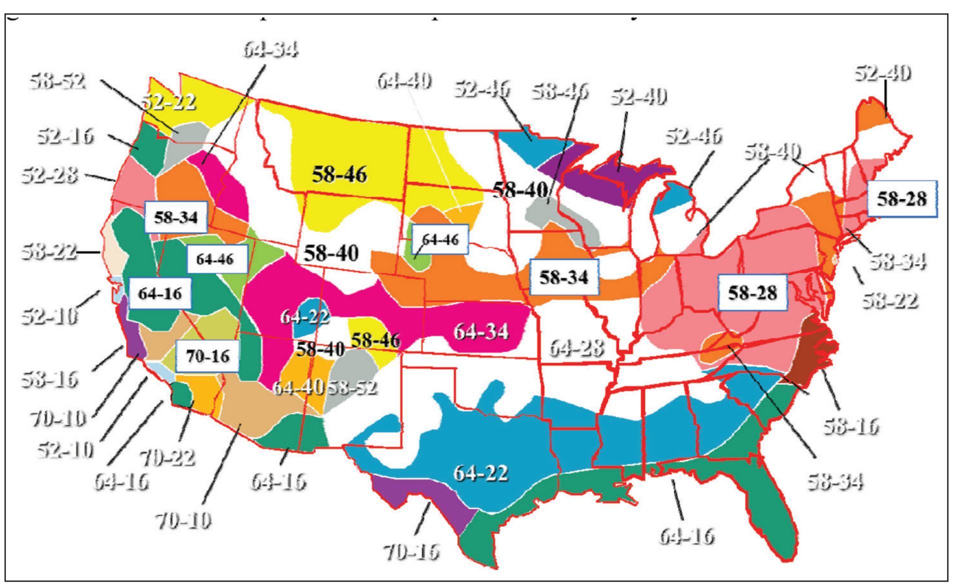


Fig. 1. SHRP binder specifications map—98 percent reliability.



The author

Arlis Kadrmas has been the technical account manager-asphalt, for BASF Corp. since June 2009.

Prior to joining BASF, Kadrmas worked in the asphalt industry for Koch Materials Co., Sem Materials L.P. and Road Science for 22 years.

His experience includes formulating asphalt, modified asphalt and asphalt emulsion products. He has worked on developing products and specifications for systems that utilize asphalt and asphalt emulsions for a wide range of field applications.

Kadrmas

Kadrmas is a member of the international technical committee for Asphalt Emulsion Manufacturers Association, and is also a member of ISSA, NAPA, ASTM, AIChE and the Asphalt Institute.

He is has a degree in chemical engineering from the University of North Dakota and resides in Wichita, Kan.

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strain divided by the peak strain.

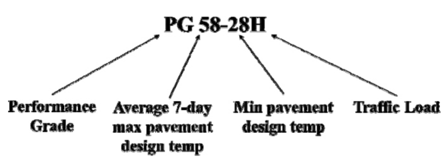
This, combined with the J_{nr}, can show evidence of polymer modification rather than just the stiffening of the binder by non-elastic additives.

Specifying SHRP grades using the MSCR

Table I gives the corresponding J_{nr} values based on defined traffic loading that is being recommended to agencies[2].

The high temperature grade from the pavement temperature will remain the same, and the letter grade will be used to define the traffic loading (amount and standing traffic). The corresponding traffic load in ESAL's is given to correspond with the J_{nr} limits.

Example of the naming of the specified binder using the MSCR J_{nr} testing is below:



This grade would represent close to a PG64-28 in the "grade bumping" specification, but note that the high temperature remains the same as in the climate area, with the inclusion of the "H" now designating this as being modified for a high traffic area.

The variability in asphalts makes the formulation to the grade bumping or MSCR specifications challenging. **Table II** shows two PG64-22 asphalts modified at a 3 percent polymer loading showing elastic testing as well as rheological testing.

Asphalt B clearly shows a more elastic nature and easily meets a PG64-22H, and barely a PG64-22V, and would easily be a PG70-22 on the grade bumping specification. Asphalt A would not meet a PG70-22 on the grade bumping specification due to the elastic recovery, but is a PG64-22H on the MSCR specification standards.

One clear way to show the polymer addition and effectiveness is in comparing the elastic recovery to the MSCR percentage recovery. The MSCR percentage recovery can be used as an alternative to the elastic recovery and would eliminate a test procedure.

MSCR testing on asphalt emulsion residues

The MSCR test can be used effectively on asphalt emulsion residues to identify polymer modification. The rheological testing is done without the RTO aging, since the emulsions do not go through a hot mix plant aging process.

Table III shows results on asphalt emulsion residues from both a distillation and low temperature evaporation procedures[3].

Rather than J_{nr} values, the percent recovery is being recommended for use in the emulsion residue testing. There has been no correlation to the J_{nr} for surface treatment applications such as a chip seal or micro-surfacing, but the percent recovery can be used as a determination of the effect of polymer.

The proper temperatures and whether the stress levels need to be changed for these applications still are being evaluated. The graphs do show that the residues from emulsions can still be tested using these rheological techniques.

The stress level that is considered to be the most representative for pavement preservation applications is that at the 3200 Pa level. At this stress level, the percent recovery is very similar between the two procedures for the asphalt emulsions manufactured at a loading of 3.75 percent latex.

Fig. 4 below shows the percentage recovery and J_{nr} at various temperatures at the 3200 Pa level for a modified CRS emulsion (used for chip seal applications)[4].

Due to the elastic nature of asphalt at cooler temperatures, it is not unusual to see very low J_{nr} values and high percentage recovery values at lower temperatures.

This graph just gives an example of this phenomenon and the need to properly define the temperature for testing the residue to achieve the correct performance characteristics.

One final example of this phenomenon is the testing of an unmodified asphalt at 25°C in comparison to a modified asphalt in the figure above. The unmodified asphalt is a PG64-22 base[4].

Temperature	% Recovery	Jnr
25°C	58	0.002
64°C	0.21	>5

Although the percent recovery is not 77 percent like the modified CRS at 25°C, it is still very high, and comparing the value at 64°C shows the true effect of polymer on the asphalt.

Conclusions

The MSCR testing can be used easily as an alternative to the "grade bumping" techniques that are currently used in agency specifications known as SHRP plus. The use of the DSR to test the properties at appropriate temperatures and stress levels allow the SHRP temperature to be maintained for the geographical area, while compensating for the traffic amount and loading.

The combination of the J_{nr} and the percent recovery of the MSCR also will be appropriate to maintain the elastic (fatigue resistance) effect of polymers rather than just the stiffening effect of other additives on the binders. The implementation and testing of these specifications in conjunction with the current agency specifications will allow proper adoption of these procedures.

The percent recovery portion of the MSCR testing also can be used for asphalt emulsion residues to determine use of polymers in the various pavement preservation systems. The temperatures and stress levels for these applications still are being evaluated.

References

1. Takamura, K., BASF Asphalt and Asphalt Emulsion Training Presentations, 2006-2009.
2. Bukowski, J.; Youtcheff, J.; Harmon, T., (April 2011) The Multiple Stress Creep Recovery (MSCR) Procedure, US Department of Transportation – Federal Highway Administration Office of Pavement Technology Tech Brief –FHWA-HIF-11-038.
3. Kadrmas, A., Using DSR-MSCR to Compare Emulsion Residue Recovery Methods Presentation to PPETG-Emulsion Task Force, May 2011.
4. Kadrmas, A., Asphalt Emulsion Residue Recovery and Rheological Testing Update -Presentation to AEMA ITC at AEMA Annual Meeting, February 2010.

Fig. 4. Percentage recovery and J_{nr} at various temperatures at the 3200 Pa level for a modified CRS emulsion (used for chip seal applications)[4].

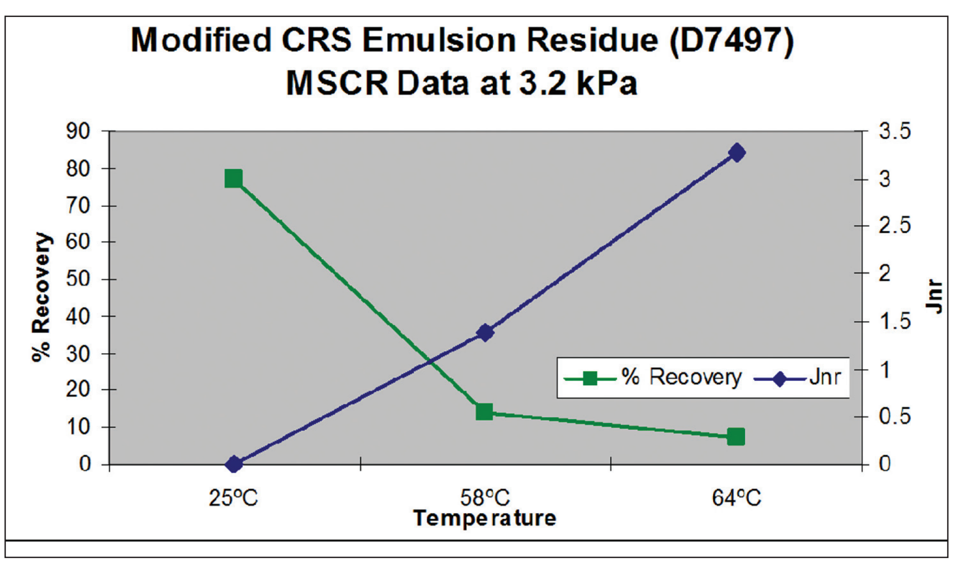


Table I. Corresponding J_{nr} values based on traffic loading recommended to agencies.

- **Standard S Grade**
  - J_{nr} 4.0 Maximum
- **Heavy – H Grade**
  - J_{nr} 2.0 Maximum
- **Very Heavy – V Grade**
  - J_{nr} 1.0 Maximum
- **Extreme – E Grade**
  - J_{nr} 0.5 Maximum

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

Table III. Results on asphalt emulsions residues from both distillation and low temperature evaporation procedures.[2]

Multiple Stress Creep Recovery Testing on Residue from Distillation (177°C minute hold)

		58°C		64°C		70°C	
Emulsion	% Latex	100Pa	3200Pa	100Pa	3200Pa	100Pa	3200Pa
PGXX-34 LR	3.75	70.21	31.67	70.09	22.79		
PG58-28 LR	3.75	48.27	27.66	47.07	19.40		
PG64-22 LR	3.75			41.8	21.57	41.14	14.22

Multiple Stress Creep Recovery Testing on Residue from Evaporation (25°C 24 hour & 60°C 24 hour)

		58°C		64°C		70°C	
Emulsion	% Latex	100Pa	3200Pa	100Pa	3200Pa	100Pa	3200Pa
PGXX-34 LR	3.75	62.66	28.78				
PG58-28 LR	3.75	45.31	26.81	51.54	18.79		
PG64-22 LR	3.75			41.12	24.68	35.11	17.25

Table II. Two PG64-22 asphalts modified at 3 percent polymer loading, showing elastic testing as well as rheological testing.

Asphalt	%Latex	ER 10C	64C MSCR Jnr @ 3200Pa	64C MSCR Rec @ 3200Pa	SHRP High Grade
A - PG64-22	3	25%	1.21	15%	70.4C
B - PG64-22	3	65%	0.954	27%	73.1C

Products

Cabot Corp. has launched two Propel carbon black products for tire applications, the Propel E7 and Propel D11.

Cabot said the Propel E7 carbon black is engineered to reduce tire rolling resistance and improve vehicle fuel economy, while the Propel D11 carbon black is designed to provide a high level of tread durability and is suited for short-haul truck and off-the-road vehicle tires.

Features include:

• Fuel efficiency—Cabot said that tests of Propel E7 carbon black demonstrate that the product reduces the energy loss of typical tire tread compounds by 15 percent when compared to the same laboratory tests of Cabot Vulcan 7H carbon black, enabling reductions in tire rolling resistance. Primary applications for this product are on-highway, long-haul truck tire treads and retreads.

• Higher durability—The high level of rubber reinforcement in the Propel D11 enables tire treads that resist cutting, tearing and abrasion, and extend the useful life of a tire, the company claims. Cabot laboratory tests of Propel D11 carbon black demonstrate a 10 percent improvement in laboratory abrasion resistance in natural rubber compounds, Cabot said.

To learn more, visit www.cabotcorp.com/Rubber-Carbon-Blacks/Tires

Quantum Silicones L.L.C. has introduced QSil 553LV, a silicone rubber designed to benefit electronic potting applications, such as power supplies, LED, circuit and electronic modules. QSil 553LV meets the UL requirements for flame retardancy, the company said, and its physical properties enable it to withstand extreme temperatures, protect sensitive components from moisture and debris, while being readily repairable.

QSil 553LV has a low viscosity allowing convenient dispensing and an easy flow throughout complex parts. The compound will cure in closed environments and not outgas or produce byproducts because it is 100-percent silicone solids, containing no solvents. Its long work life of 100 minutes will allow time for air bubbles to dissipate, the company said.

For more information, visit www.quantumsilicones.com.