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Introduction to the Multiple-Stress Creep-Recovery (MSCR) Test and its Use in the PG Binder Specification

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  - Michael Arasteh, AOTR (00033)
- Asphalt Binder ETG
  - John D'Angelo
- Member Companies of the Asphalt Institute
  - Technical Advisory Committee

Discussion

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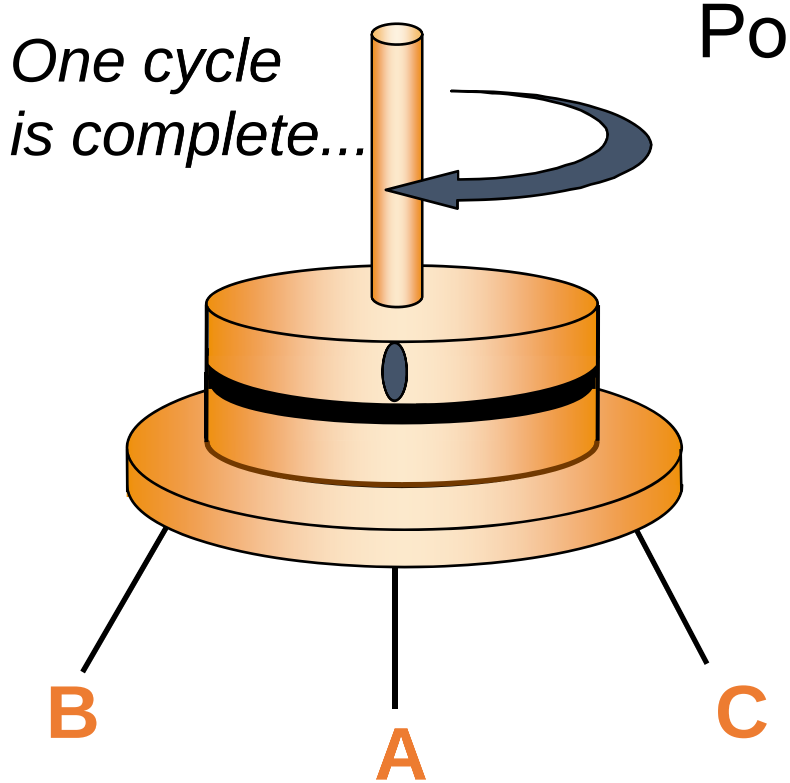
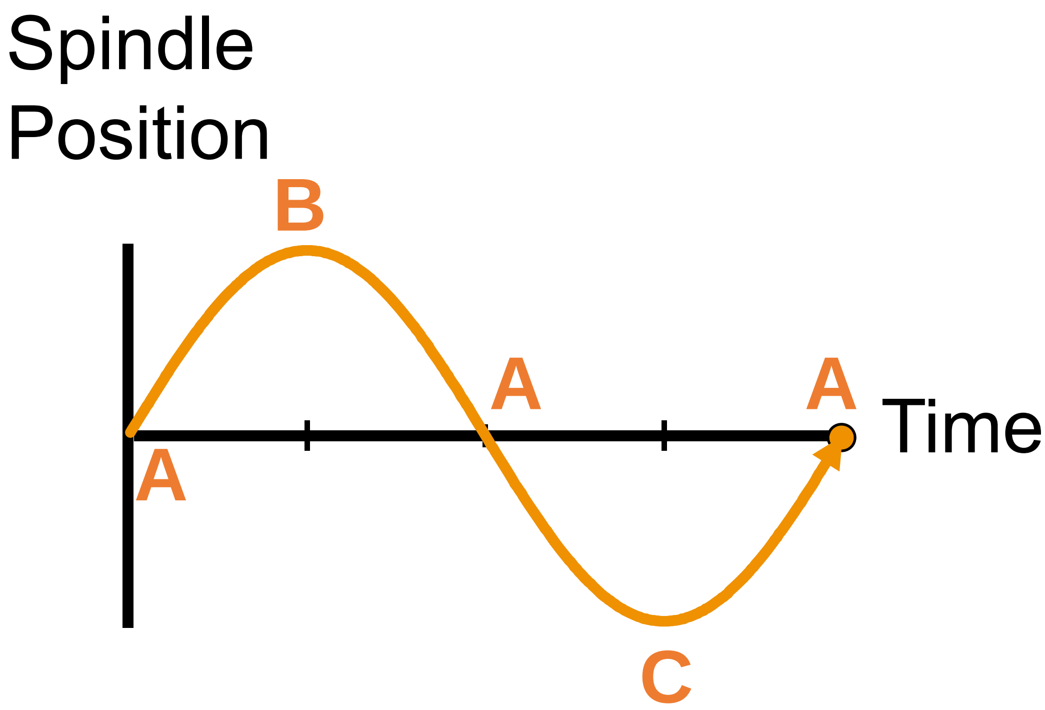
- Why do we need a new high temperature parameter?
- How does the MSCR test work?
- How do MSCR results (J_{nr}) relate to rutting?
- How can MSCR Recovery be used and what does it indicate?
- How does the specification work?
- What educational and implementation activities are going on?

DSR Operation: AASHTO T315

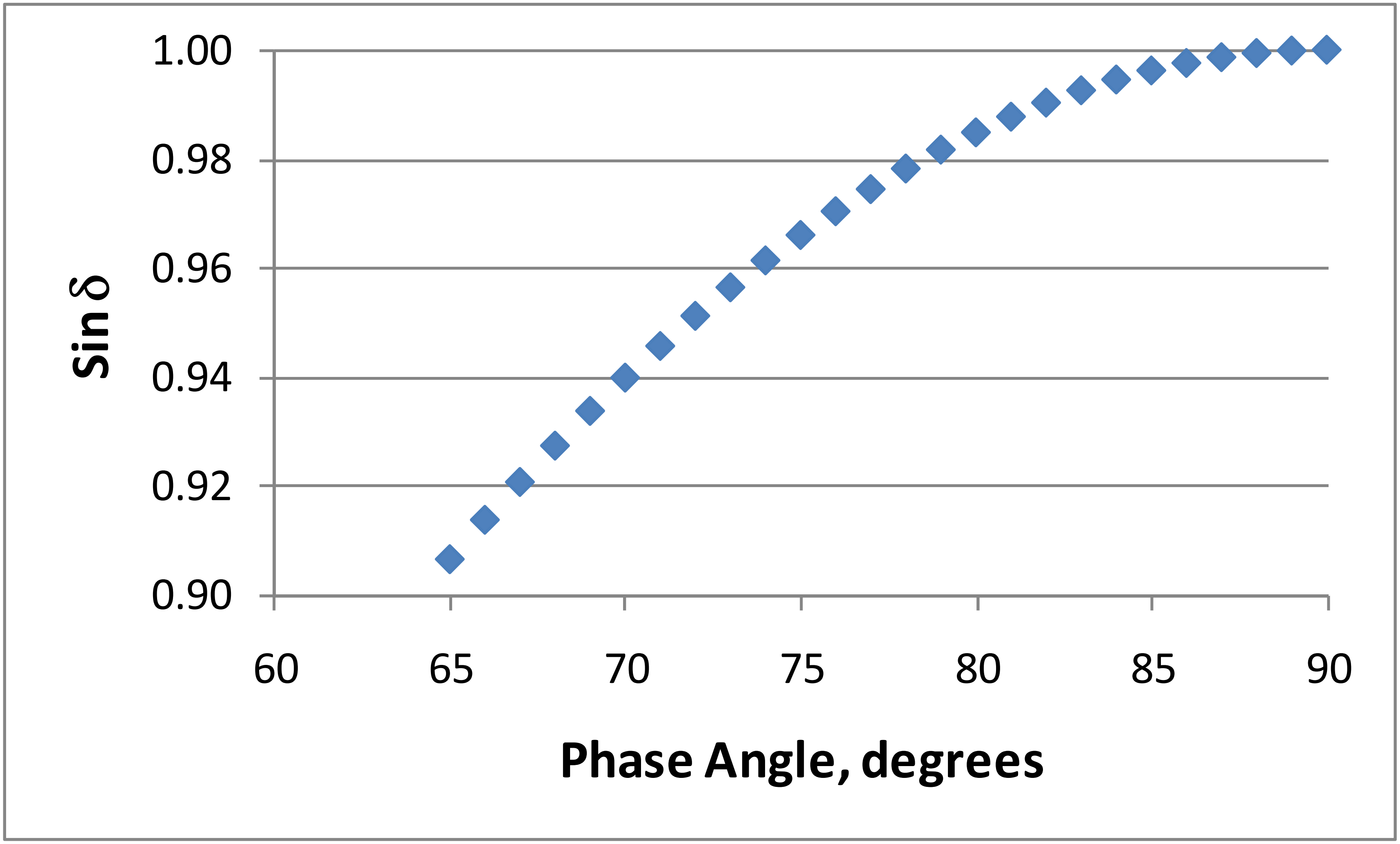




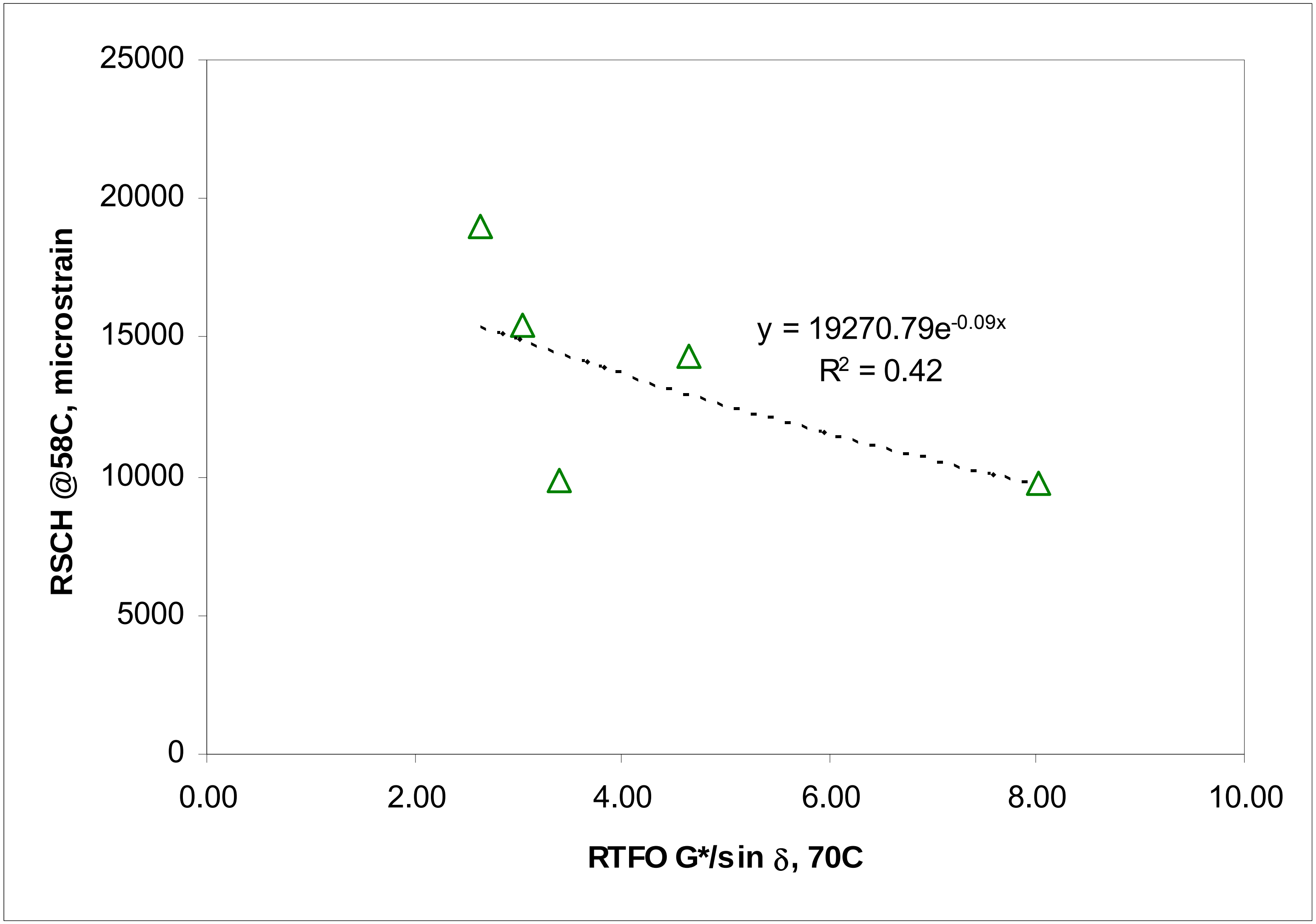
Shortcomings of G*/sin δ

- G*/sin δ as a High Temperature Parameter
  - Properties determined in Linear Viscoelastic (LVE) region
    - No damage behavior
      - Rutting is a non-linear failure
      - Polymer-modified systems engaged in non-linear region
    - Characterizes stiffness
      - Related to rutting

Effect of Phase Angle



Effect of Binder G*/sin δ on Mixture Permanent Shear Strain



High Temperature Testing

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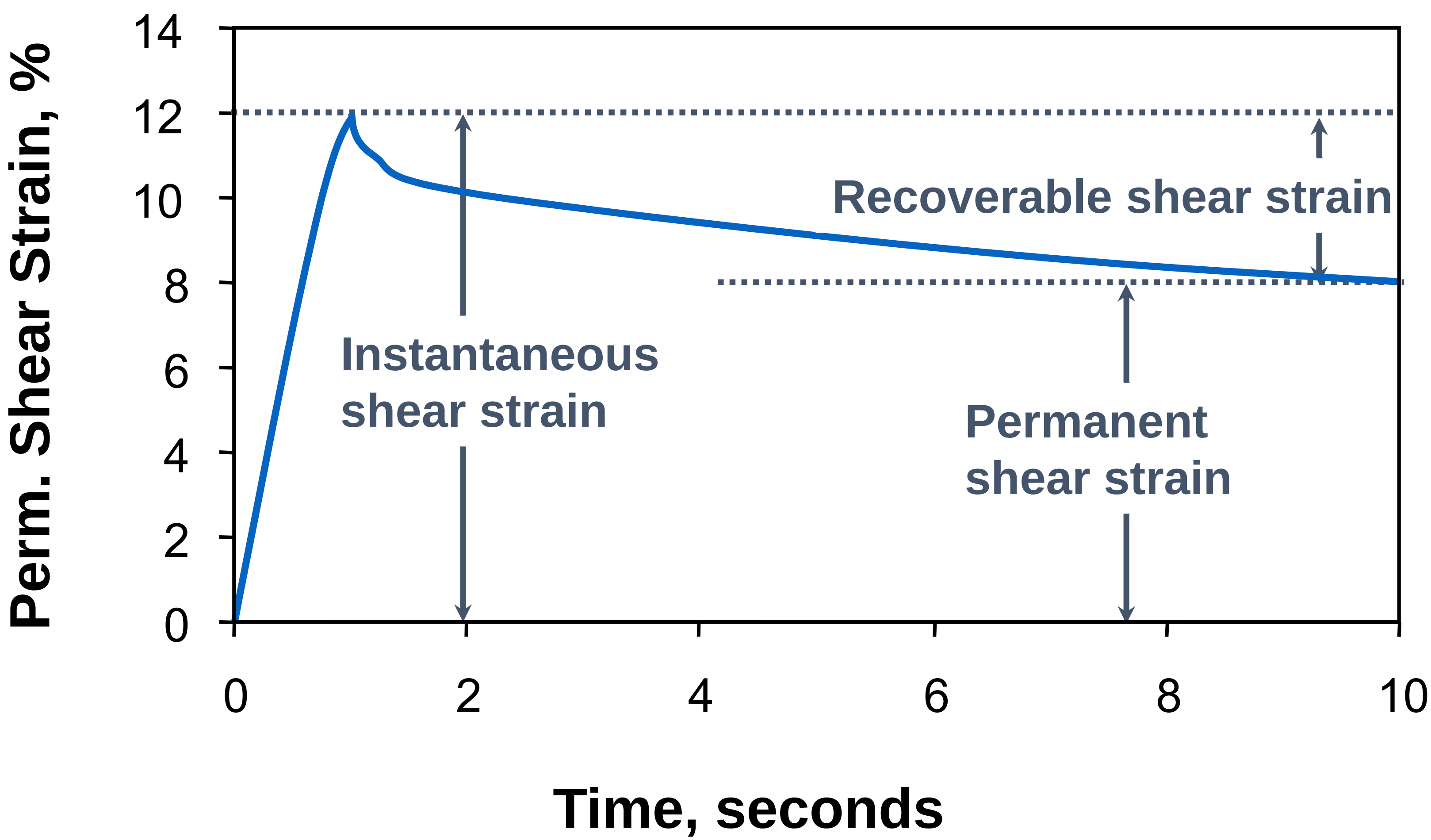
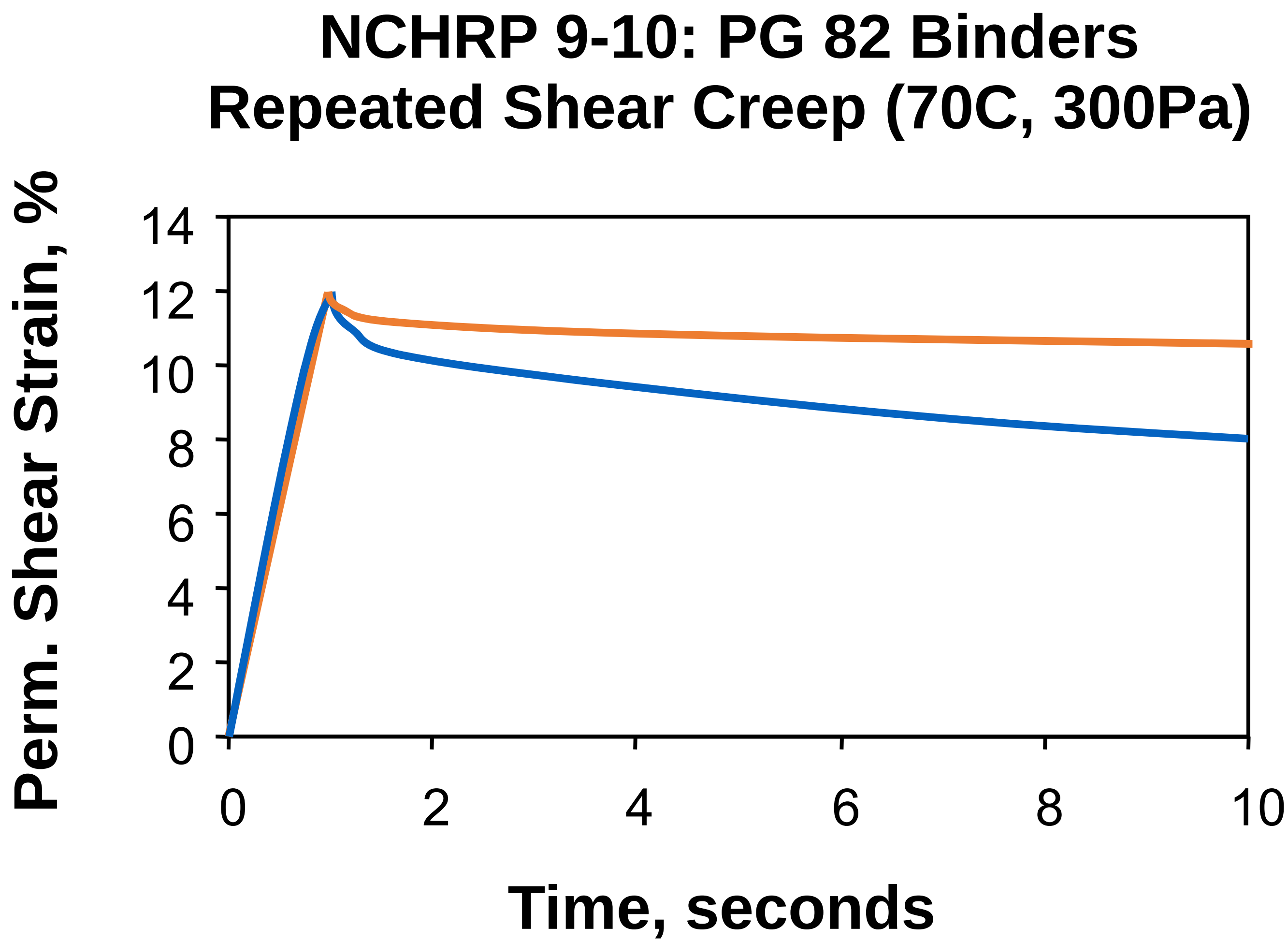
- Repeated Shear Creep
  - Analogous to mixture test (RSCH)
  - Performed in DSR
    - Controlled shear stress (i.e., 25 Pa or 300 Pa)
    - 100 cycles
    - 1-second load, 9-second rest per cycle
    - High test temperature (HT-?)
  - Response: permanent shear strain (γ_p) or strain slope

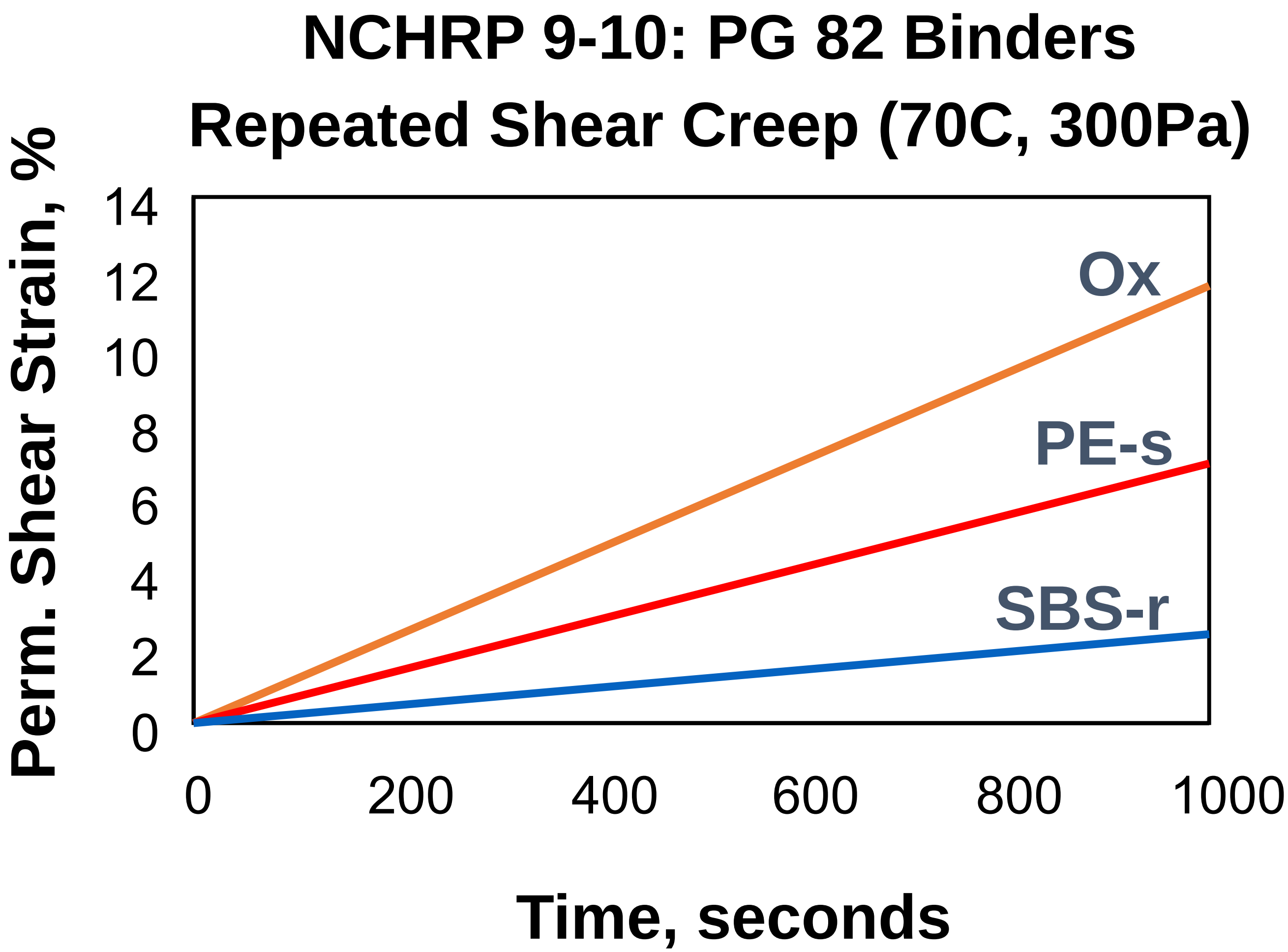
Repeated Shear Creep



Repeated Shear Creep



Repeated Shear Creep



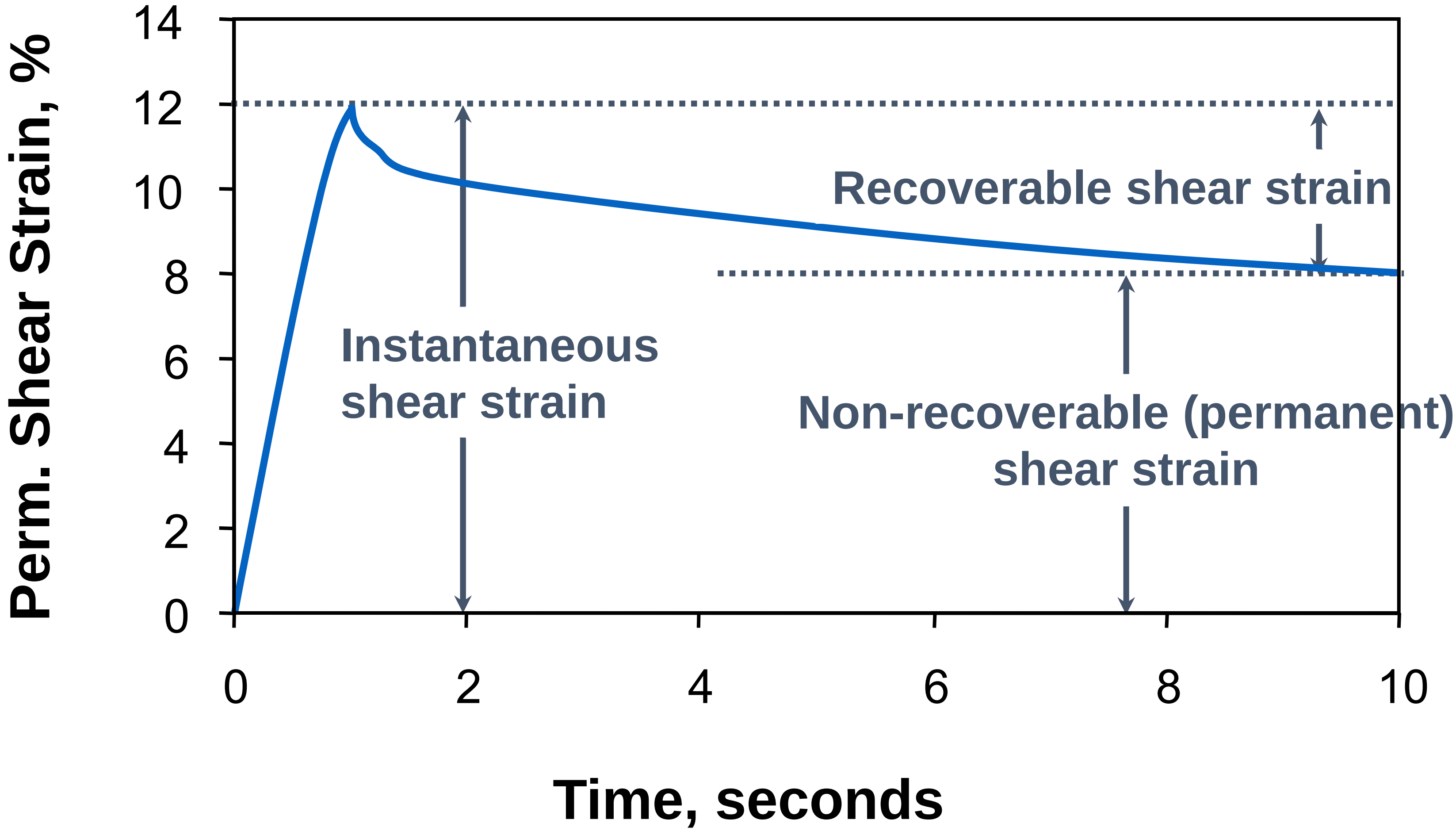
Multiple-Stress Creep-Recovery (MSCR) Test: AASHTO T350

- Performed on RTFO-aged Binder
- Test Temperature
  - Environmental Temperature
  - Not Grade-Bumped
- 10 cycles per stress level
  - 1-second loading at specified shear stress
    - 0.1 kPa
    - 3.2 kPa
  - 9-second rest period

MSCR Test

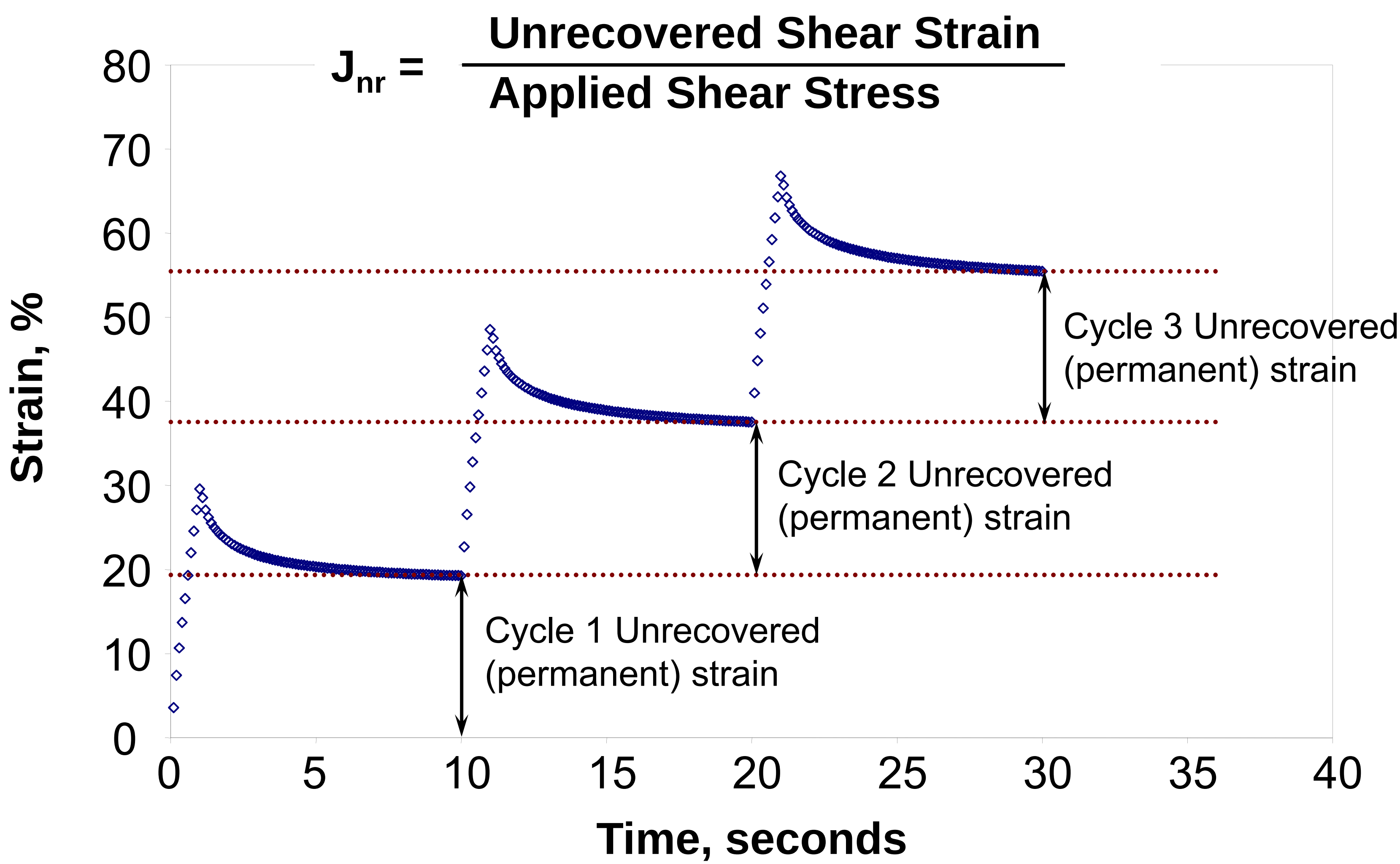
- Calculate Non-recoverable Creep Compliance (J_{nr})
  - Non-recoverable shear strain divided by applied shear stress
    - "J" = "compliance"
    - "nr" = "non-recoverable"
- Calculate Recovery for each Cycle, Stress
  - Difference between strain at end of recovery period and peak strain after creep loading

MSCR

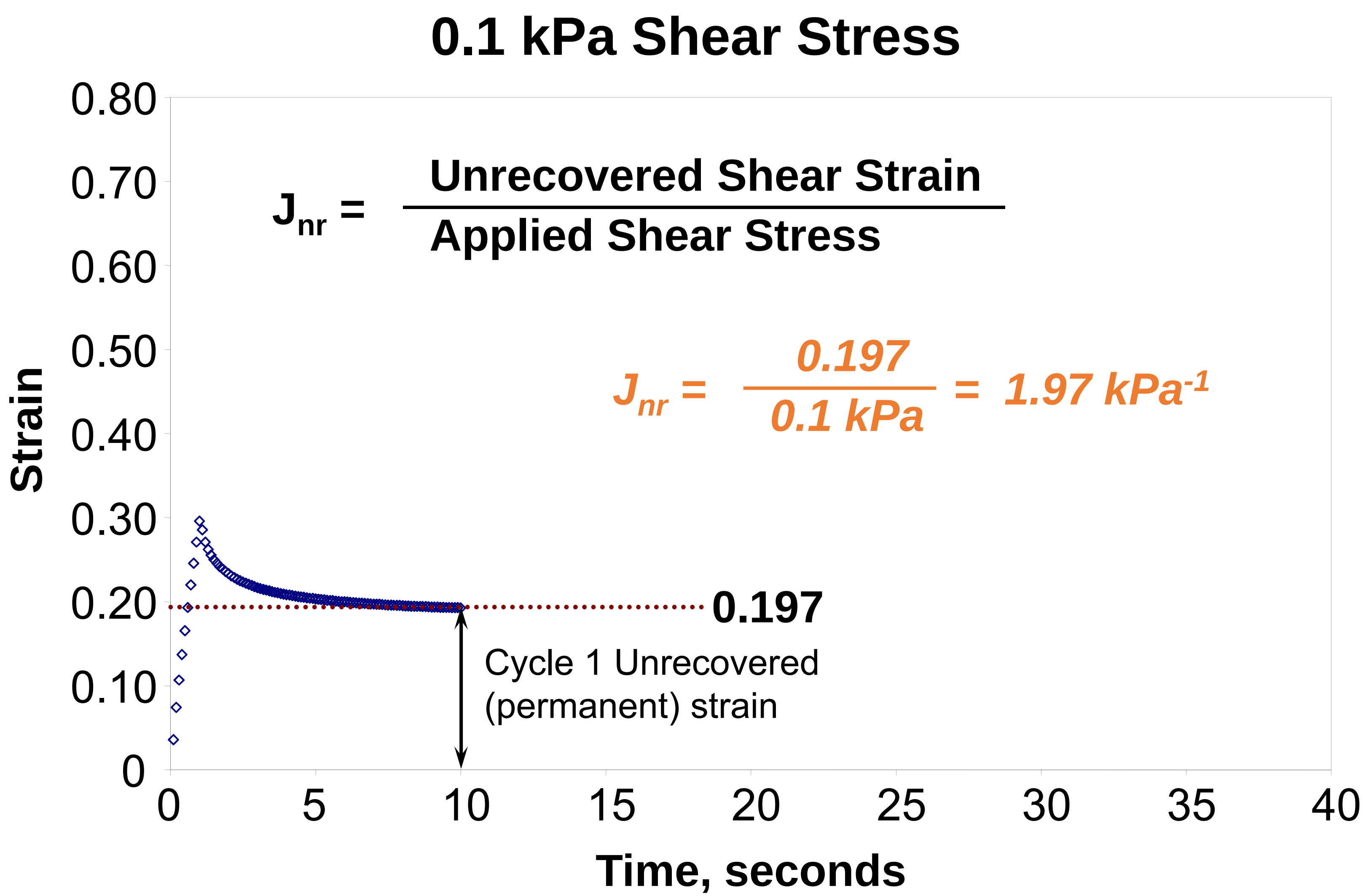


Perm. Shear Strain, %
14
12
10
8
6
4
2
0
0
2
4
6
8
10
Time, seconds
Instantaneous
shear strain
Recoverable shear strain
Non-recoverable (permanent)
shear strain

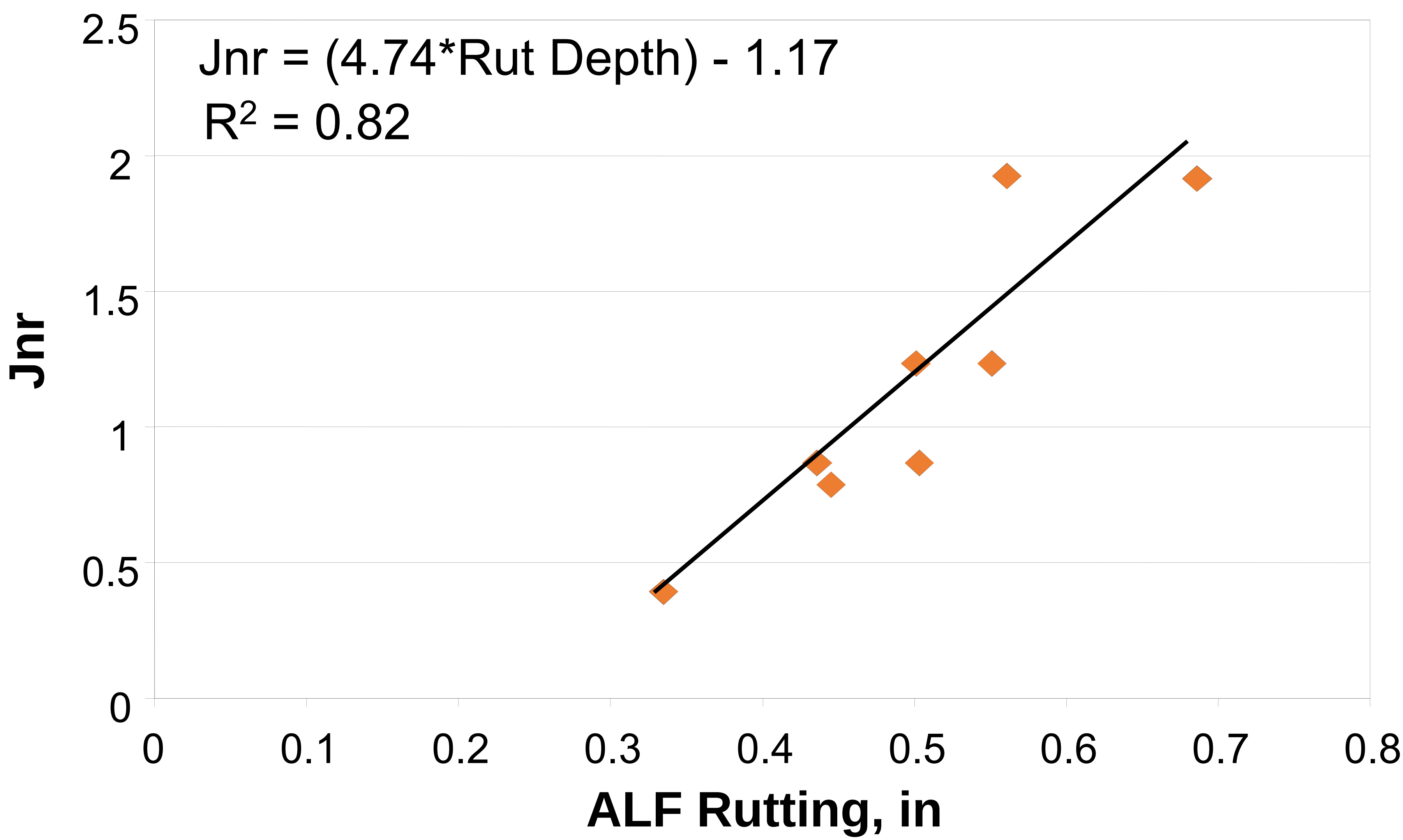
MSCR – Non-Recoverable Compliance (J_{nr})



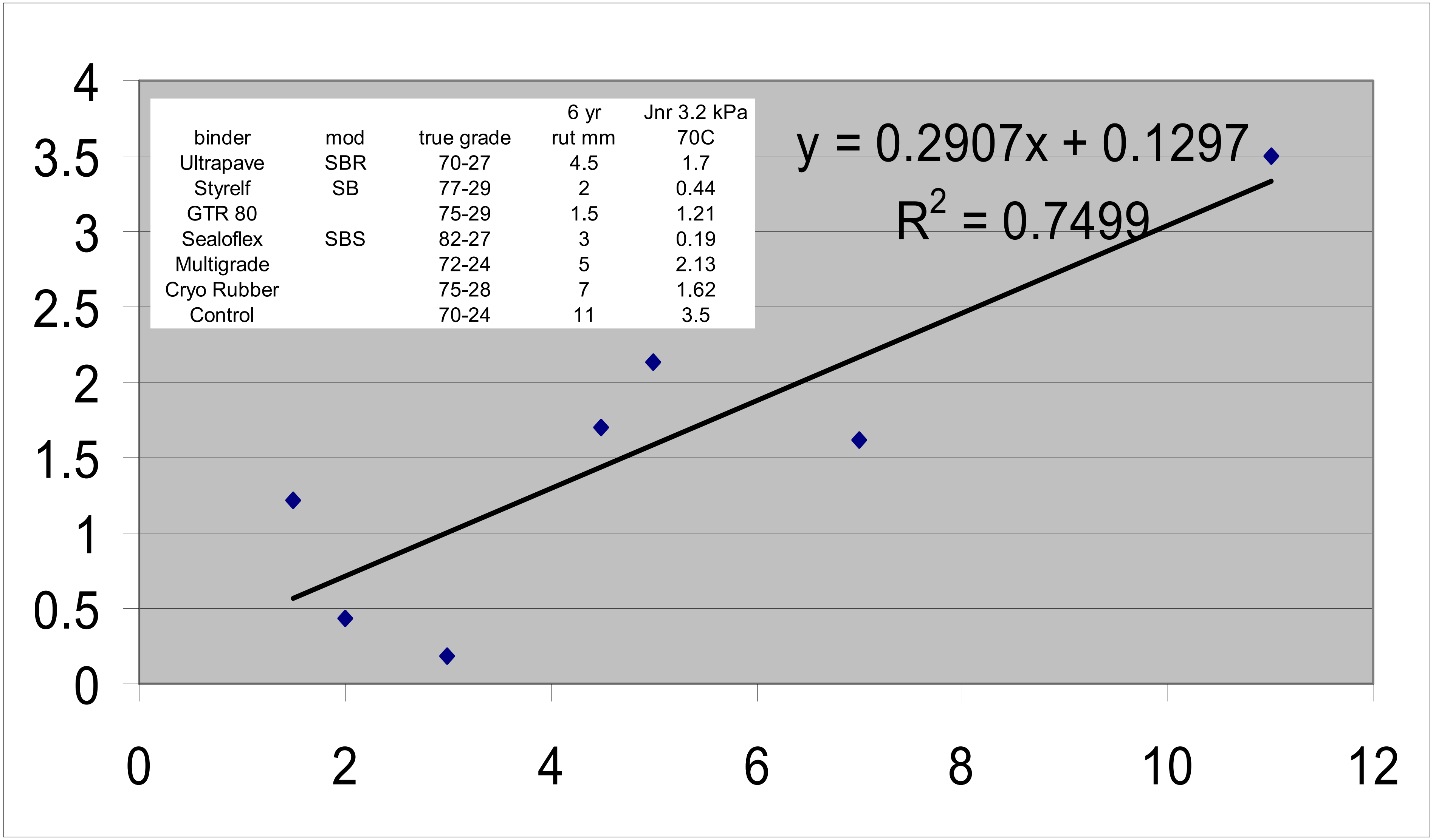
MSCR – Non-Recoverable Compliance (J_{nr})



Relationship between Jnr and ALF Rutting
Jnr-25.6

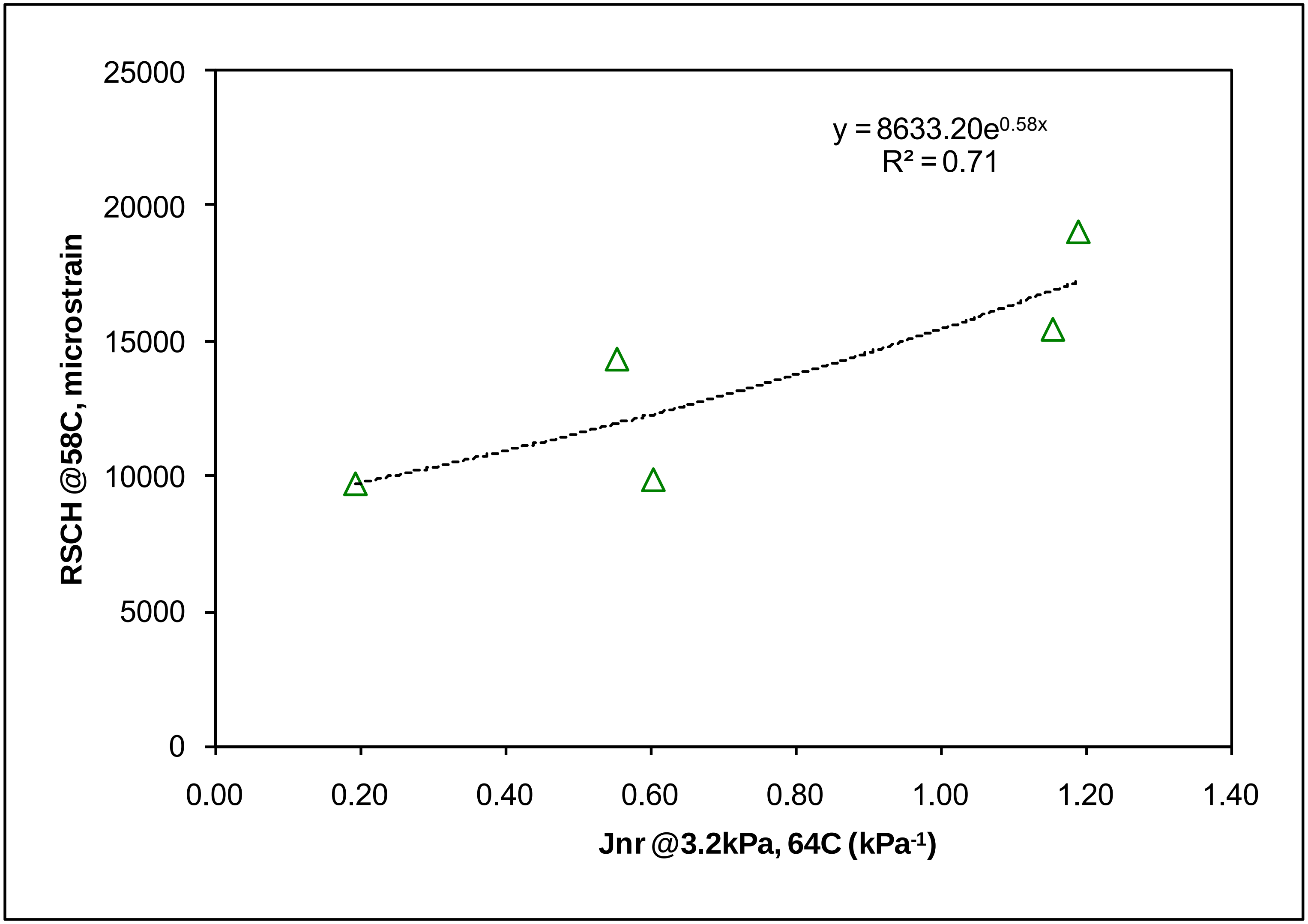


Mississippi I55: 6-yr rutting Jnr-3.2



binder	mod	true grade	6 yr rut mm	Jnr 3.2 kPa 70C
Ultrapave	SBR	70-27	4.5	1.7
Styrelf	SB	77-29	2	0.44
GTR 80		75-29	1.5	1.21
Sealoflex	SBS	82-27	3	0.19
Multigrade		72-24	5	2.13
Cryo Rubber		75-28	7	1.62
Control		70-24	11	3.5

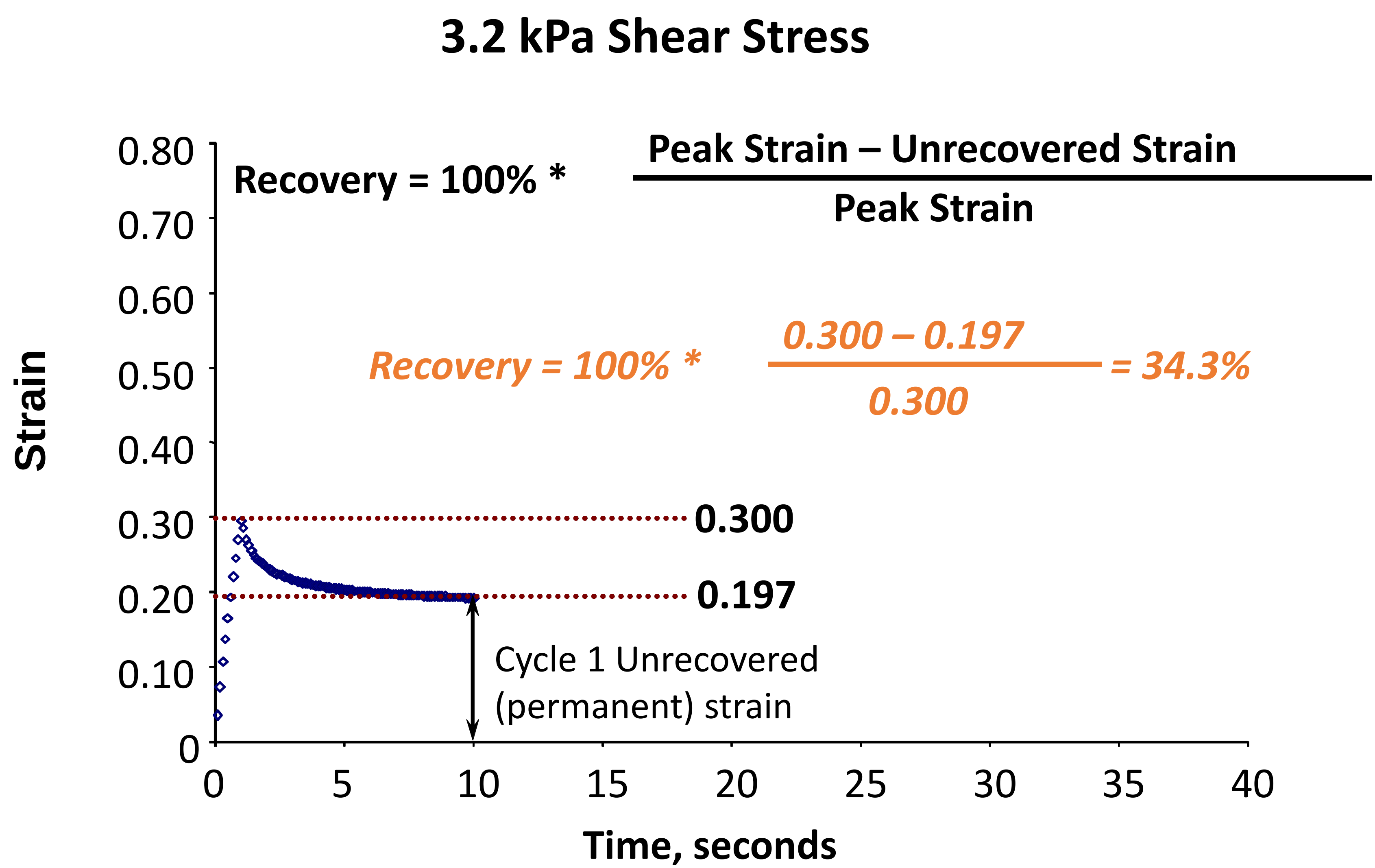
Effect of Binder J_{nr} on Mixture Permanent Shear Strain



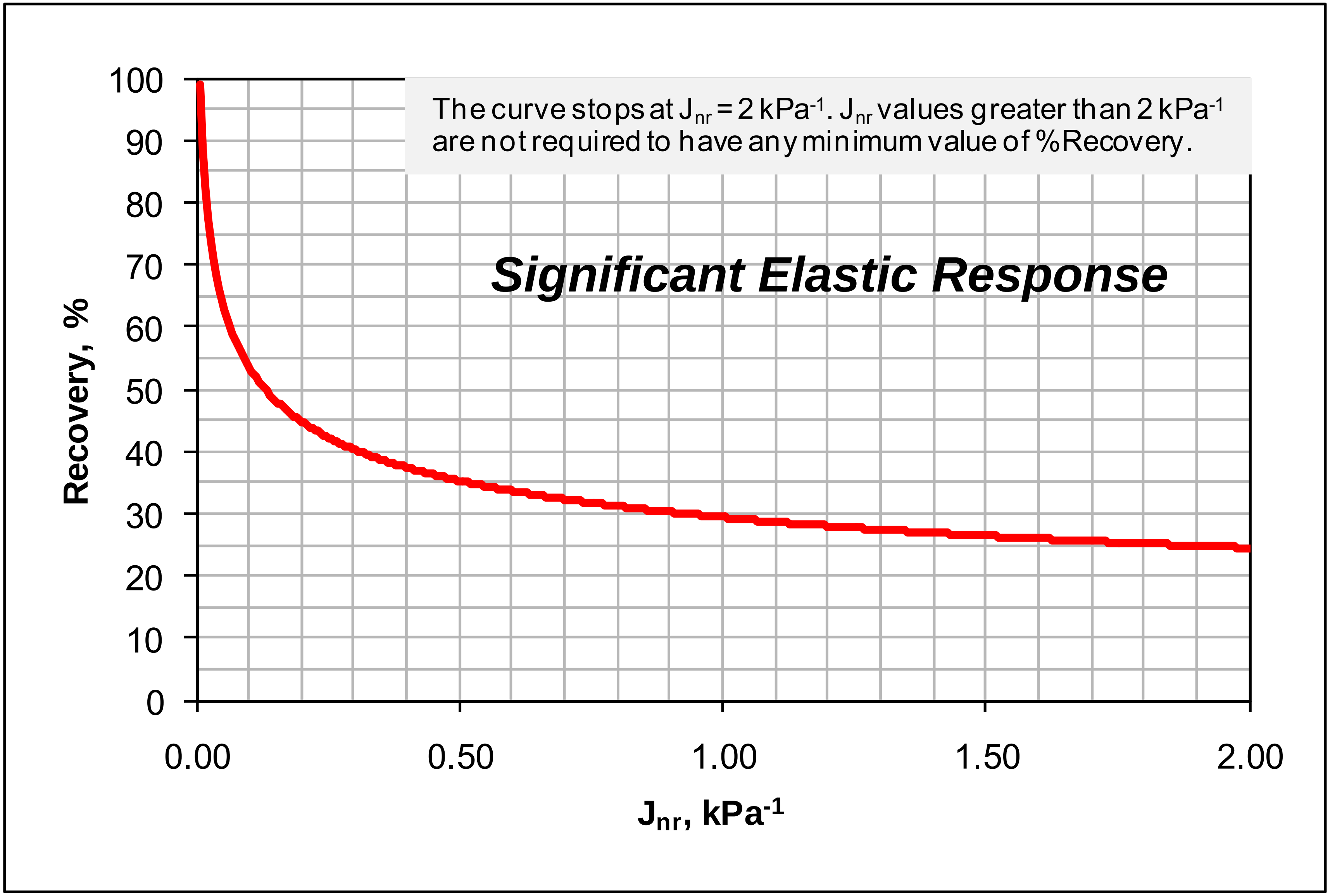
MSCR: What is % Recovery?

- MSCR J_{nr} addresses the high temperature rutting for both neat and modified binders
  - but many highway agencies require polymers for cracking and durability.
- The MSCR % Recovery measurement can identify and quantify how the polymer is working in the binder.

MSCR Recovery



MSCR Recovery:
Validate Polymer Modification



MSCR Recovery: Validate Polymer Modification

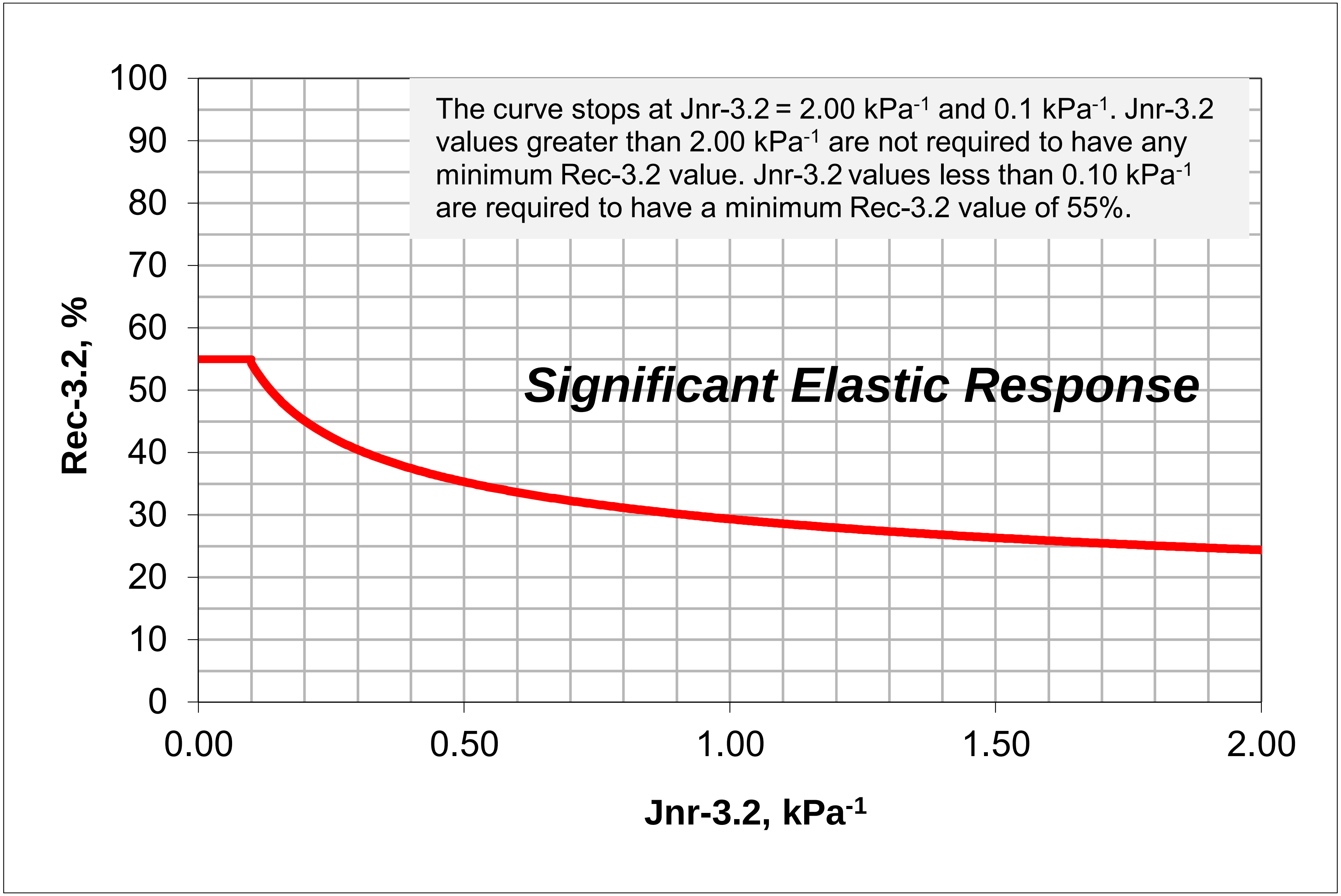


Table for MSCR % Recovery: Minimum Values

Minimum % Recovery for Measured J_{nr} values	
J_{nr} @3.2 kPa, kPa^{-1}	**Recovery**
> 2.00	n/a
≤ 2.00	≥ 30%
≤ 1.00	≥ 35%
≤ 0.50	≥ 45%
≤ 0.25	≥ 50%
≤ 0.10	≥ 55%

Validate Polymer Modification

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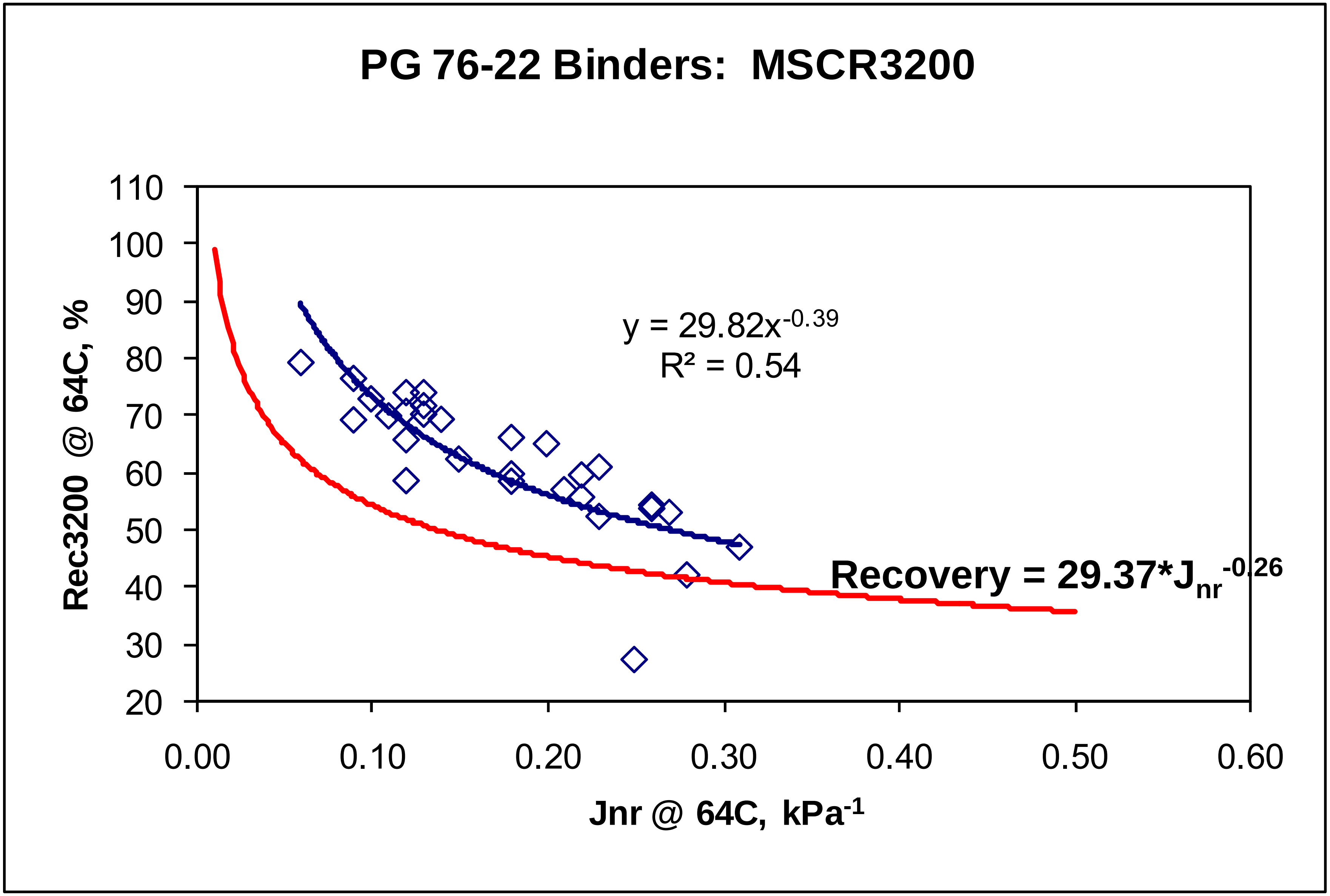

Evaluation of the MSCR Test for Canadian Asphalt Binders

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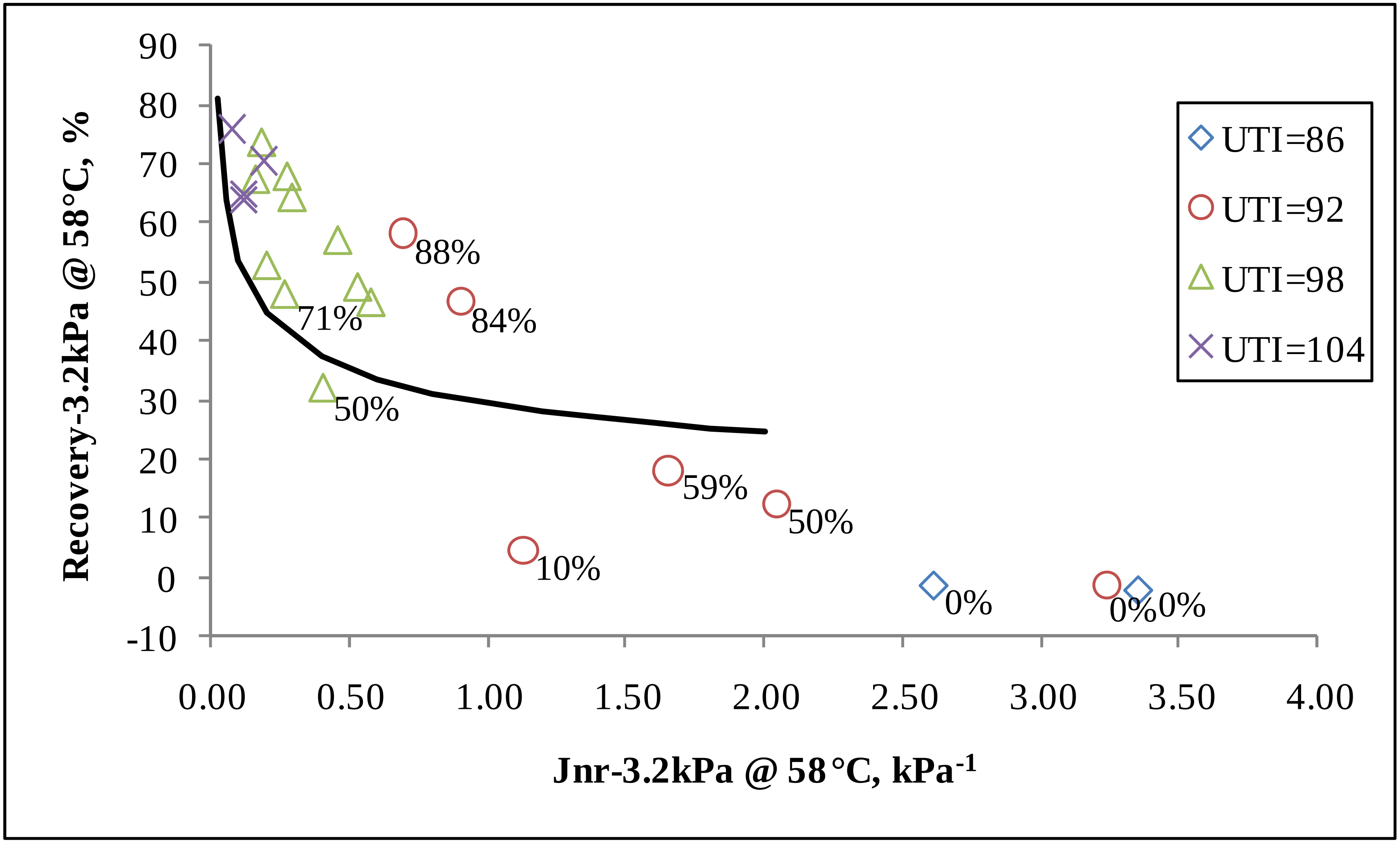


AASHTO M332

	PG 64					
	-10	-16	-22	-28	-34	-40
	Original Binder					
DSR (T315) – temp @ 10 rad/s G*/sin δ ≥ 1.00 kPa	64					
	RTFO-Aged Binder					
MSCR (TP70) – temp All Grades: Jnr,Diff ≤ 75% “S” Grade: Jnr-3.2 ≤ 4.5 kPa^{-1} “H” Grade: Jnr-3.2 ≤ 2.0 kPa^{-1} “V” Grade: Jnr-3.2 ≤ 1.0 kPa^{-1} “E” Grade: Jnr-3.2 ≤ 0.5 kPa^{-1}	64					

AASHTO M332

	PG 64					
	-10	-16	-22	-28	-34	-40
	PAV-Aged Binder @100°C					
DSR (T315) – temp @ 10 rad/s “S” Grade”: G*sin δ ≥ 5000 kPa “H” Grade”: G*sin δ ≥ 6000 kPa “V” Grade”: G*sin δ ≥ 6000 kPa “E” Grade”: G*sin δ ≥ 6000 kPa	31	28	25	22	19	16
BBR (T313) – temp @ 60 s All Grades: Stiffness ≤ 300 MPa m-value ≥ 0.300	0	-6	-12	-18	-24	-30

AASHTO M332

- Grades
  - Based on Climatic Temperature
    - High and Low Pavement Temperature
  - Traffic Designation
    - “S” – Standard
    - “H” – Heavy
    - “V” – Very Heavy
    - “E” – Extreme

AASHTO M332

- Grades
  - Based on Climatic Temperature
    - High and Low Pavement Temperature
  - Traffic Designation
    - "S" – Standard *< 10 Million ESAL*
    - "H" – Heavy *10-30 Million ESAL*
    - "V" – Very Heavy *> 30 Million ESAL*
    - "E" – Extreme *> 30 Million ESAL and standing traffic*

AASHTO M332

- PG 64V-22 asphalt binder
  - What do I need to test?
  - What are the temperatures and criteria?

PG 64V-22 Asphalt Binder

- Original (Unaged) Binder
  - COC Flash Point
    - Must be ≥ 230°C
  - Rotational Viscosity @ 135°C
    - Must be ≤ 3 Pa-s
  - DSR (AASHTO T315)
    - $G^*/\sin\delta$ must be ≥ 1.00 kPa @ 64°C

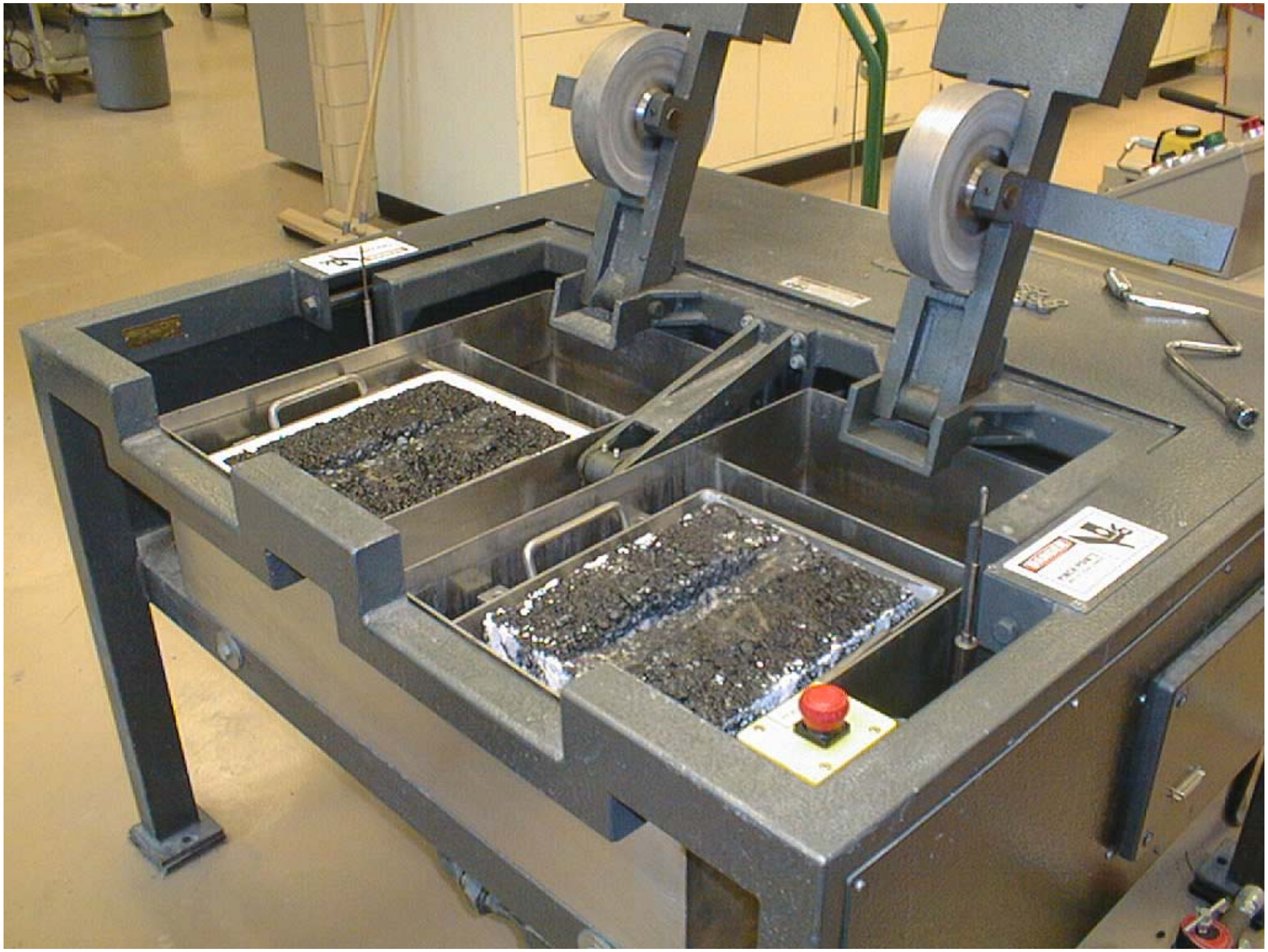
PG 64V-22 Asphalt Binder

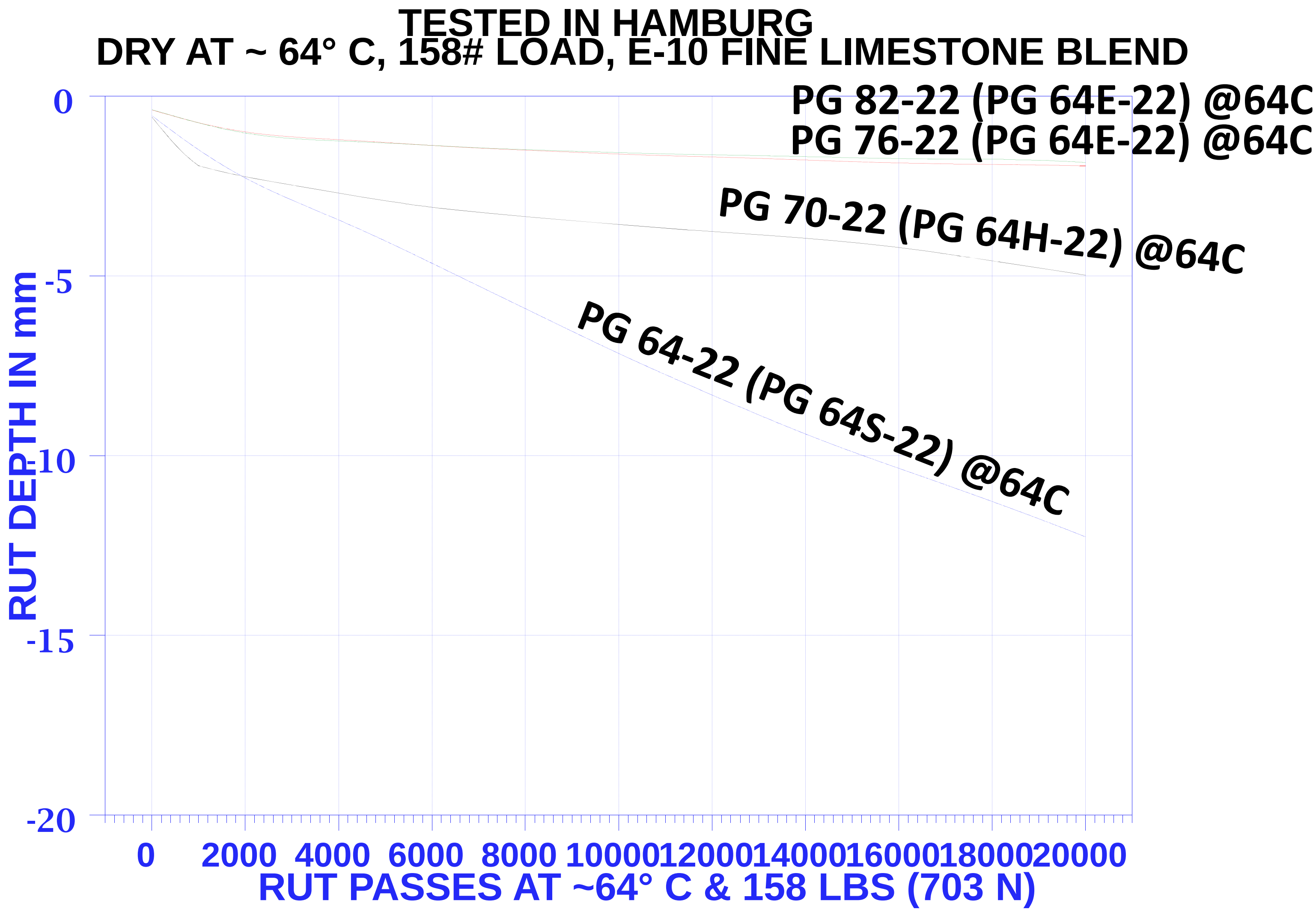
- RTFO Aged Binder
  - RTFO Mass Change
    - Must be ≤ 1.00%
  - MSCR (AASHTO T350)
    - J_{nr} @ 3.2 kPa Shear Stress must be ≤ 1.0 kPa^{-1} @ 64°C
    - Stress Sensitivity must be ≤ 75%

PG 64V-22 Asphalt Binder

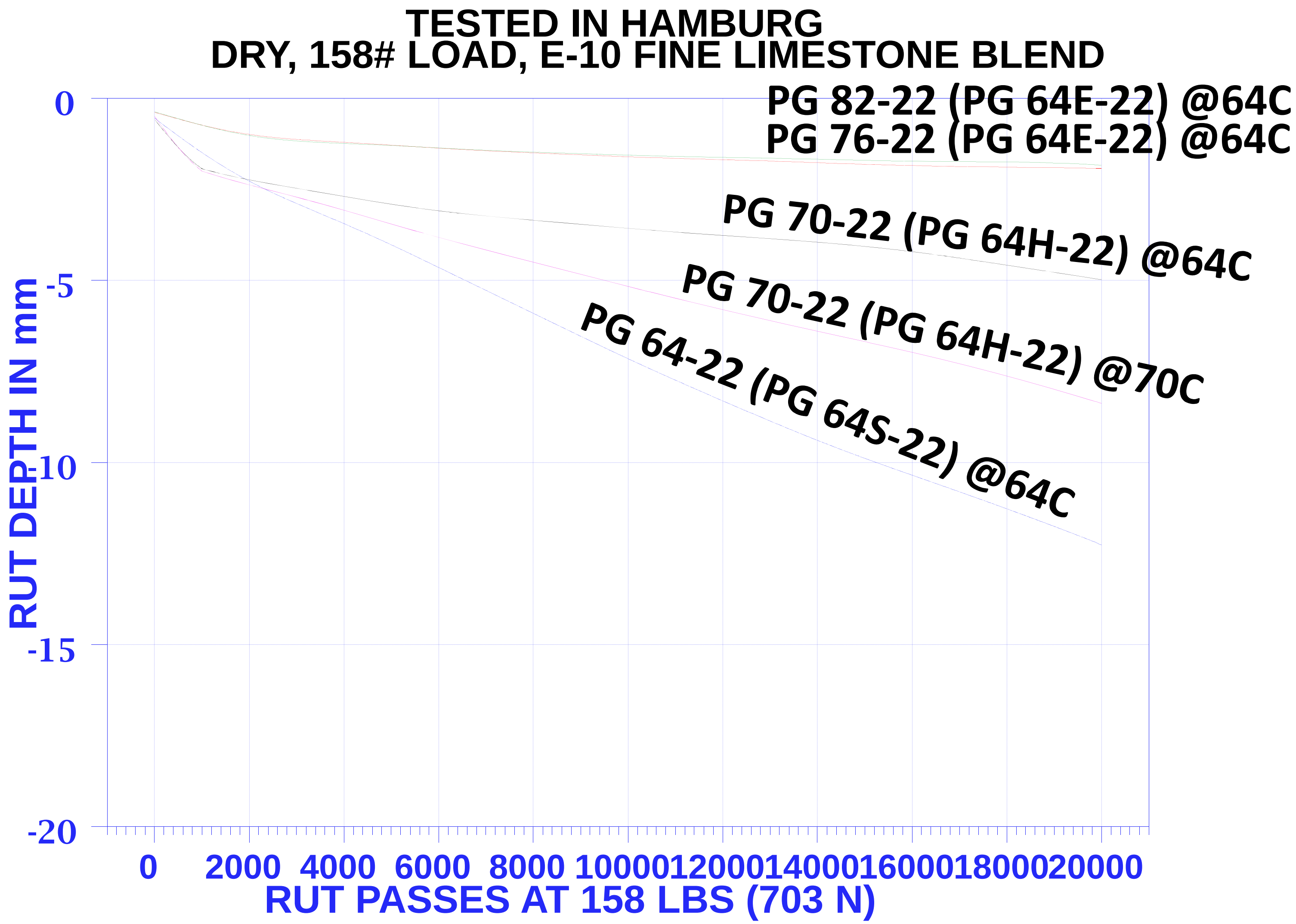
- PAV Aged Binder
  - DSR (AASHTO T315)
    - G*sin δ must be ≤ 6000 kPa @ 25°C
  - BBR (AASHTO T313)
    - S(60) must be ≤ 300 MPa @ -12°C
    - m(60) must be ≥ 0.300 @ -12°C

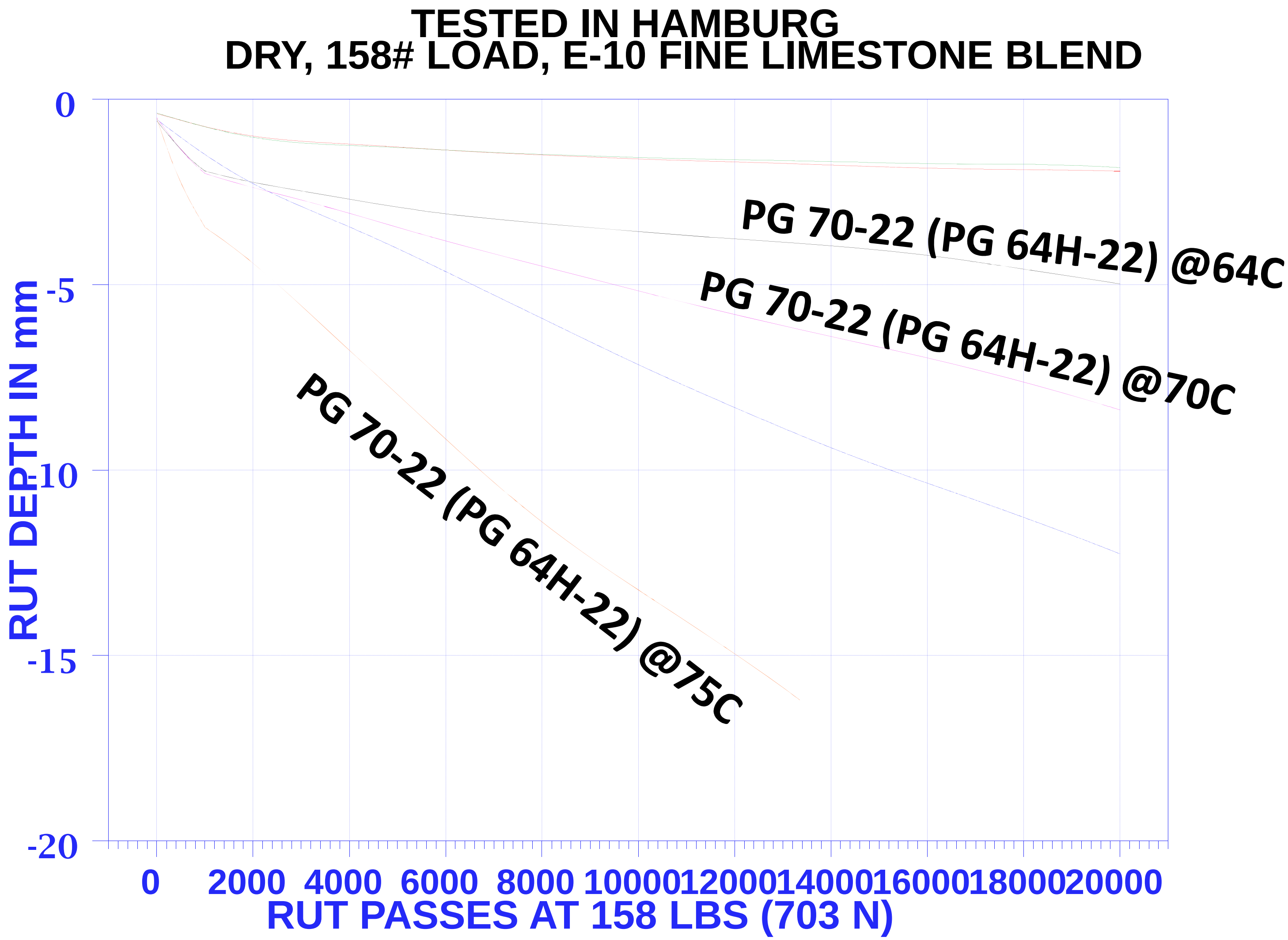
Dry Hamburg Testing





TESTED IN HAMBURG
DRY AT ~ 64° C, 158# LOAD, E-10 FINE LIMESTONE BLEND
PG 82-22 (PG 64E-22) @64C
PG 76-22 (PG 64E-22) @64C
PG 70-22 (PG 64H-22) @64C
PG 64-22 (PG 64S-22) @64C
RUT DEPTH IN mm
0
-5
-10
-15
-20
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
RUT PASSES AT ~64° C & 158 LBS (703 N)


TESTED IN HAMBURG
DRY, 158# LOAD, E-10 FINE LIMESTONE BLEND
PG 82-22 (PG 64E-22) @64C
PG 76-22 (PG 64E-22) @64C
PG 70-22 (PG 64H-22) @64C
PG 70-22 (PG 64H-22) @70C
PG 64-22 (PG 64S-22) @64C
RUT DEPTH IN mm
0
-5
-10
-15
-20
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
RUT PASSES AT 158 LBS (703 N)



TESTED IN HAMBURG
DRY, 158# LOAD, E-10 FINE LIMESTONE BLEND
0
-5
-10
-15
-20
RUT DEPTH IN mm
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
RUT PASSES AT 158 LBS (703 N)
PG 70-22 (PG 64H-22) @64C
PG 70-22 (PG 64H-22) @70C
PG 70-22 (PG 64H-22) @75C

MTE Rutting Study:
Dry Hamburg WI E10 Fine Mix

PG GRADE (M320)	PG GRADE (M332)	Test Temp, C	Jnr-3.2 at Test Temp, kPa^{-1}	Rec-3.2, %	HWT Rut Depth at 10,000 Passes, mm
70-22	n/a	75	5.74	0.5	13.2
64-22	64S-22	64	3.40	3.4	7.1
70-22	70S-22	70	2.92	1.5	5.1
70-22	64H-22	64	1.35	4.4	3.6
76-22	64E-22	64	0.24	55.8	1.7
82-22	64E-22	64	0.08	78.5	1.6

Implementation Activities

- User-Producer Groups
  - Task Force participation
  - Coordination of round-robin testing
- Conducting testing for individual user agencies

MSCR Information and Guidance

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- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
  - "The Multiple Stress Creep Recovery (MSCR) Procedure"
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"

MSCR Information and Guidance

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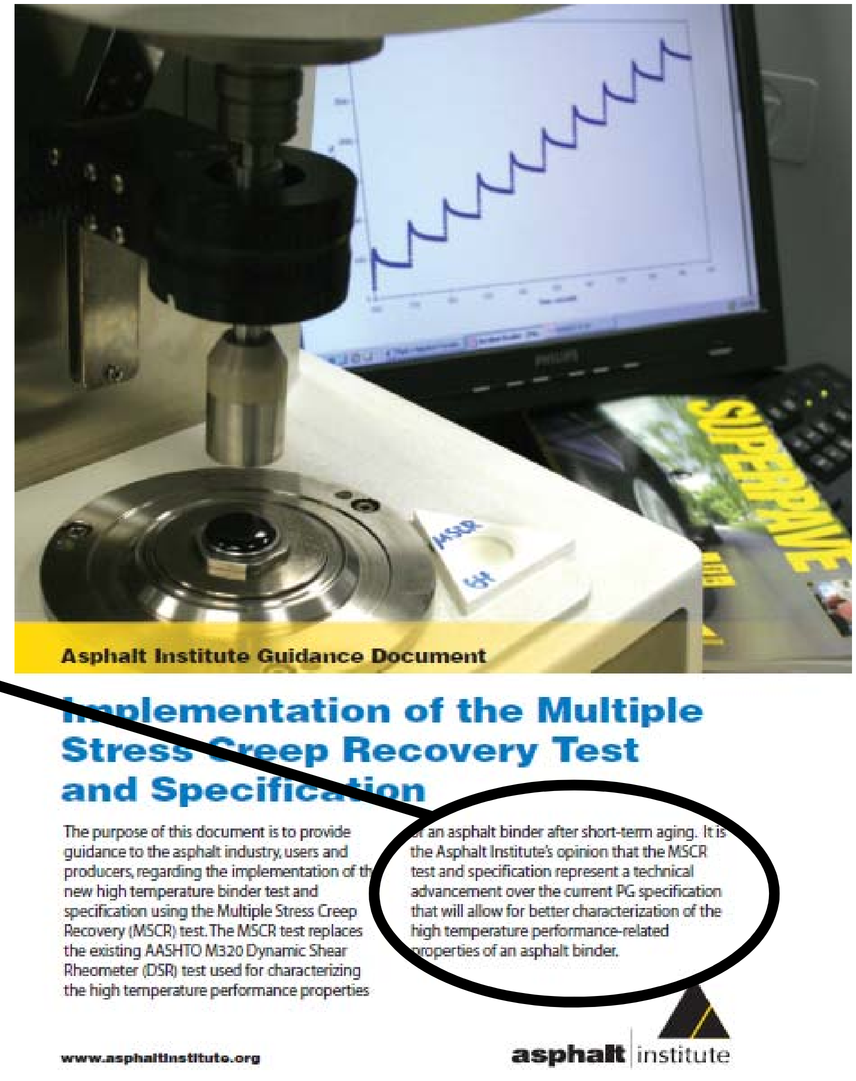
- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - April 2010
    - Joint effort between AI TAC and FHWA
    - Purpose of the document is "…to provide guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test and specification using the MSCR test."

MSCR Information and Guidance

- "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
  - "It is the Asphalt Institute's opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder."



MSCR Information and Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - Background
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and G*/sin δ?
        - J_{nr} better correlated with rutting potential
        - Works for both unmodified and modified binders

MSCR Information and Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and $G^*/\sin\delta$?
        - Criterion to eliminate binders that are overly stress-sensitive

MSCR Information and Guidance

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- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and $G^*/\sin\delta$?
        - MSCR Recovery faster/easier than other PG Plus tests and does better job of characterizing polymer modification
        - Conducted at actual pavement temperature

MSCR Information and Guidance

- Informational Documents
  - “Implementation of the Multiple-Stress Creep-Recovery Test and Specification”
    - Implementation
      - Become familiar with the MSCR test
      - Become familiar with the specification
      - Conduct transitional testing as needed
      - Transition regionally and uniformly

MSCR Information and Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - Implementation
      - Use MSCR Recovery if there is a need to identify elastomeric modification in an asphalt binder…
      - …and eliminate the use of other PG Plus tests

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - December 2010
    - AI Technical Advisory Committee
    - Recognize that many user agencies would prefer to use MSCR in conjunction with AASHTO M320

MSCR Information and Guidance

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- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”

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Guidance on the Use of the MSCR Test with the AASHTO M320 Specification

The Asphalt Institute (AI) Implementation Guidance Document, Implementation of the Multiple Stress Creep Recovery Test and Specification, provides guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test – the Multiple Stress Creep Recovery, MSCR, (AASHTO TP70) – and specification (AASHTO MP19). It is AI's opinion that the MSCR test and specification represent a technical advancement over the current performance-graded (PG) asphalt binder specification, AASHTO M320, which will allow for better characterization of the high temperature performance-related properties of an asphalt binder.

Although the implementation of the revised performance-graded asphalt binder specification (which uses J_{nr} from the MSCR test instead of RTFO $G^*/\sin \delta$) is still the ultimate goal, the Asphalt Institute Technical Advisory Committee (AI-TAC) recognizes that many user agencies would simply prefer to use the MSCR test in conjunction with the AASHTO M320 specification rather than transitioning to a system that uses different grade names. In this case, the AI-TAC would recommend the following procedures for user agencies to consider:

- Use the MSCR test (AASHTO TP70) as a replacement PG-Plus test for modified asphalt binders that currently require an "elasticity evaluation" Plus test such as Elastic Recovery. Testing can also be conducted on standard, unmodified asphalt binders if desired.
- Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO TP70. To have useful information, testing must be conducted on RTFO-aged material at the appropriate climate grade. Recommended test temperatures are shown in TABLE 1 below. Although TABLE 1 provides likely test temperatures, the 98% reliability high PG from LTPPBind 3.1 provides the most accurate representation of the climatic conditions and should be used if the agency is in doubt about the proper test temperature. A 98% reliability high PG map is shown in FIGURE 1 as a reference.
- Following AASHTO TP70, determine the J_{nr} values at 0.1 and 3.2 kPa shear stress and the corresponding MSCR Recovery values at the same stress levels.
- Using the data from the 3.2 kPa shear stress portion of the test, plot the MSCR Recovery as a function of J_{nr} and compare to FIGURE 2 below. Data points above the curve are considered to have sufficient delayed elastic response for an elastomeric-modified asphalt binder.
- Calculate the stress sensitivity parameter, $J_{nr,diff}$, by using the equation $J_{nr,diff} = (J_{nr,3.2kPa} - J_{nr,0.1kPa}) \div J_{nr,0.1kPa}$. If the ratio is greater than 0.75 then the asphalt binder is considered stress sensitive. In AASHTO MP19, a maximum ratio of 0.75 is permitted. If using the MSCR with AASHTO M320, it is suggested that the $J_{nr,diff}$ value be reported and noted if the criterion is not met.

As stated in the Implementation of the Multiple Stress Creep Recovery Test and Specification, AI recommends that if the MSCR Recovery is used to evaluate the delayed elastic response of the asphalt binder, then other PG-Plus tests with a similar purpose – such as Elastic Recovery, Force Ductility, and Toughness and Tenacity tests – should be eliminated. This saves testing time for both the user and supplier. If the current PG-Plus tests are not eliminated, then the time savings is lost. In this instance, the MSCR Recovery test should not be added.

Comparison testing between the MSCR Recovery value and the values of the current PG-Plus tests will no doubt be conducted. However, technologists should be cautioned not to expect a strong correlation because of the different test conditions that are used. AI has conducted some limited comparison testing between the MSCR Recovery and other PG-Plus tests and may be able to provide guidance on appropriate values to consider.

Please contact Mike Anderson of the Asphalt Institute (manderson@asphaltinstitute.org) with any specific questions or comments regarding this guidance.

Asphalt Institute Technical Advisory Committee
2 December 2010

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MSCR Information and Guidance

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - Use the MSCR test (AASHTO T350) as a replacement PG-Plus test for modified asphalt binders that currently require an “elasticity evaluation” Plus test such as Elastic Recovery.

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO T350.
        - Some guidance on temperature provided

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO T350.
        - "…the 98% reliability high PG from LTPPBind 3.1 provides the most accurate representation of the climatic conditions and should be used if the agency is in doubt about the proper test temperature."

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Determine J_{nr} and Recovery at 0.1 and 3.2 kPa stress
      - Plot Rec-3.2 versus Jnr-3.2 and determine if data point plots above the curve. Data points above the curve are considered to have sufficient delayed elastic response for an elastomeric-modified asphalt binder.

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Calculate the stress sensitivity parameter and determine if the ratio is less than 75%.

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - if the MSCR Recovery is used to evaluate the elastic response of the asphalt binder, then other PG-Plus tests with a similar purpose – such as Elastic Recovery, Force Ductility, and Toughness and Tenacity tests – should be eliminated.

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Comparison testing between the MSCR Recovery value and the values of the current PG-Plus tests will no doubt be conducted.
      - Technologists are cautioned not to expect a strong correlation because of the different test conditions that are used.

MSCR Information and Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"

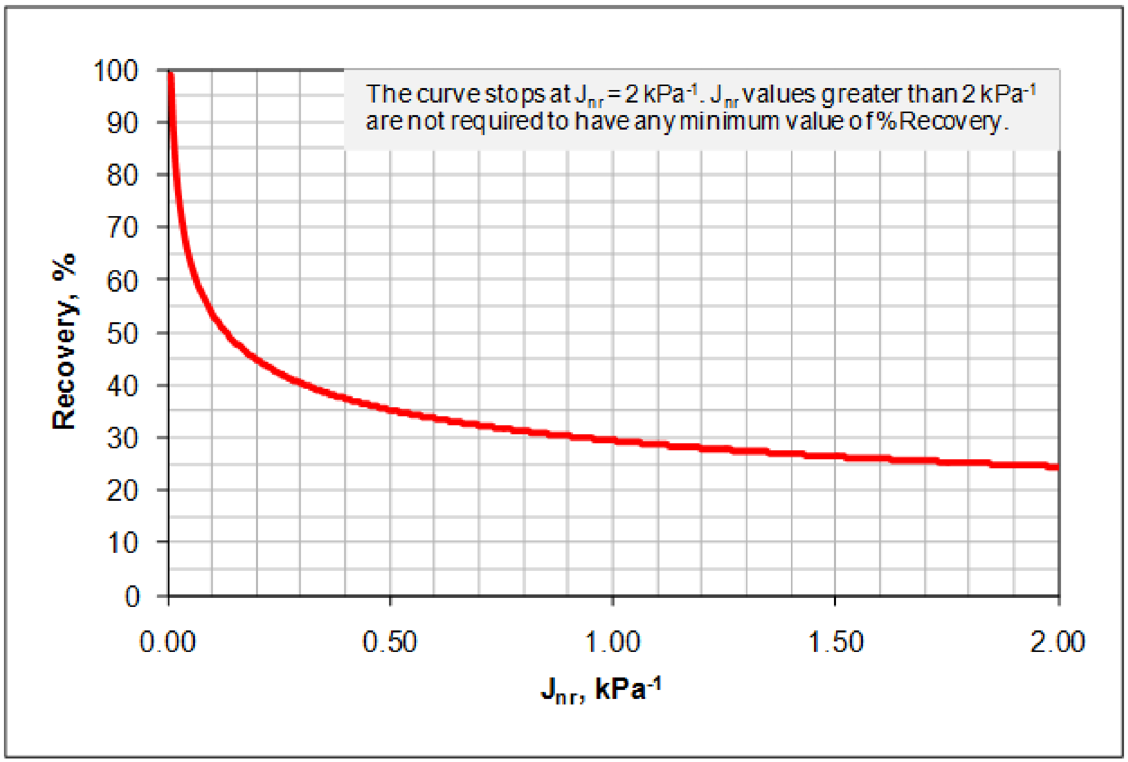

FIGURE 2: Comparison of MSCR J_{nr} and Recovery to Assess Delayed-Elastic Response

MSCR Information and Guidance

- Informational Documents
  - “The Multiple Stress Creep Recovery (MSCR) Procedure”
    - April 2011
    - FHWA
    - Provide an overview of the intent of the Superpave MSCR procedure to evaluate asphalt binder and its relation to asphalt pavement performance

MSCR Information and Guidance

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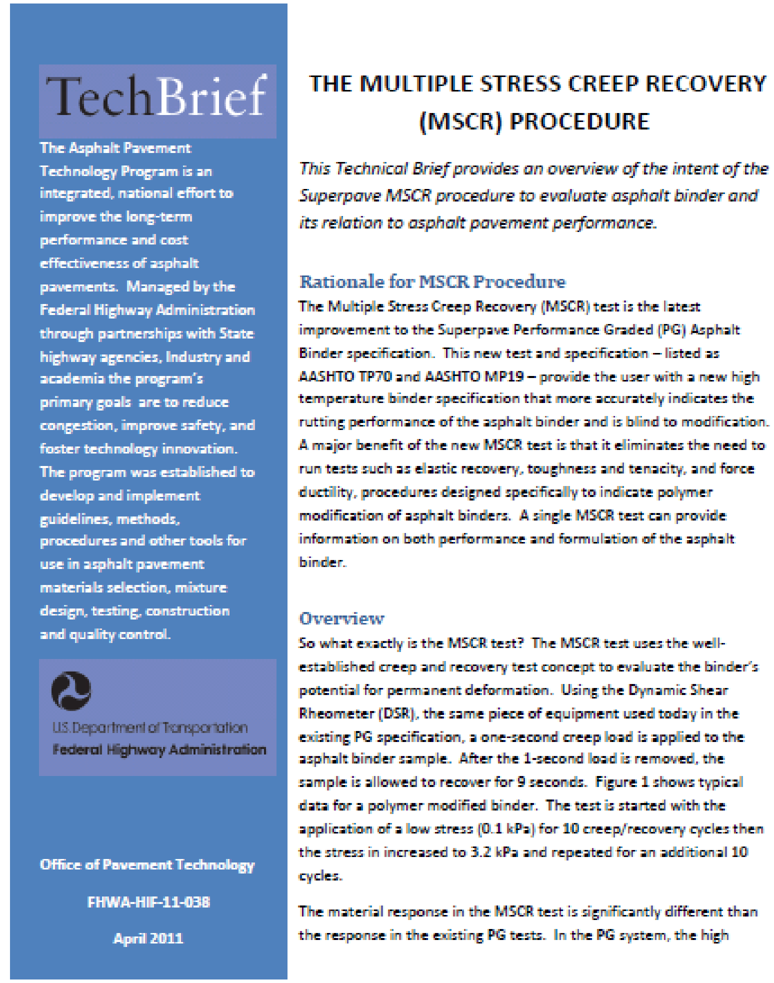
- Informational Documents
  - “The Multiple Stress Creep Recovery (MSCR) Procedure”
  - FHWA-HIF-11-038



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

MSCR Information and Guidance

- Informational Documents
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"
    - April 2012
    - AI TAC
    - Provide specifics on how the MSCR should be performed (64°C) and offer possible criterion based on AI testing.

MSCR Information and Guidance

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- Informational Documents
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"

Use of MSCR Recovery to Replace PG Plus Tests
In the Southeast Asphalt User-Producer Group

To ensure polymer modification in premium asphalt binders, many user agencies require that one or more "PG Plus" tests be performed as supplemental tests to the requirements of the current performance-graded (PG) asphalt binder specification, AASHTO M320. In the SEAUPG, for premium asphalt binders (i.e., PG 70-28, PG 76-22, and PG 76-28) many user agencies require that the asphalt binder either meet a minimum elastic recovery value (usually performed on RTFO-aged binder) or maximum DSR phase angle (usually performed on unaged binder).

There are two major advantages to using the MSCR Recovery versus the current PG-Plus tests. First, while it is similar to Elastic Recovery in that it indicates the presence of an elastomeric modifier, testing has indicated that the MSCR Recovery may be more discriminating in assessing how the polymer network is performing within the asphalt binder. Second, the MSCR test is much quicker, requiring no additional equipment, less preparation time, and less effort than running a separate sample for Elastic Recovery by either AASHTO T 301 or ASTM D 6084, while losing none of the reliability. Although the DSR phase angle determination does not require any additional time (since the value is determined as a normal part of the AASHTO T315 procedure), the Elastic Recovery procedure (either AASHTO T301 or ASTM D6084) can take several hours to complete.

To use the MSCR Recovery value as a replacement PG-Plus test for premium asphalt binders in the SEAUPG, the following procedure is recommended:

1. Perform the MSCR test (AASHTO TP70) on RTFO-aged asphalt binder at 64°C.
2. Use the average MSCR Recovery value calculated from the test at 3.2kPa shear stress (MSCR Rec-3.2).
3. Compare the MSCR Rec-3.2 value to the suggested criterion below.

Data from the Asphalt Institute's research suggests the following:

- If using the Elastic Recovery (AASHTO T301) value at 25°C, an appropriate MSCR Rec-3.2 criterion at 64°C is 15 percentage points less than the current Elastic Recovery criterion. For example, a user agency that has a minimum requirement of 75% for Elastic Recovery would instead require a minimum MSCR Rec-3.2 value of 60%.
  - If the Elastic Recovery value is based on testing performed at 10°C, a limited analysis by AI suggests that an appropriate MSCR Rec-3.2 criterion at 64°C is 5% less than the current Elastic Recovery criterion.
- If using DSR Phase Angle (AASHTO T315) of the *Original (unaged)* asphalt binder, with a requirement that the phase angle be a maximum of 75 degrees, an appropriate minimum MSCR Rec-3.2 value at 64°C is 55%.

The Asphalt Institute also suggests that the average MSCR Creep Compliance (J_{nr}) value calculated from the test at 3.2kPa shear stress (termed MSCR Jnr-3.2) be determined and used with the MSCR Rec-3.2 value to generate a data point on the Recovery-J_{nr} curve in AASHTO TP70 (shown in Figure 1 below). This point provides an indication of the delayed elastic response of the modified asphalt binder and should be above the curve.

DRAFT

MSCR Information and Guidance

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- "Understanding the MSCR Test and its Use in the PG Asphalt Binder Specification"
  - Two-hour informational webinar on the MSCR test and how it is used in the specification
  - www.asphaltinstitute.org/public/asphalt_academy/Webinars/MSCR_Test_and_its_Use.asp

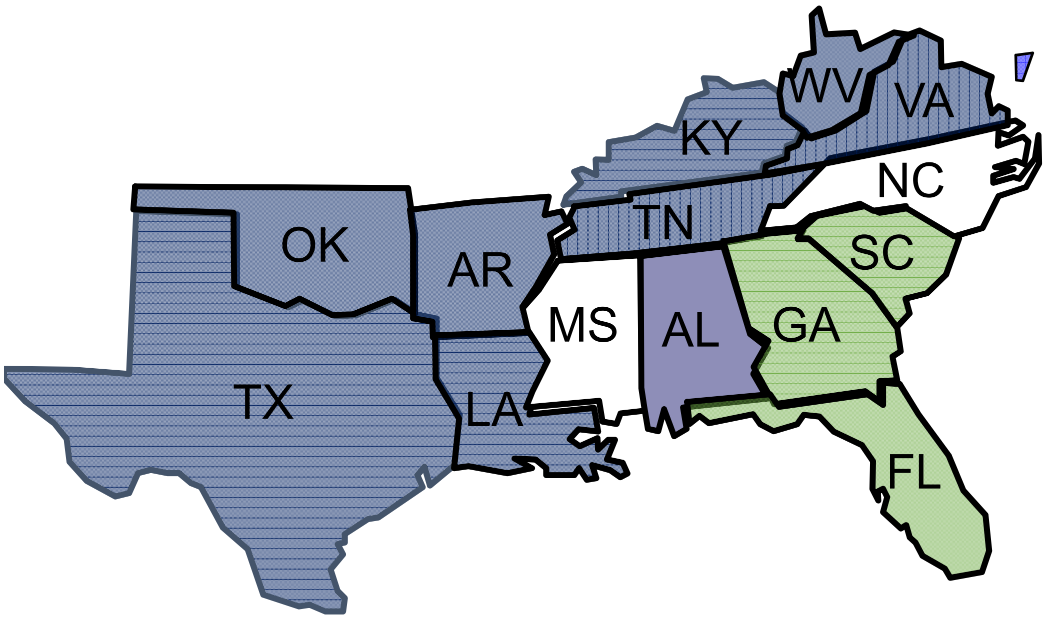
MSCR Implementation

- Recognize that the refineries that serve your state may also serve bordering states.
- This may be a good reason to work with other states to implement regionally
- Note that every Performance Grade may not equate to a distinct MSCR grade - for example, the current polymer loading in both a PG 70-22 and PG 76-22 may be high enough that both grade to a PG 64E-22

MSCR Implementation

- SEAUPG
  - MSCR Task Force of Binder Subcommittee
    - Formed in 2010
    - Periodic WebEx Meetings since 2011
    - Established to evaluate possibility of using MSCR Recovery as a replacement for current PG Plus tests (Elastic Recovery, Phase Angle)

PG Plus Tests in SEAUPG



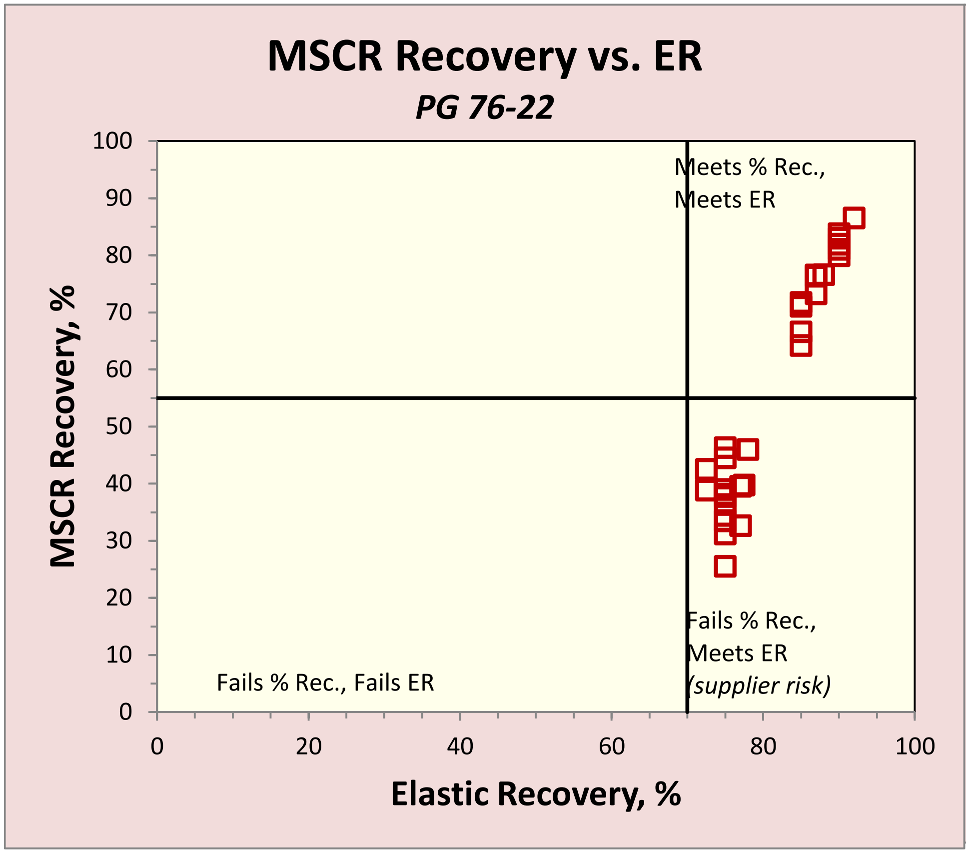
- 12 of 14 SEAUPG states have a PG Plus test
- 9 states use Elastic Recovery
- 3 states use Phase Angle
- 2 states do not have a PG Plus test
  - MS has a polymer type and % requirement
  - NC has a polymer type requirement

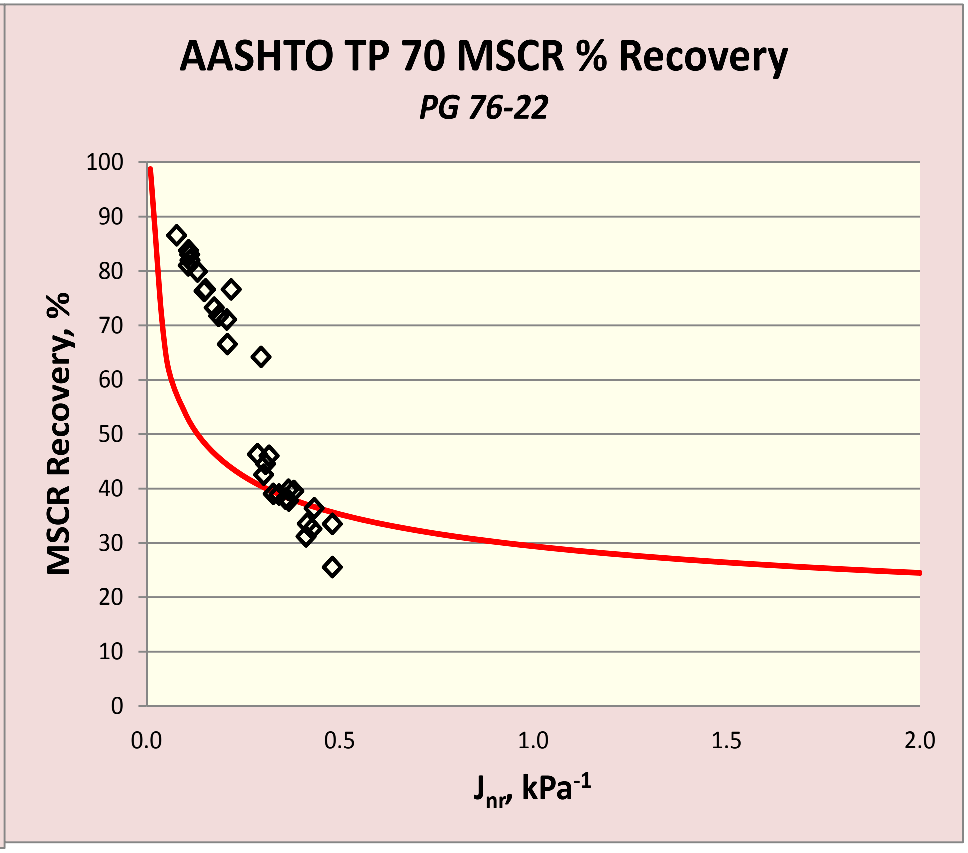
States use Elastic Recovery

States use Phase Angle

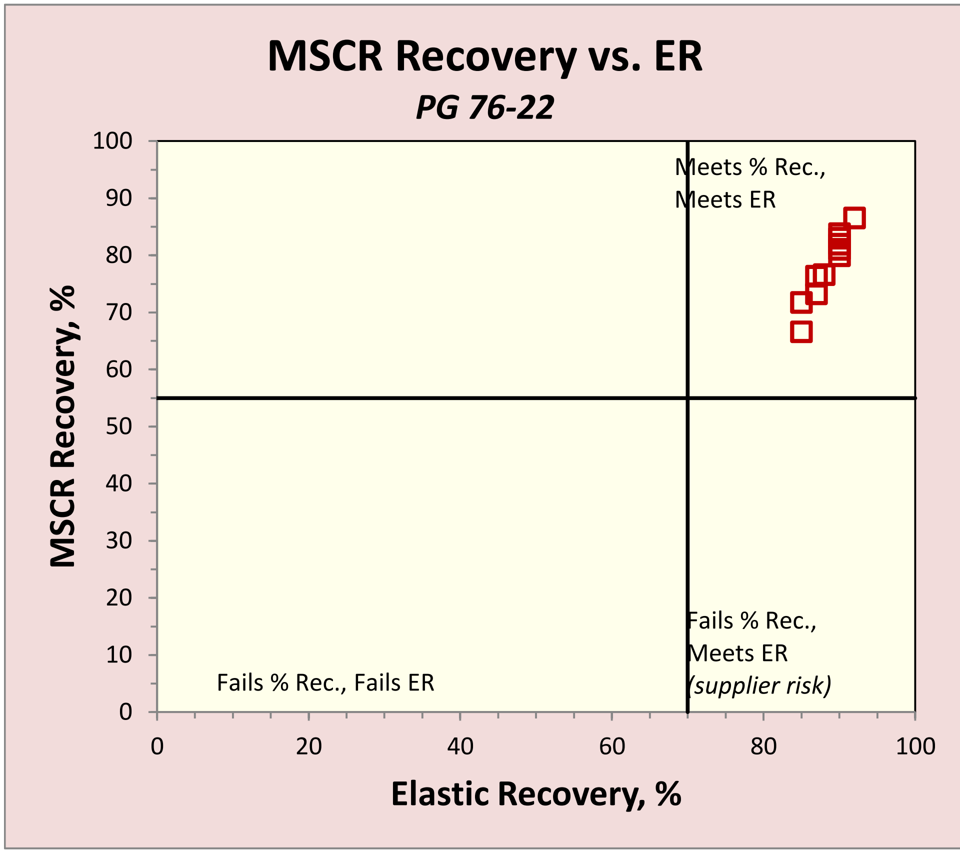
States do not have a PG Plus test

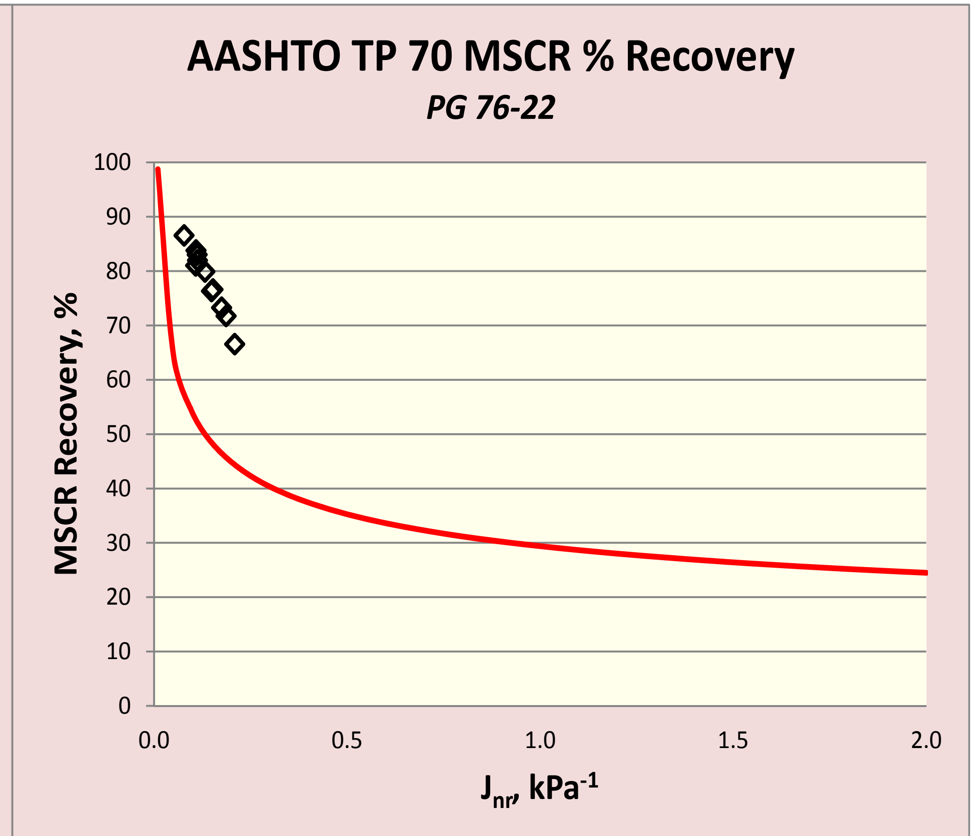
SEAUPG MSCR Evaluation: User 1 – All PG 76-22 Binders



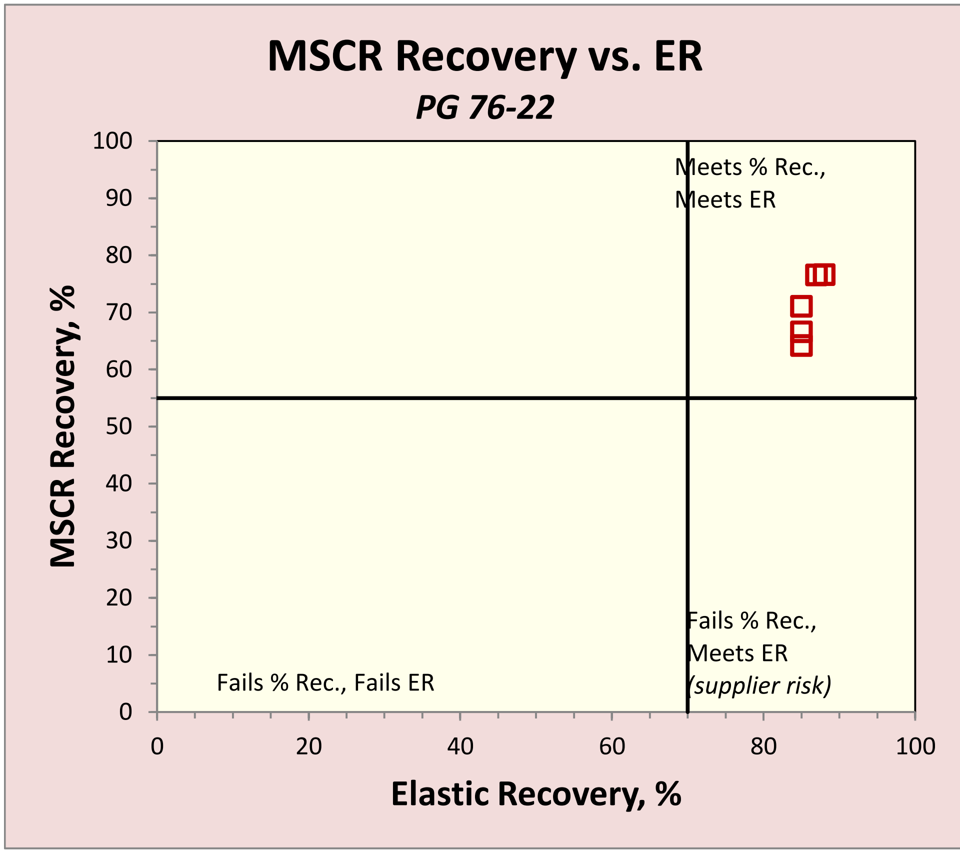


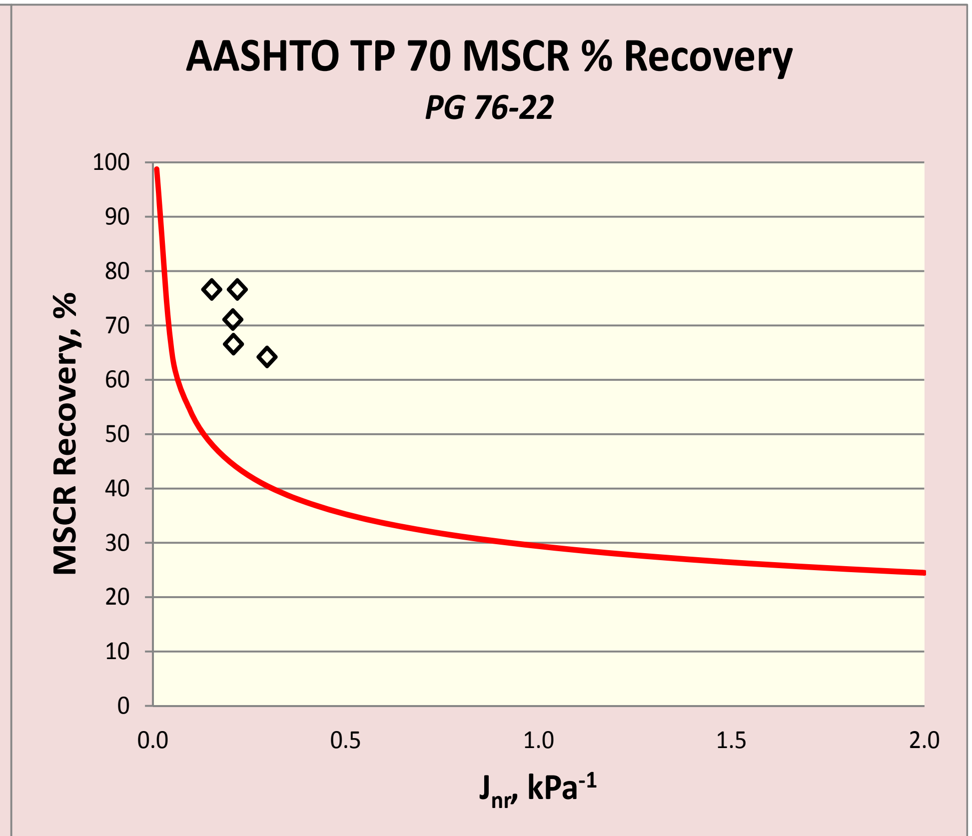
SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 1



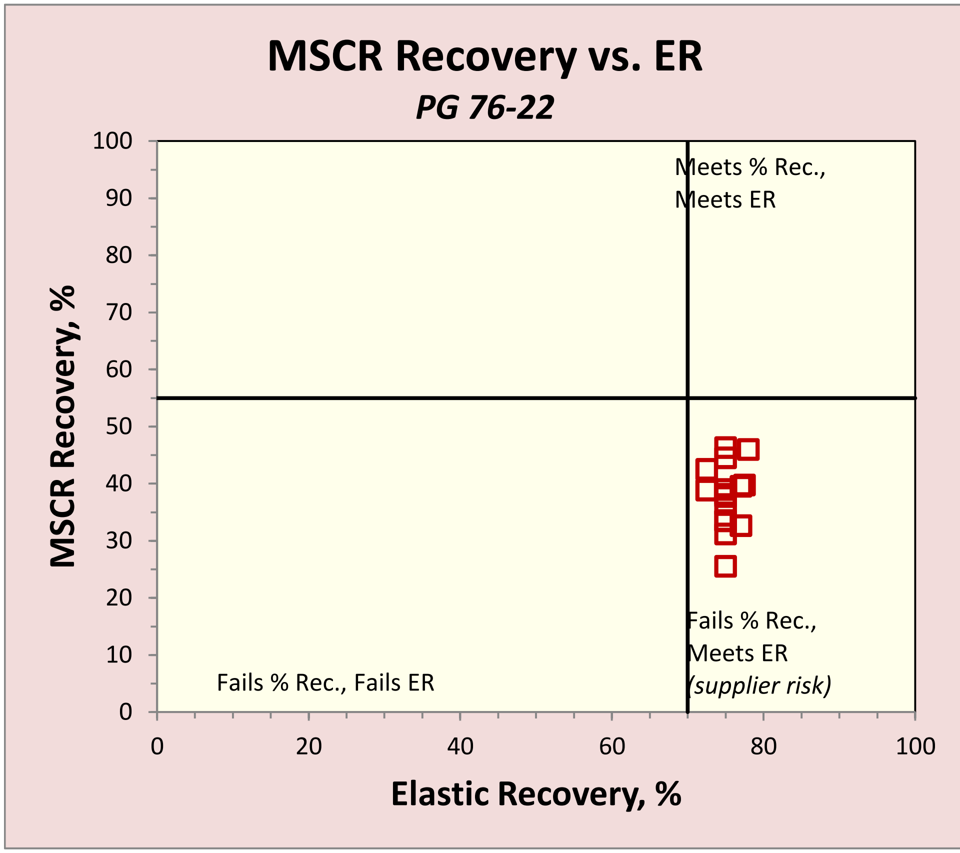


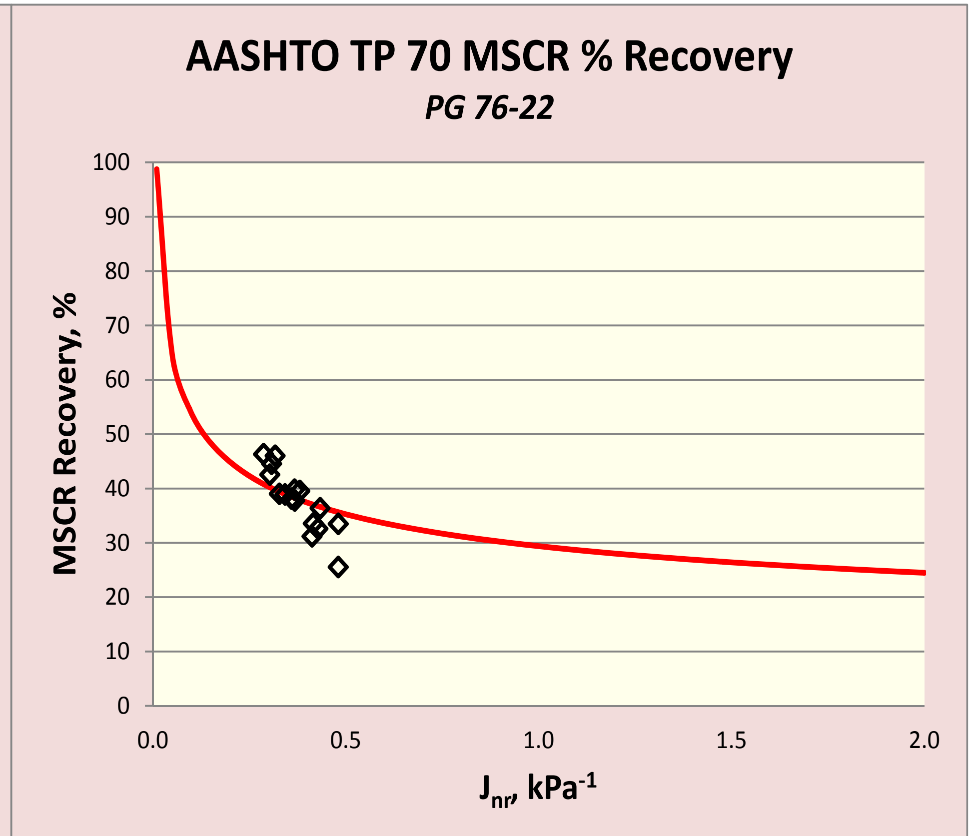
SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 2



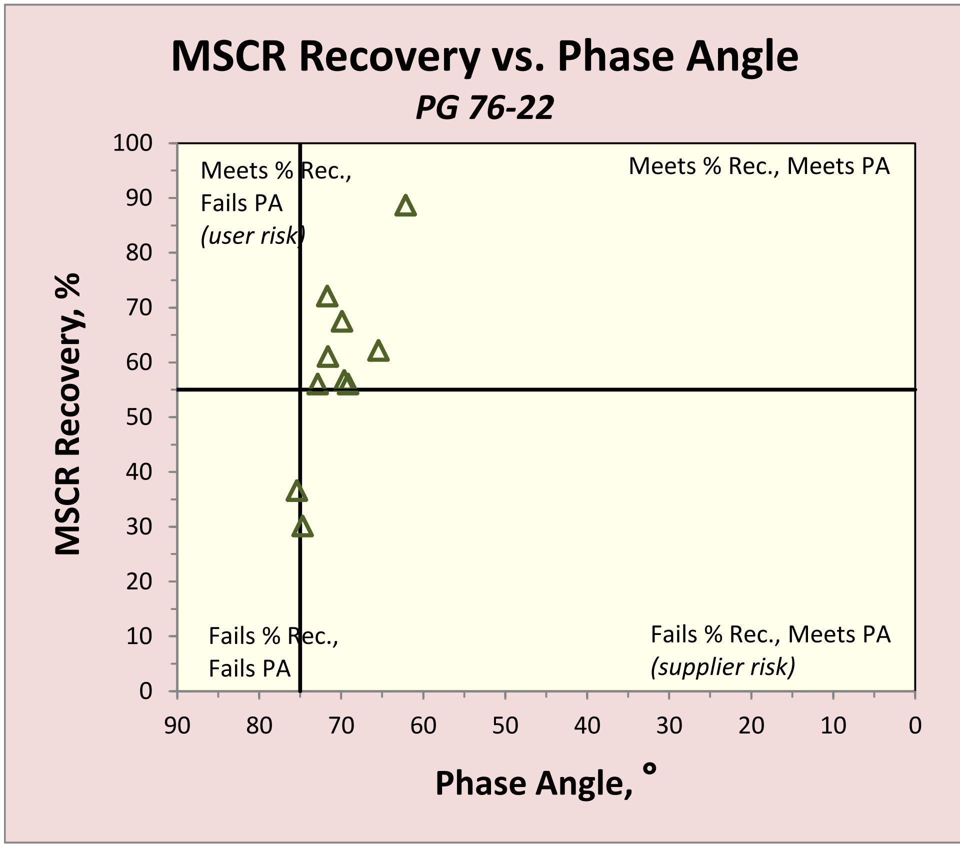


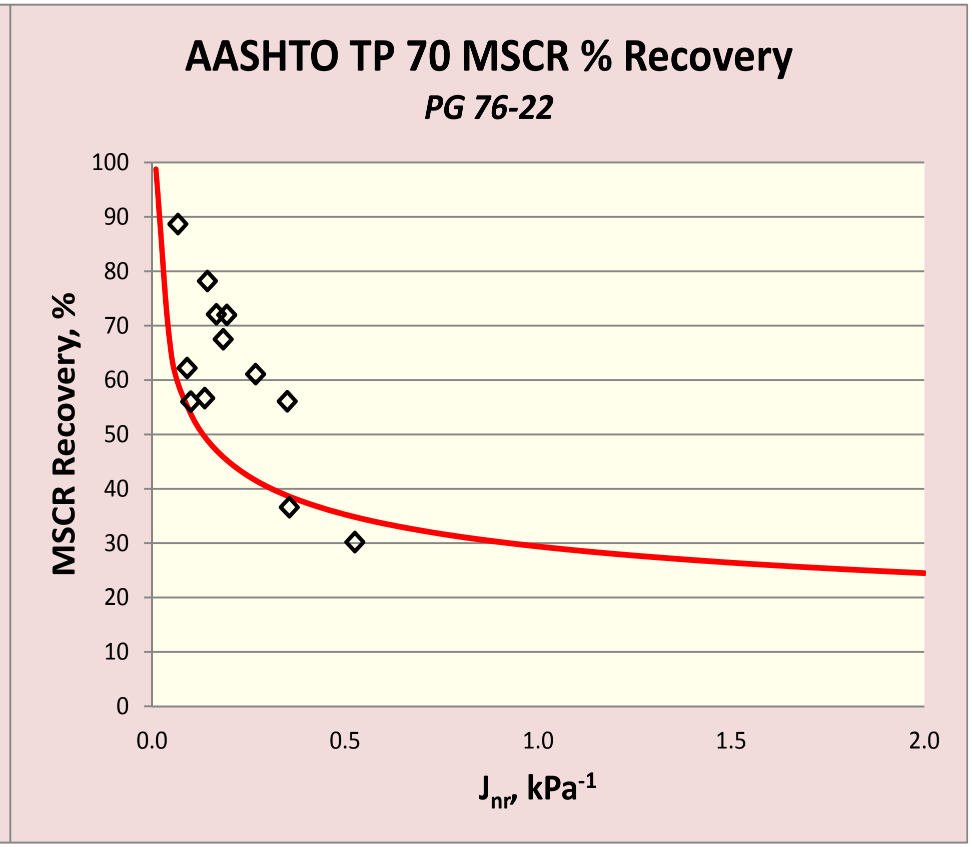
SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 3





SEAUPG MSCR Evaluation: User 4 – All PG 76-22 Binders





MSCR Implementation

- Interlaboratory Studies
  - NEAUPG
    - 2010
    - 2012
  - SEAUPG
    - 2011
  - PCCAS
    - 2013

2013 PCCAS ILS

- Five Asphalt Binders
  - PG 76-28 (Binder A)
  - PG 70-22ER (Binder B)
  - PG 64-28NV (Binder C)
  - PG 64-28PM (Binder D)
  - PG 58-34PM (Binder E)
- Two RTFO-Aged Binders (MSCR-only)
  - Aged by Asphalt Institute
    - PG 76-28 (Binder A-AI)
    - PG 58-34 (Binder E-AI)

2013 PCCAS ILS

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Table 3: 2013 PCCAS ILS Testing Program

	Original			RTFO		
	R&B SP[1]	Ductility[2]	T&T[3]	MSCR[4]	ER[5]	Ductility[2]
Binder A				64[6]	25	
Binder A-AI				64[7]		
Binder B				64,70[6]	25	
Binder C	X	4	25	58,64[6]		4
Binder D	X		25	58,64[6]	25	
Binder E			25	58[6]	25	
Binder E-AI				58[7]		

Cells indicated with a number indicate that the test is performed at the specified temperature(s) (in °C).
Cells indicated with an "x" indicate that the test is performed, but the temperature is the result of the test.
Cells that are blank indicate that testing is not conducted.

[1] Ring-and-Ball Softening Point test (AASHTO T53)
[2] Ductility test (AASHTO T51)
[3] Toughness and Tenacity test (ASTM D5801)
[4] Multiple-Stress Creep-Recovery (MSCR) test (AASHTO TP70)
[5] Elastic Recovery test (AASHTO T301)
[6] Conducted on RTFO-aged residue from Testing Lab
[7] Conducted on RTFO-aged residue supplied by AI

Binder B (PG 70-22ER): Jnr-3.2 at 64°C (all data)

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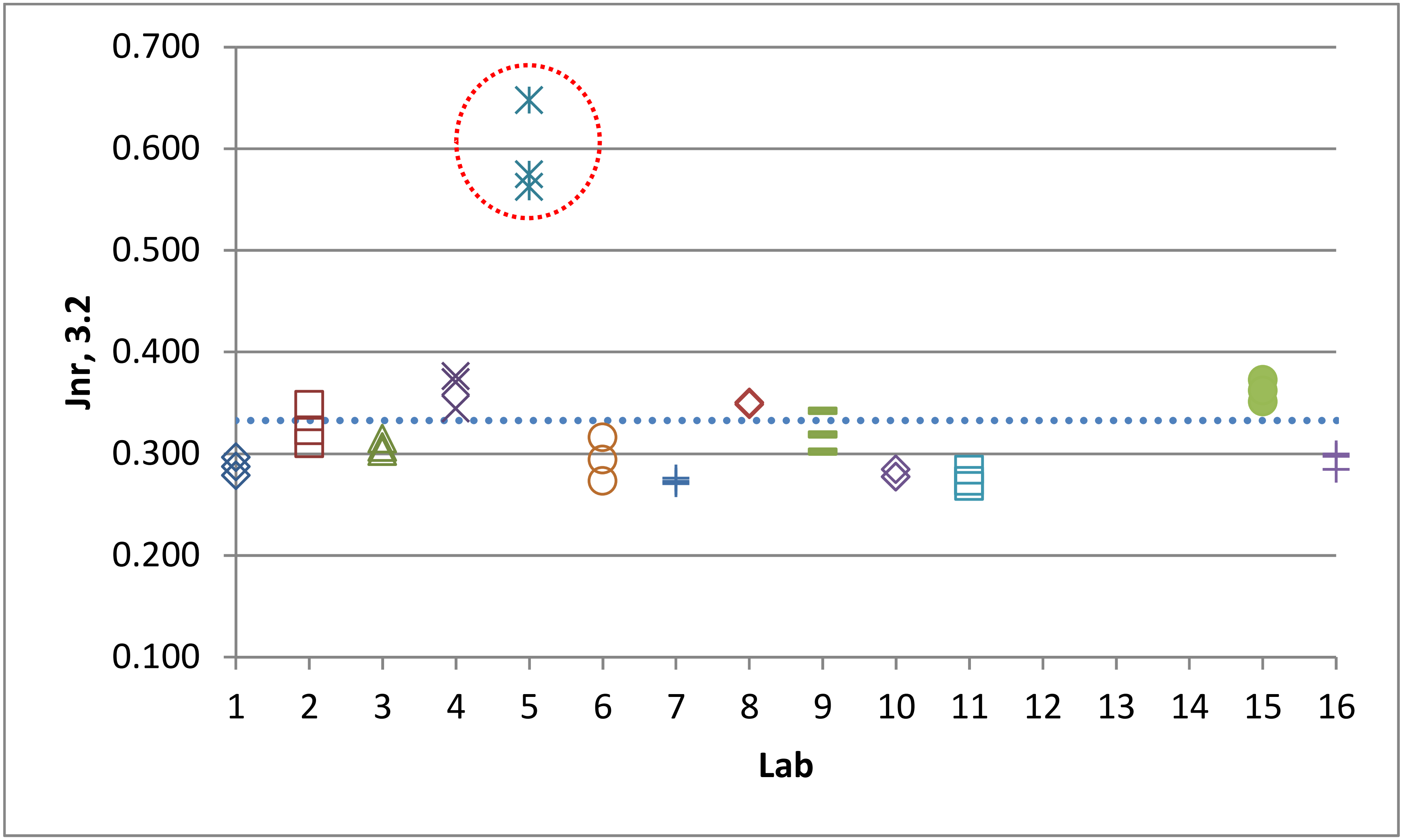

Effect on Repeatability (r) and Reproducibility (R)?

Binder B: Jnr-3.2	w/ Lab 5	w/o Lab 5
Average	0.333	0.311
1s (within lab)	0.018	0.013
d2s (within lab)	0.049	0.035
d2s% (within lab)	14.8%	11.4%
1s (between labs)	0.086	0.035
d2s (between labs)	0.241	0.097
d2s% (between labs)	72.3%	31.3%

Multi-Lab Precision Estimates: AI ILS Studies

ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	17.3%	36.0%

Multi-Lab Precision Estimates: AI ILS Studies with AMRL PSP Data

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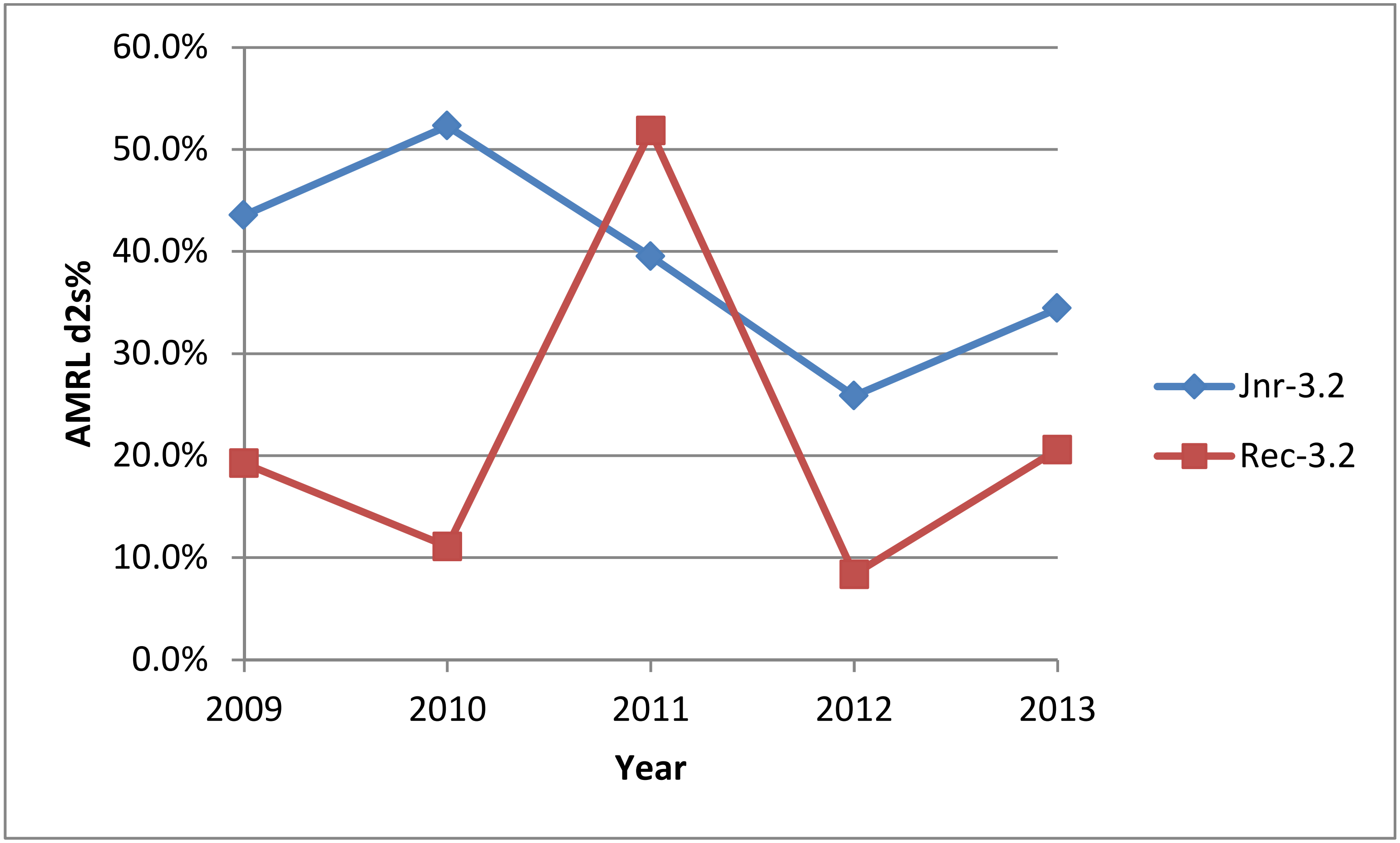
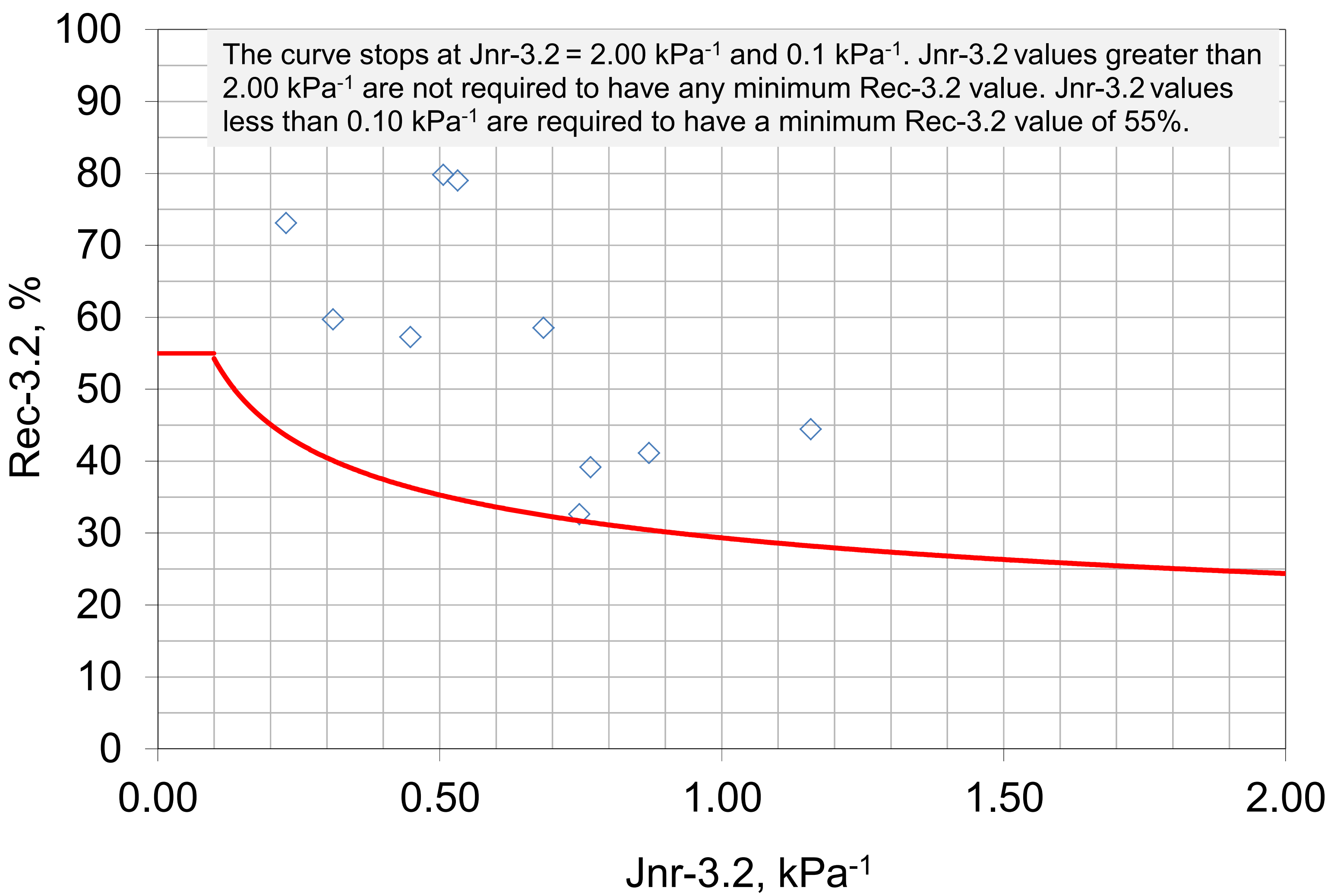
ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	17.3%	36.0%
AMRL PSP (2009-2011) (2012-2013)	 27.4% 14.5%	 45.1% 30.1%

AMRL PSP Analysis



Jnr-Recovery Curve



Jnr-Recovery Curve

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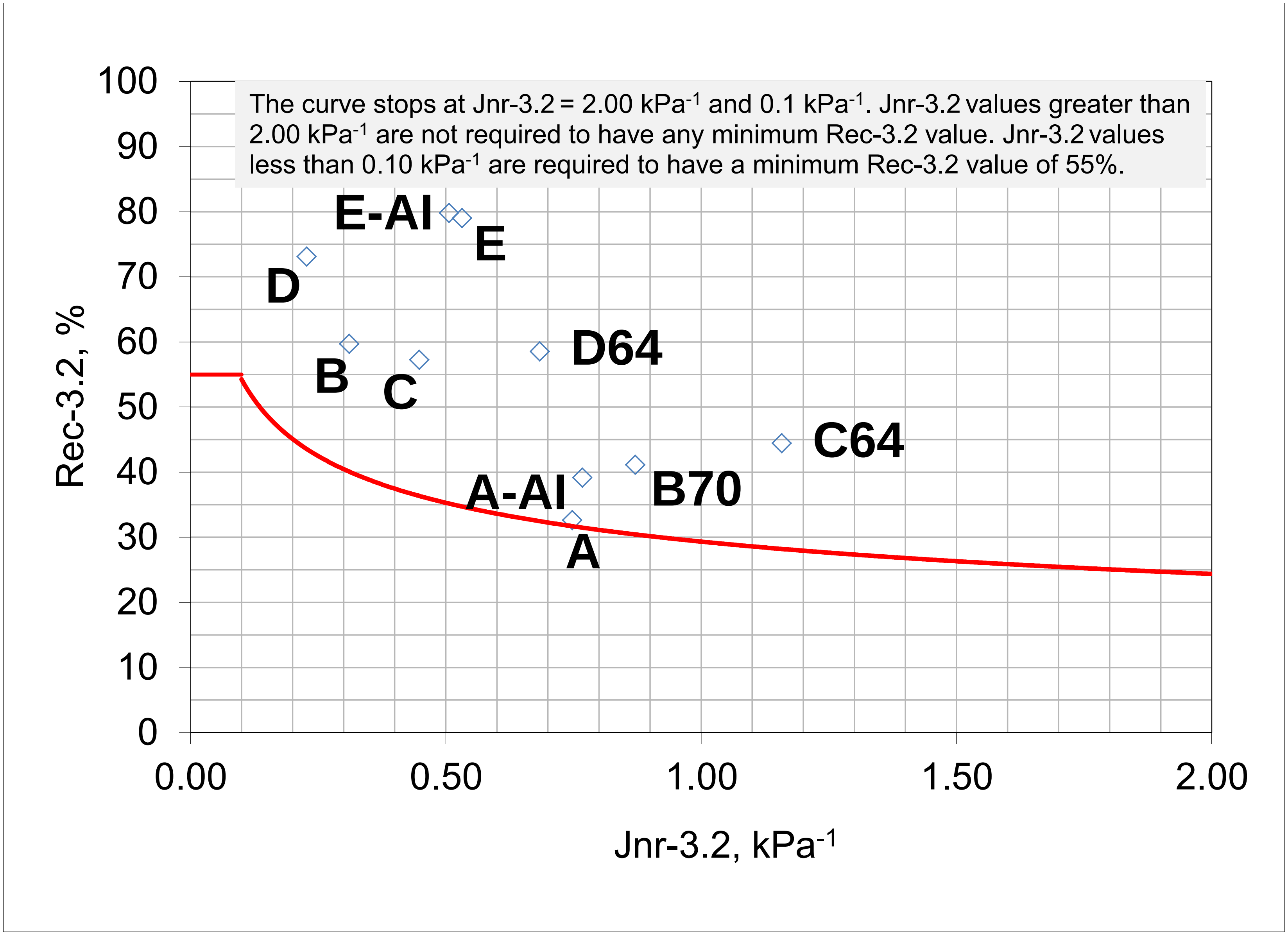

Repeatability and Reproducibility Estimates

Table 20: Estimated Repeatability and Reproducibility from ILS

Test	*Acceptable Range of Two Test Results (d2s%) 2013 PCCAS ILS* — *Single Operator Precision*	*Multilaboratory Precision*
Elastic Recovery (RTFO) at 25°C	5.6%	9.2%
R&B Softening Point	2.8%	7.7%
Ductility (Original) at 4°C	17.9%	75.0%
Ductility (RTFO) at 4°C	19.5%	95.1%
Toughness at 25°C	15.3%	29.1%
Tenacity at 25°C	17.9%	30.0%

MSCR Rec-3.2	8.0%	17.3%

2013 PCCAS ILS

	MSCR Rec-3.2	ER	R&B SP	Ductility (O)	Ductility (R)	T&T Toughness	T&T Tenacity
Binder A	32.6	87.4					
Binder A-AI	39.1						
Binder B	59.7	78.4					
Binder C	57.3			91.4	49.7	81.2	68.7
Binder D	73.1	86.2	138.7			141.0	120.3
Binder E	79.0	90.7	187.0			79.2	72.9
Binder E-AI	79.8						

MSCR, ER tests performed on RTFO-aged binder
R&B Softening Point, Toughness and Tenacity tests performed on original binder
Ductility tests performed on both original and RTFO-aged binder

PCCAS 2013 ILS

- Summary
  - Analysis of MSCR results after outlier removal indicated similar precision as in other studies
  - High variability seen with Binder A
    - Test results indicate highly stress-sensitive binder
    - Meets M332 criterion for PG64V-28
    - Meets Elasticity Evaluation by Jnr-Recovery curve
  - Some improvement in variability noted when aging was conducted by a single lab (AI)
    - Expected response since there is some inherent variability in RTFO procedure

PCCAS 2013 ILS

- Summary
  - PG-Plus tests not correlated directly with MSCR Rec-3.2
    - ER directionally correlated for 3 of 4 binders
    - Binder A indicated high ER value with low MSCR Rec-3.2
  - All binders plot above the Jnr-Recovery curve

Why MSCR?

- Why Use the MSCR Test and Spec?
  - Non-recoverable creep compliance, J_{nr}, is better correlated with pavement rutting than G*/sin δ
    - The high temperature parameter is truer to the intent of the PG specification, that it be blind to method of modification

Why MSCR?

- Why Use the MSCR Test and Spec?
  - MSCR Recovery can be used to identify elastomeric modification, thereby eliminating the need for many PG-Plus tests like Elastic Recovery
    - Much quicker test
    - Not directly tied to performance

Summary

- Industry Actively Involved
  - Asphalt Institute Technical Advisory Committee
  - Participation in UPG Meetings
- Supportive of Elimination of PG Plus Tests
  - Replacing ER, other similar tests, with MSCR Recovery
  - Recovery-Jnr curve
- Supportive of Using J_{nr} instead of $G^*/\sin\delta$
  - Modified asphalts in particular
- M332 Grade Names
  - Remains an issue for some

Thanks!

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