Understanding Multiple Stress Creep & Recovery (MSCR)

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SEAUPG MEETING NOVEMBER 20TH, MOBILE, AL

History of Asphalt Grading

- Chewing
- Penetration Grading
- Viscosity Grading
- Performance Grading (PG) (AASHTO M320)
- MSCR (AASHTO M332)

Agenda

- Background
- What is MSCR?
- Why MSCR?
  - What are we trying to fix?
- MSCR Deep Dive: What do all the symbols and numbers mean?
- How to best use MSCR
- Conclusions
- Questions?

History of Asphalt Grading

- Chewing
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Background

A BRIEF HISTORY

Performance Grading

Distresses addressed by the binder portion of the PG system:

- Rutting
- Fatigue cracking
- Low temperature cracking

Performance Grading

Distresses addressed by the binder portion of the PG system:

- **Rutting**
- Fatigue cracking
- Low temperature cracking

Rutting

- Binder rutting parameter before MSCR :

  $G^*/\sin(\delta) \geq 2.2$ kPa on RTFO aged material

- Designed to ensure sufficient binder stiffness to resist premature rutting.
- Parameter developed during SHARP Program
- Part of the SuperPave® Performance Grading system
- Primarily built on/for non modified asphalt binders.

Rutting

Definition*:

Rutting in pavements refers to the permanent deformation or longitudinal depressions that form along the wheel paths of a roadway. This type of distress typically occurs in the asphalt surface layer but can also extend to the base, subbase, and subgrade layers. Rutting is primarily caused by the repeated loading and unloading of traffic, especially from heavy vehicles, which compresses the pavement materials and causes them to move laterally and longitudinally. The result is a series of grooves that align with the paths of vehicle tires, which can compromise the structural integrity of the pavement and affect driving safety by collecting water and causing hydroplaning risks.

*Generated by "Hey NAPA"

What is MSCR?

Definition*:

Multiple Stress Creep Recovery (MSCR) is a test method used to evaluate the performance characteristics of asphalt binders at high temperatures. It specifically measures the creep and recovery behavior of asphalt binders subjected to repeated shear loads. The MSCR test is conducted using a Dynamic Shear Rheometer (DSR) and is outlined under AASHTO M 332 standards.

The test involves applying multiple levels of stress to an asphalt binder sample and observing its deformation (creep) and its ability to recover its original form once the stress is removed. The key parameters measured during an MSCR test are the non-recoverable creep compliance (Jnr) and the percent recovery. These parameters help in assessing the binder's susceptibility to permanent deformation under loading, providing essential insights into its performance in high-temperature conditions typical of pavement surfaces during summer or in hot climates. This test is particularly useful for evaluating modified binders, which are often used to enhance the performance of asphalt pavements.

*Generated by "Hey NAPA"

Rutting


Why MSCR? What are we trying to fix?

The tale of 2 roads:

1. Road built with 64-22 unmodified binder: After a few years shows unacceptable rutting.
2. Road built with 58-34 polymer modified binder: After similar number of years in service as road #1 shows no rutting in same climate and type of traffic.

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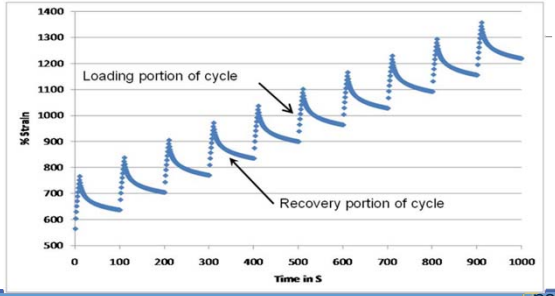
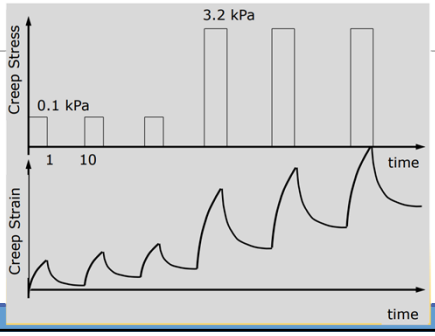
MSCR Deep Dive



What do all the symbols & numbers mean?

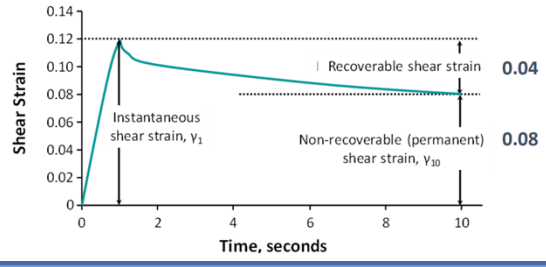
DEEP DIVE INTO MSCR

MSCR Deep Dive



MSCR Deep Dive

- Multiple Stress (100 Pa & 3200 Pa) as in 2 stress levels, which is more than 1, hence "multiple"
- Creep (a period of 1 second under constant load/stress allowing the material to "creep" for 1 second)
- Recovery (a period of 9 seconds under zero load/stress allowing the material to recover, if it has the ability to do so)



MSCR deep Dive

MSCR Deep Dive: some definitions

Viscosity: Resistance to flow

Compliance: Willingness of material to deform under stress/load (read flow here)

Based on the above definitions one can conclude that Viscosity and Compliance are more or less the inverse of each other.

J is the symbol for compliance. Since we measure it in Creep it is Creep Compliance.

γ is strain and σ is stress (either 100 or 3200 Pa, a.k.a. 0.1 kPa or 3.2 kPa)

MSCR (pronounced massacre)

This is one thing a lot of practitioners either do not realize or just don't understand:

Once you test a sample of asphalt in MSCR you "massacred" the sample. It is DONE, FINISHED! The sample has been damaged to the point it is no longer the same material with the same properties as when you started the test (yes, the 3.2kPa stress cycles are to blame for that).

It literally sacrificed its integrity for your benefit (the benefit of getting useful data related to rutting performance).

WHAT DOES THIS MEAN??? It means you **can not run another test on the same sample AFTER MSCR**. The sample **must be discarded**, and a **new fresh one must be loaded** in the DSR if there is **more testing needed** (this is for you TXDOT in the back row!!!)

MSCR Deep Dive

Jnr is the non-recoverable creep compliance calculated as:

$$J_{nr} = \frac{\gamma_{nr}}{\sigma} \qquad [1/Pa(kPa)]$$

% recovery is the % of total strain recovered in the 9 second recovery period, calculated as:

$$\%Recovery = \frac{\gamma_{rec}}{\gamma_{total}} \text{x}100 \qquad [\%]$$

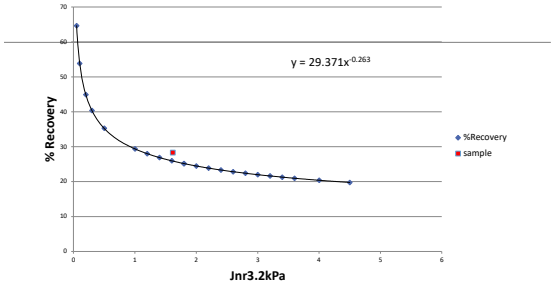
Jnr Difference is the % change between the Jnr at 3.2kPa and Jnr at 0.1 kPa, calculated as:

$$J_{nr}\text{Difference} = \frac{(J_{nr3.2kPa} - J_{nr0.1kPa})}{J_{nr0.1kPa}} \text{x}100 \qquad [\%]$$

How to Best Use MSCR?

AASHTO M-332 & SPECIFICATIONS

MSCR Deep Dive – The Curve (The SBS Curve)



MSCR Specifications

- We will use an asphalt from Mississippi as an example (perks of being the presenter)
- Highest environmental temperature in Mississippi according to LTTP Bind is 64°C so we will use a 67 PG grade (ask me why 67 and not 64)
- PG Grades: 67-22, 70-22, 76-22, 82-22
- MSCR Grades:

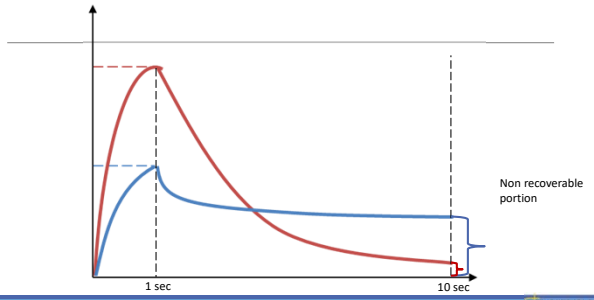
67S-22	$J_{nr} \leq 4.5$ kPa^{-1}	S = Standard
67H-22	$J_{nr} \leq 2.0$ kPa^{-1}	H = Heavy
67V-22	$J_{nr} \leq 1.0$ kPa^{-1}	V = Very Heavy
67E-22	$J_{nr} \leq 0.5$ kPa^{-1}	E = Extreme

MSCR Specifications

No temperature grade bumping needed. Grade bumping reflected in the traffic level letter.

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

MSCR and the 2 roads: PG64-22 & PG58-34



MSCR & Performance

Rutting: hope it is obvious by now, Jnr is a parameter that better correlates to rutting performance on the binder properties.

The curve: when SBS modified asphalts are being specified the curve can ensure polymer modification quality. The % recovery parameter is a sum of 2 distinct properties (amount of polymer and degree of network development). By looking at this number alone (% recovery) one can not make accurate performance predictions. That being said this measurement is valuable. It is an indicator of the presence of enough polymer with a good enough network in place when compared against the curve. In other words, if it is SBS modified, above the curve is better than below the curve.

So how did we come up with the curve? The answer is: the same way we came up with the 2.2kPa limit for G*/sin(δ) for RTFO DSR.

Conclusions

THE GRAND FINALE

Back to the beginning

THE TALE OF 2 ROADS – HOW ARE WE DOING NOW?

Conclusions

MSCR (Jnr3.2) does a better job than G*/sin(δ) at predicting **rutting performance**/resistance of the binder portion of the mix (can't predict aggregate performance or mix performance)

By using % recovery and the curve one can get a pretty good idea of the network development degree and the amount of elastomeric polymer (especially if that polymer is SBS) present in the modified asphalt.

This information makes % recovery a good indicator of performance, not a direct measurement.

It also makes % recovery a cheap (practically free) and easy replacement alternative for the PG+ tests such as ductility, elastic recovery, etc.

Looking at the Jnr difference one gets a good idea of the material's (read binder) shear sensitivity as long as that % Difference in Jnr is calculated at reasonable values (Jnr3.2values no lower than 0.25kPa)

MSCR in the context of AASHTO M322 eliminates the need for grade bumping due to traffic.


Questions?
LET THE FUN BEGIN!
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