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

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Acknowledgments

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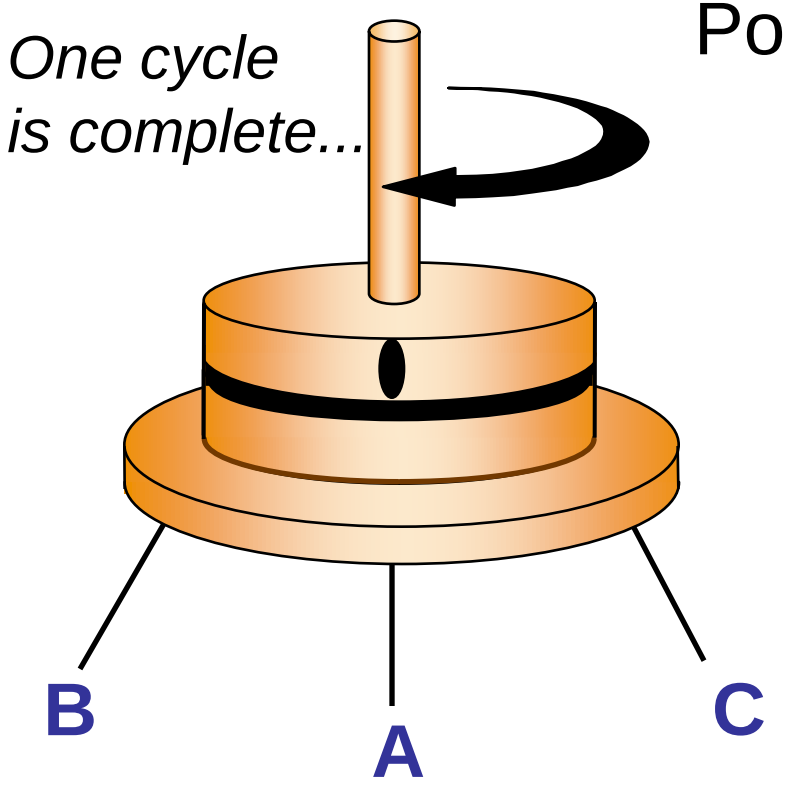
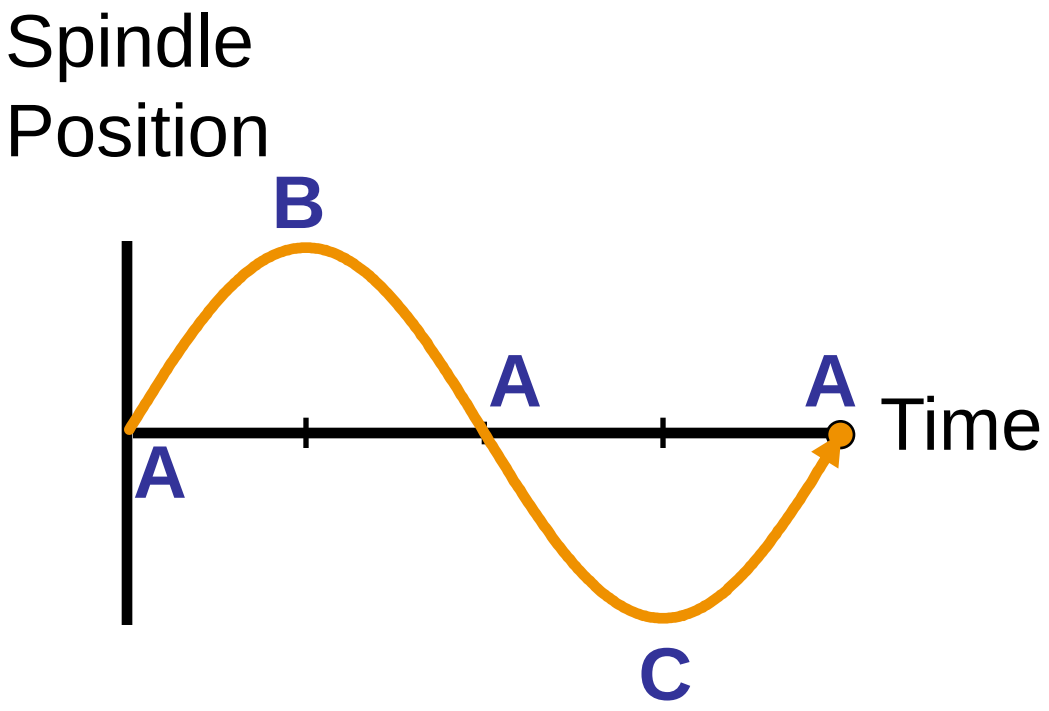
  - Michael Arasteh, AOTR (00033)
- Asphalt Binder ETG
  - John D'Angelo
- Member Companies of the Asphalt Institute
  - Technical Advisory Committee

Discussion

- 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?
- How are user agencies looking to implement the test/specification?

DSR Operation: AASHTO T315

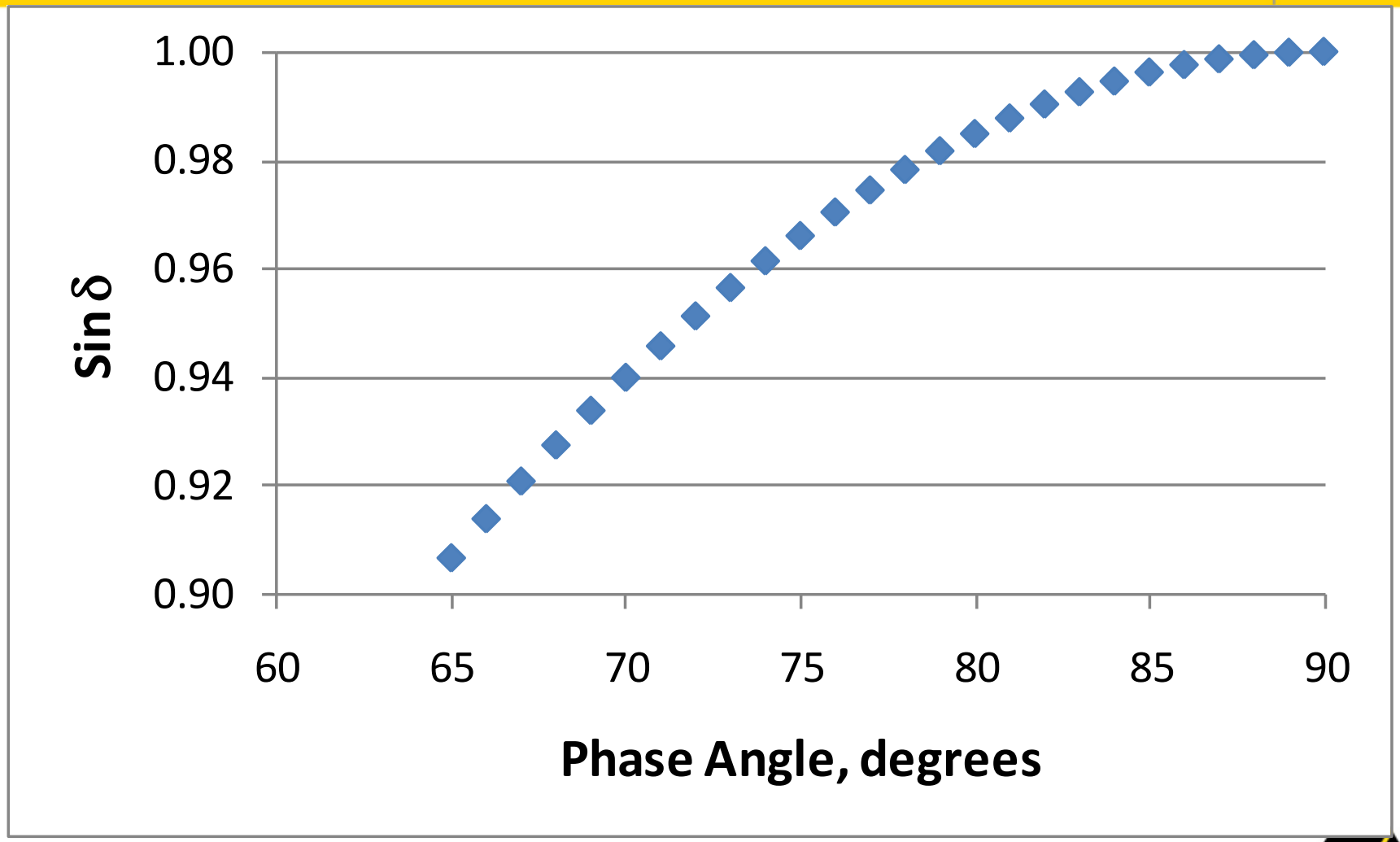




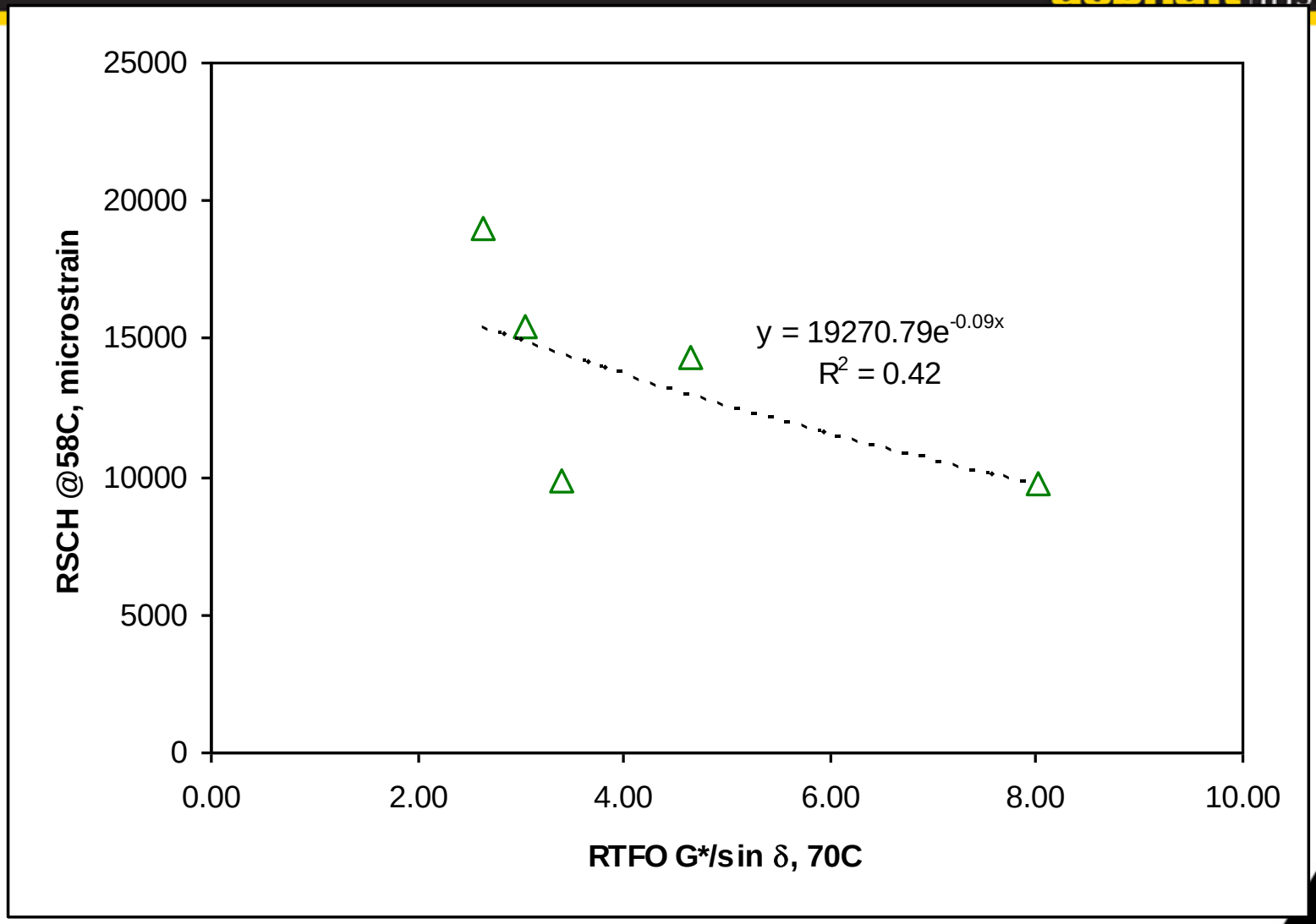
Shortcomings of G*/sin δ

- 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



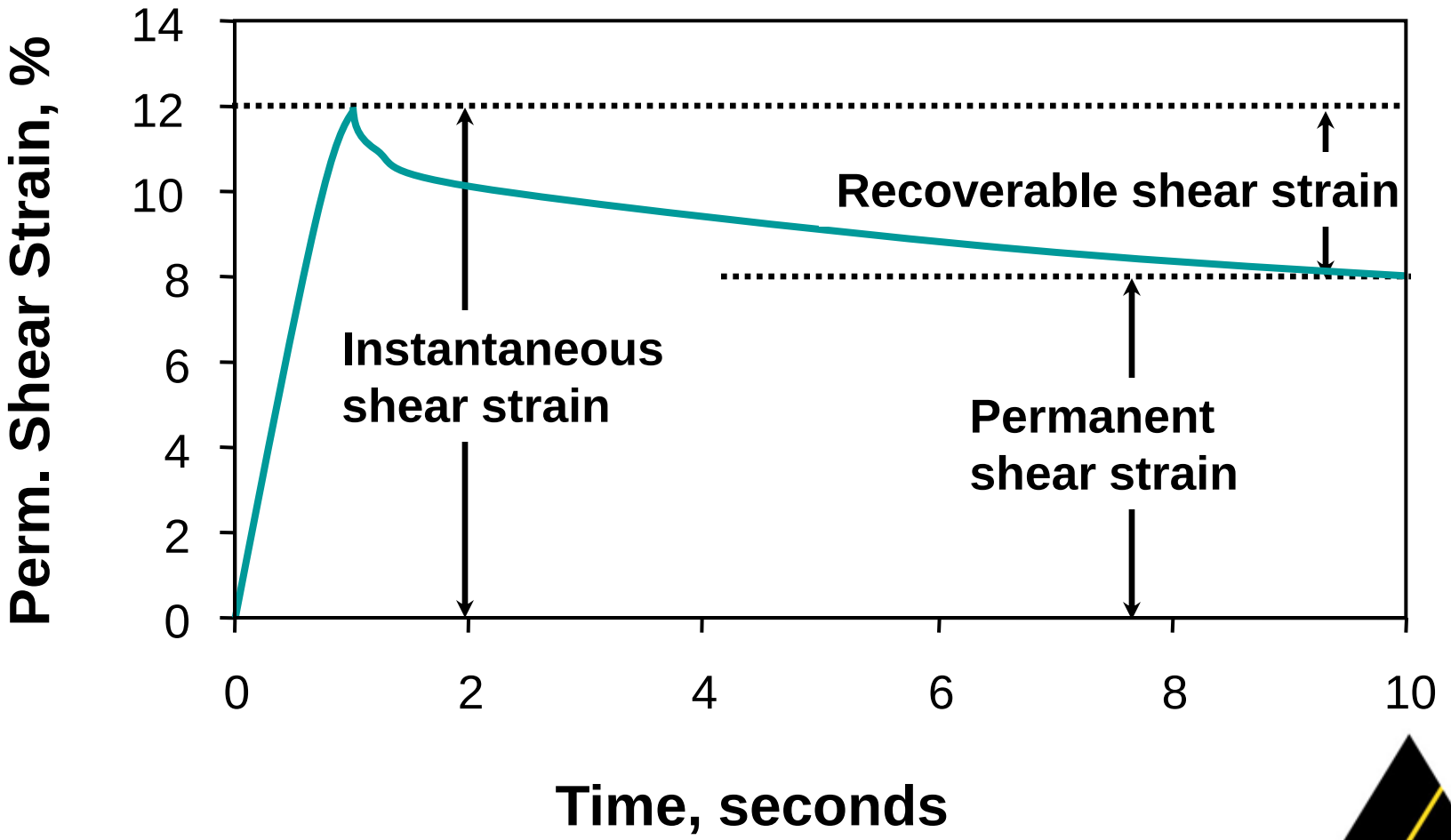
Effect of Binder G*/sin δ on Mixture Permanent Shear Strain



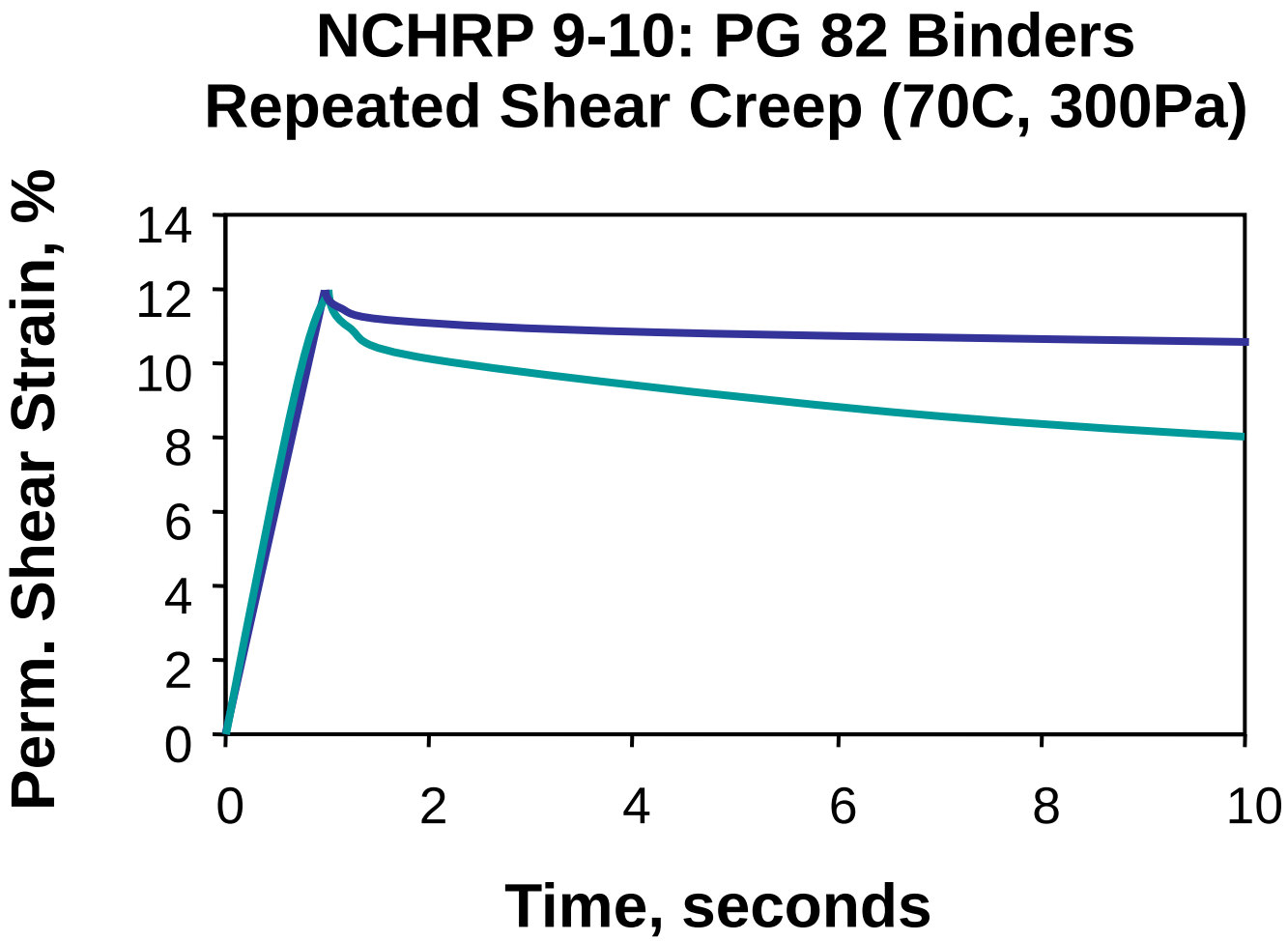
High Temperature Testing

- 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

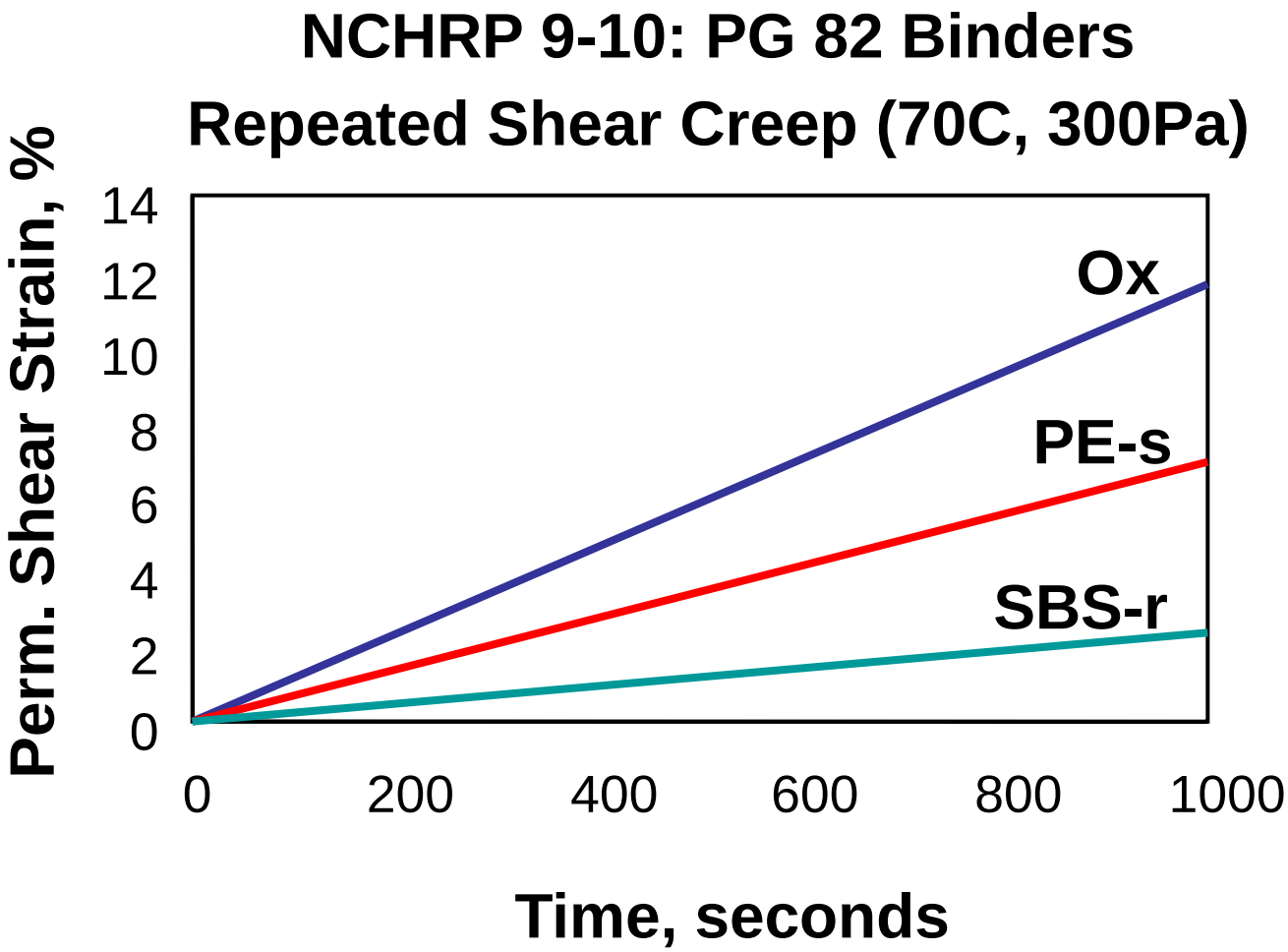
Repeated Shear Creep



Repeated Shear Creep



Repeated Shear Creep



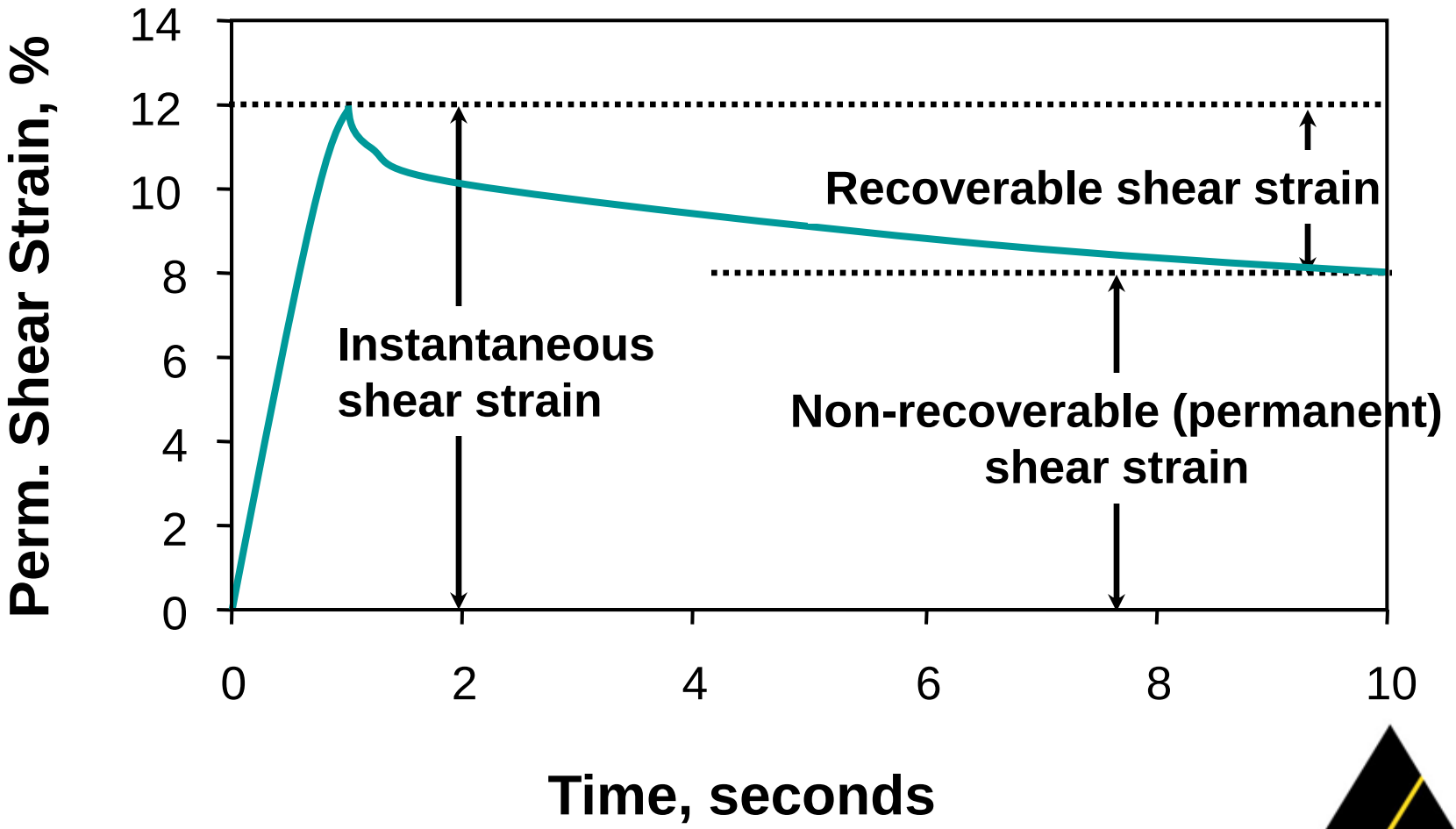
Multiple-Stress Creep-Recovery (MSCR) Test: AASHTO TP70

- 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

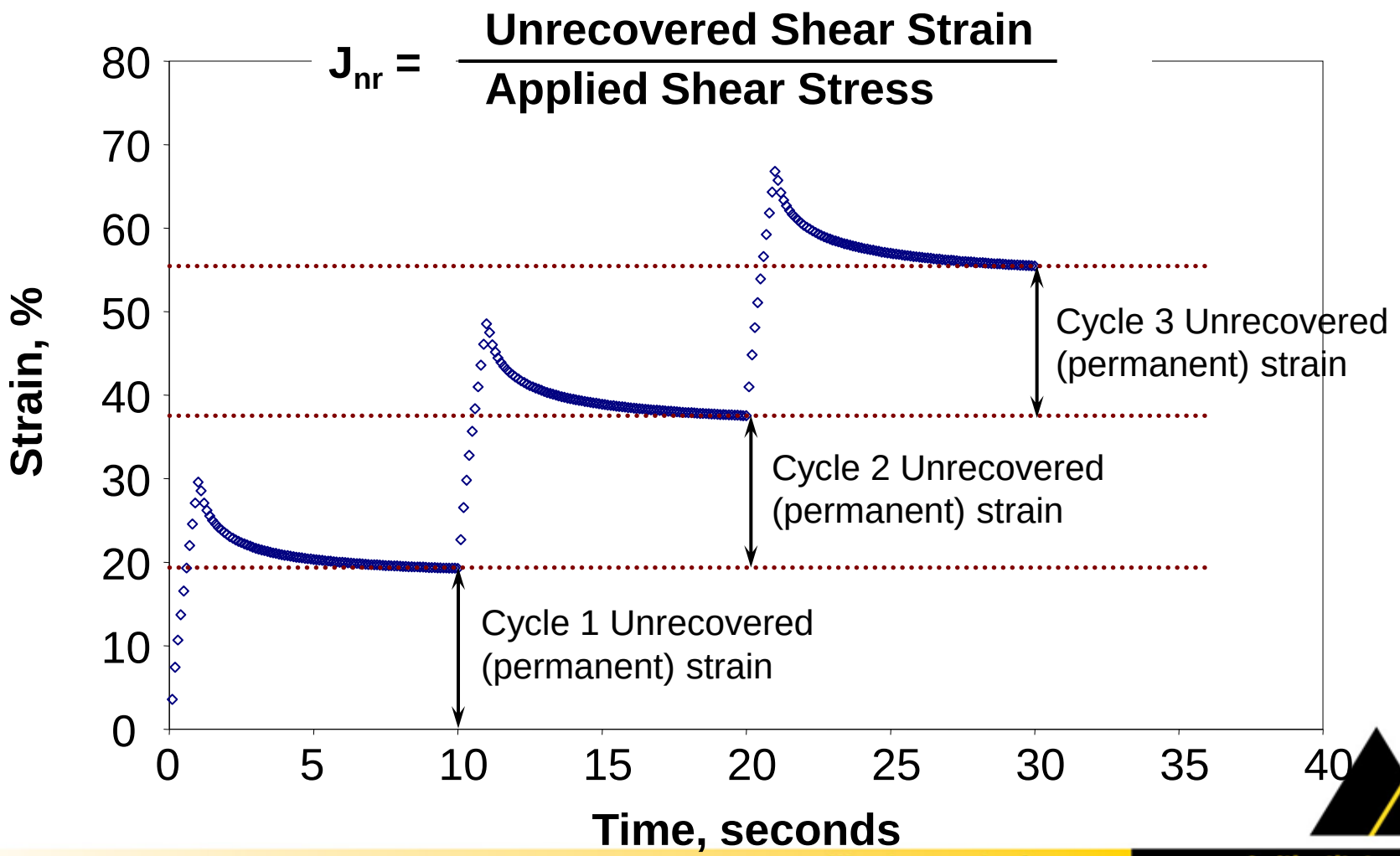
MSCR Test

- 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

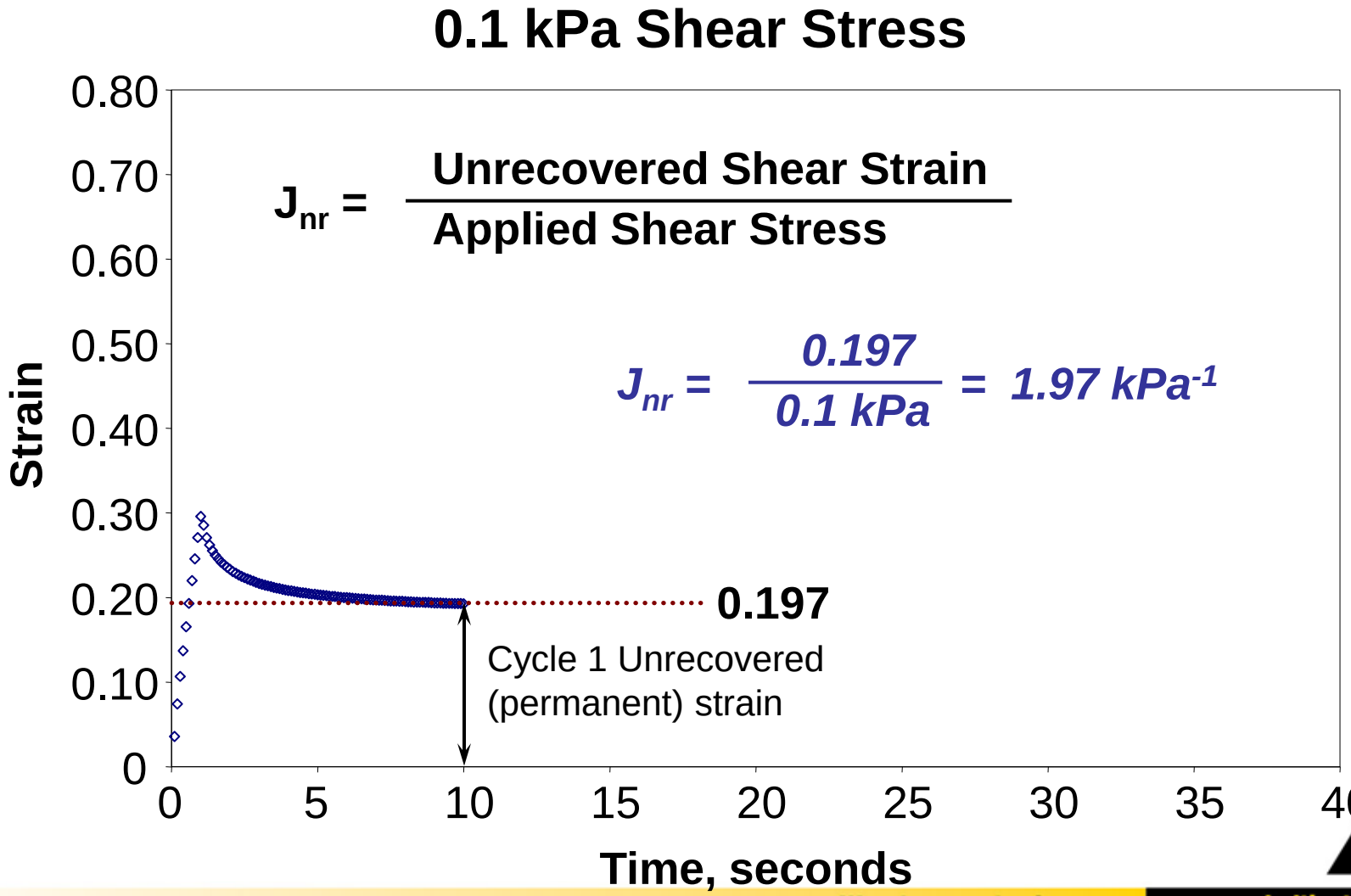
MSCR


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 25.6kPa

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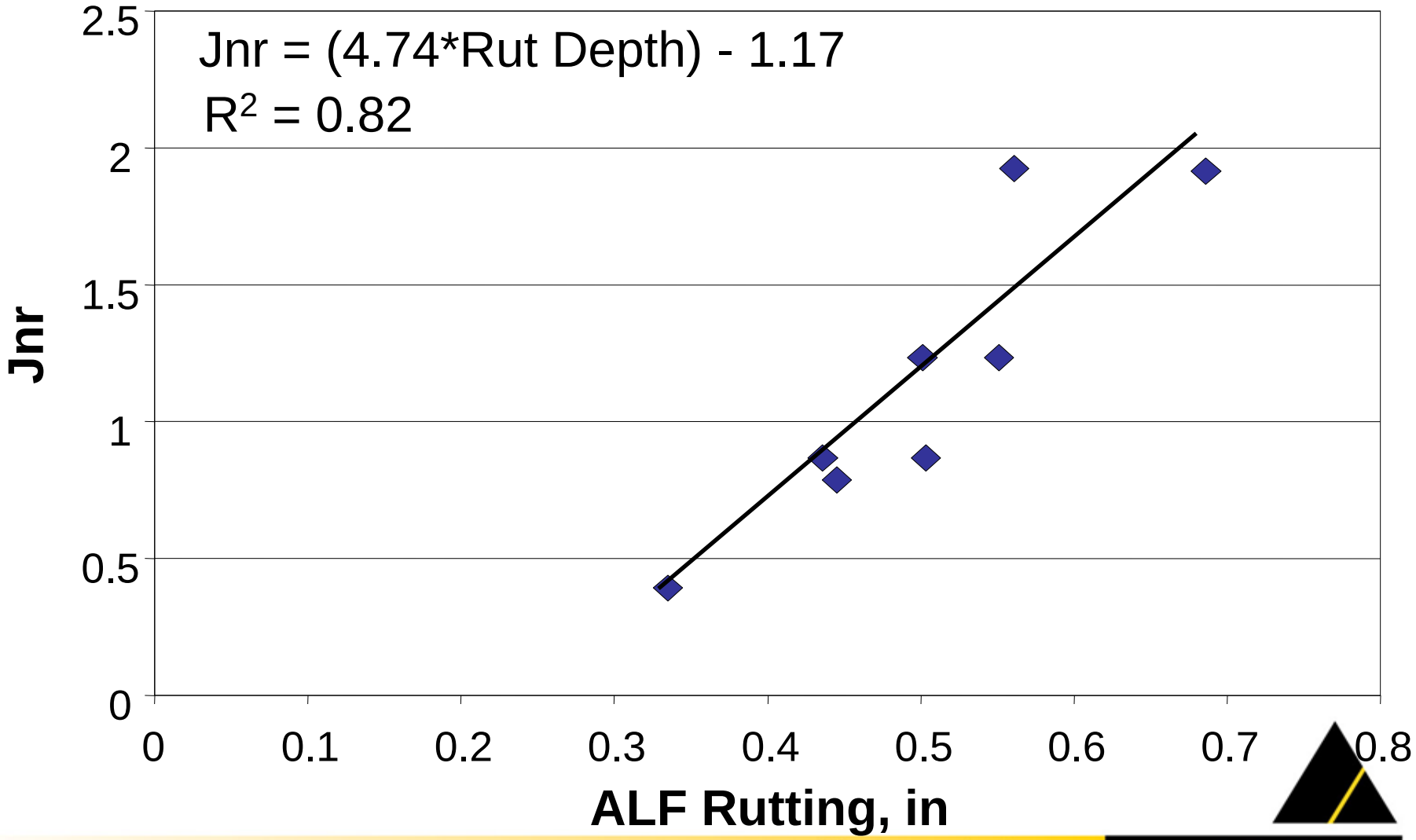

Mississippi I55: 6yr rutting J_{nr} 3.2 kPa

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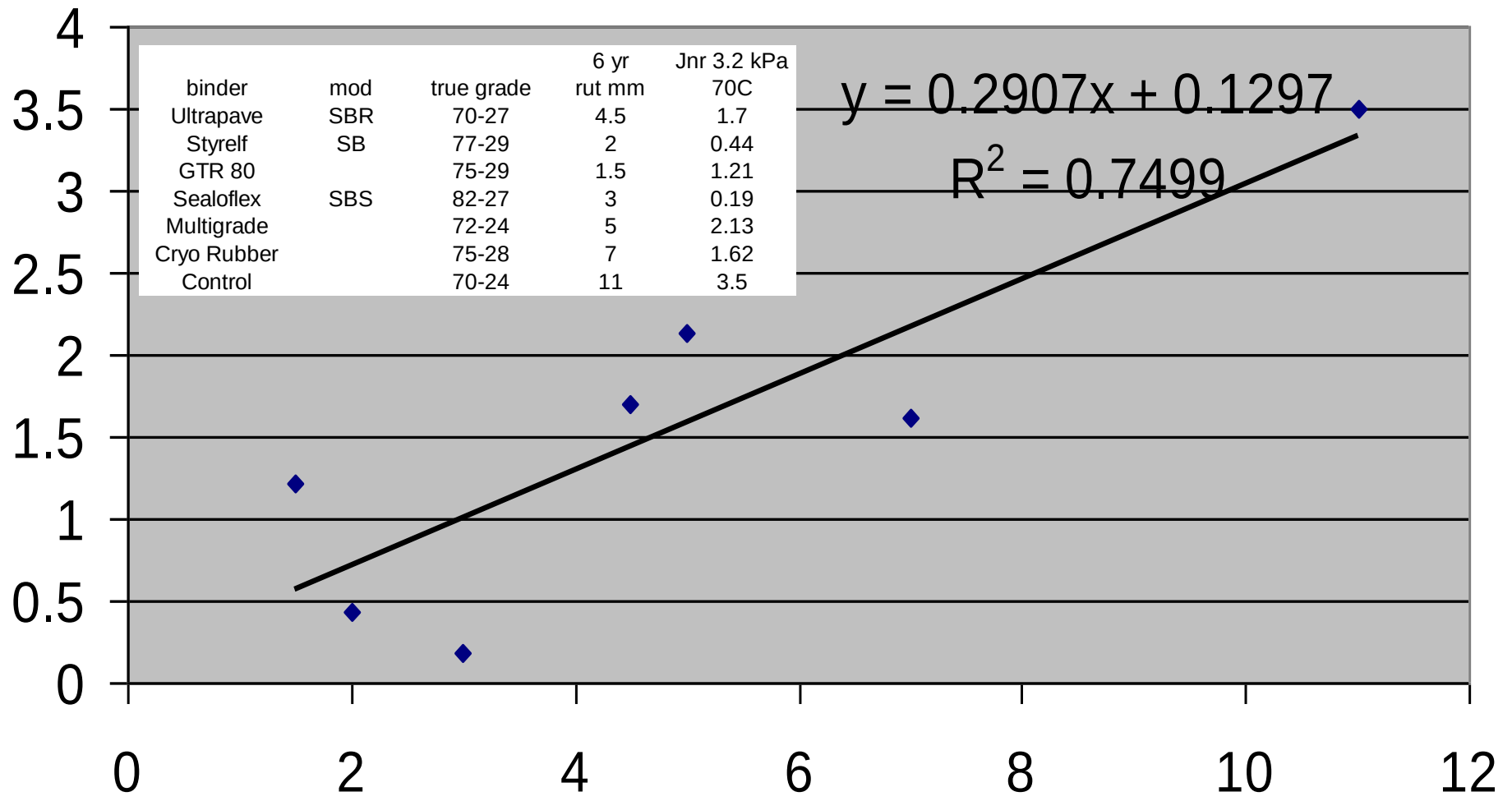
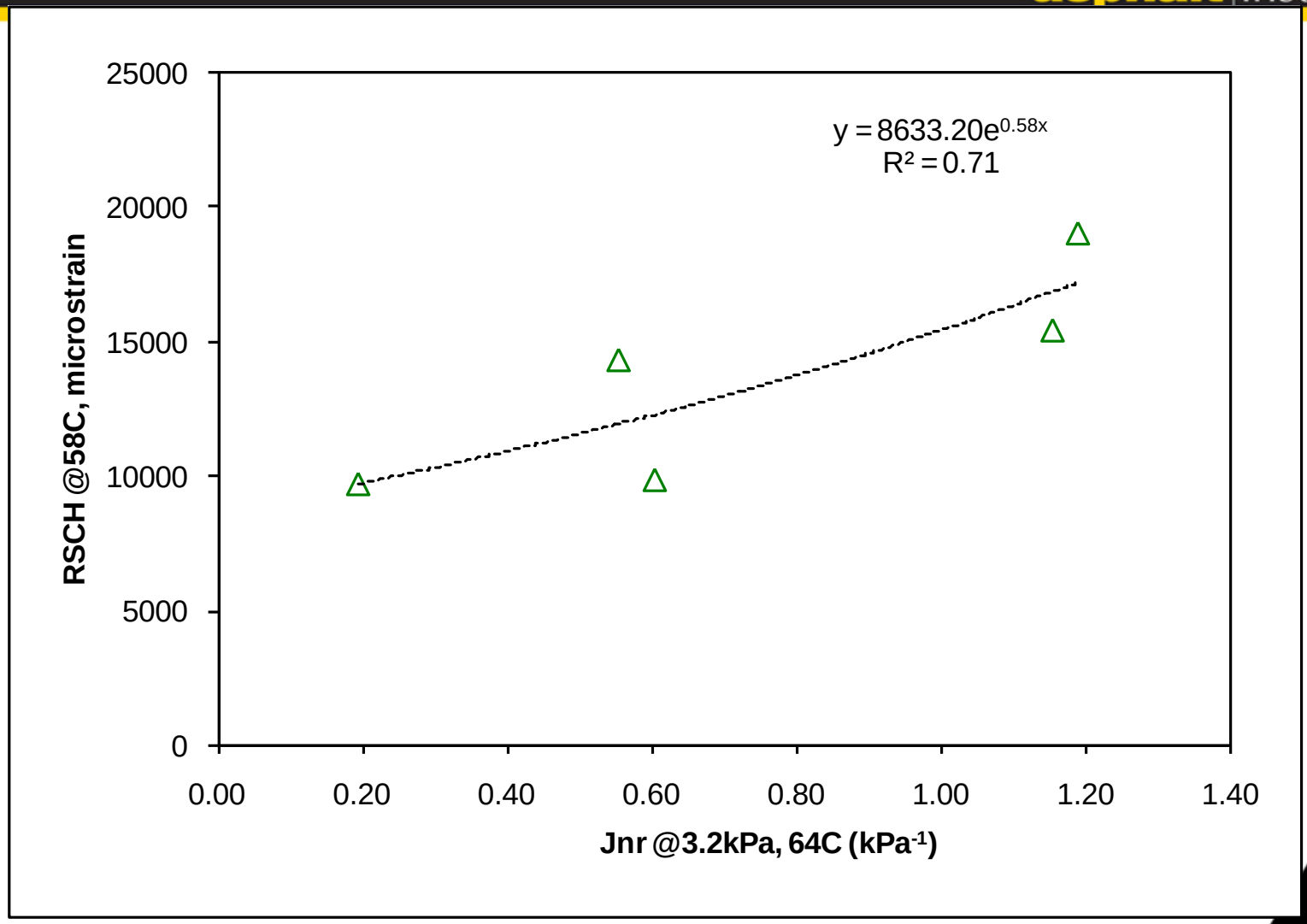
binder	mod	true grade	6 yr rut mm	Jnr 3.2 kPa 70C
Ultrapave	SBR	70-27	4.5	1.7
Styrelf	SB	77-29	2	0.44
GTR 80		75-29	1.5	1.21
Sealoflex	SBS	82-27	3	0.19
Multigrade		72-24	5	2.13
Cryo Rubber		75-28	7	1.62
Control		70-24	11	3.5



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



MSCR: What is % Recovery?

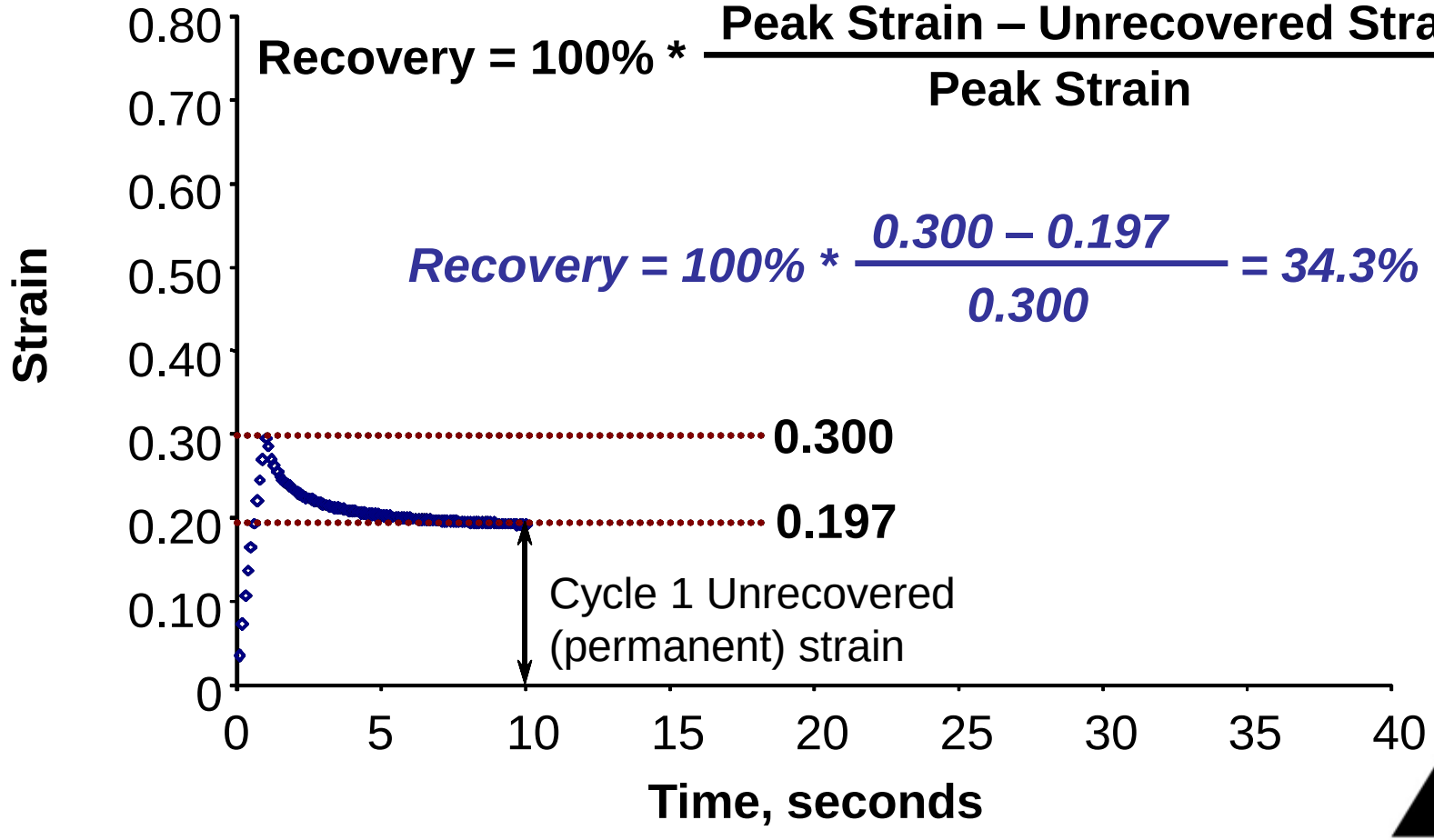
- MSCR J_{nr} addresses the high temperature rutting for both neat and modified binders
  - but many highway agencies require polymers for cracking and durability.
- The MSCR % Recovery measurement can identify and quantify how the polymer is working in the binder.

MSCR Recovery

3.2 kPa Shear Stress

$$\text{Recovery} = 100\% * \frac{\text{Peak Strain} - \text{Unrecovered Strain}}{\text{Peak Strain}}$$

$$\textit{Recovery} = 100\% * \frac{0.300 - 0.197}{0.300} = 34.3\%$$



MSCR Recovery: Validate Polymer Modification

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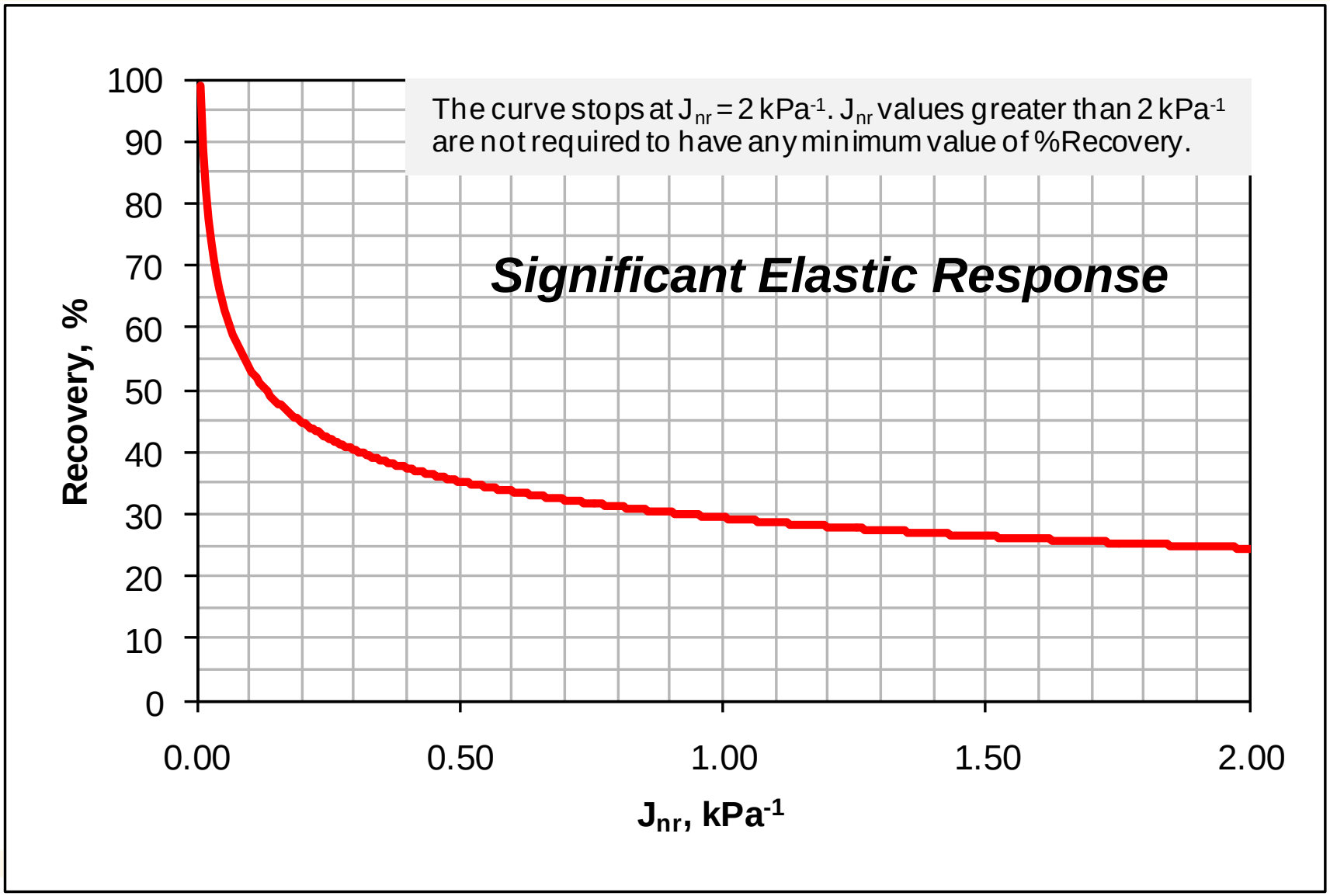

MSCR Recovery: Validate Polymer Modification

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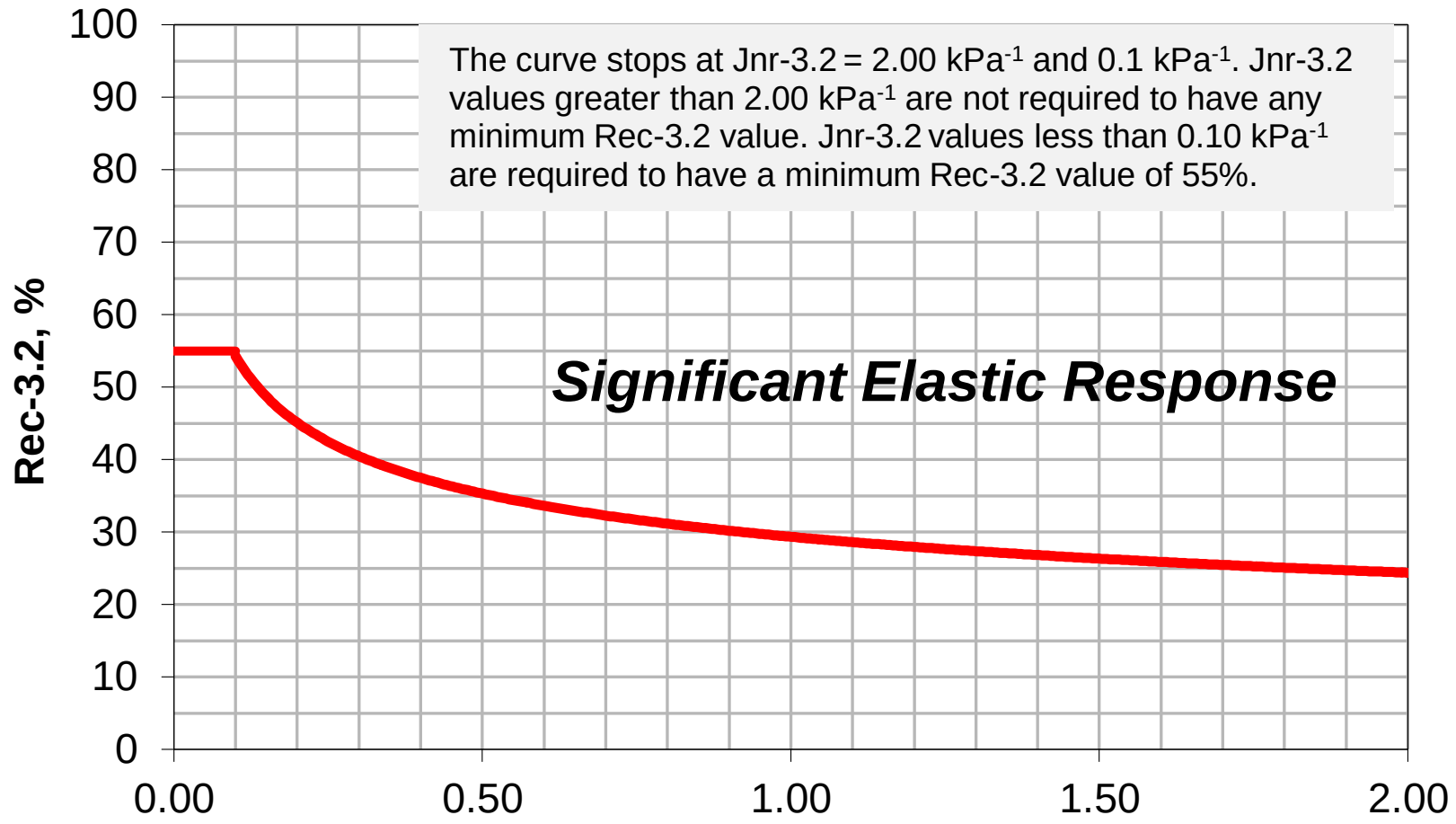

Table for MSCR % Recovery: Minimum Values

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Minimum % Recovery for Measured J_{nr} values	
J_{nr} @ 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%

Validate Polymer Modification

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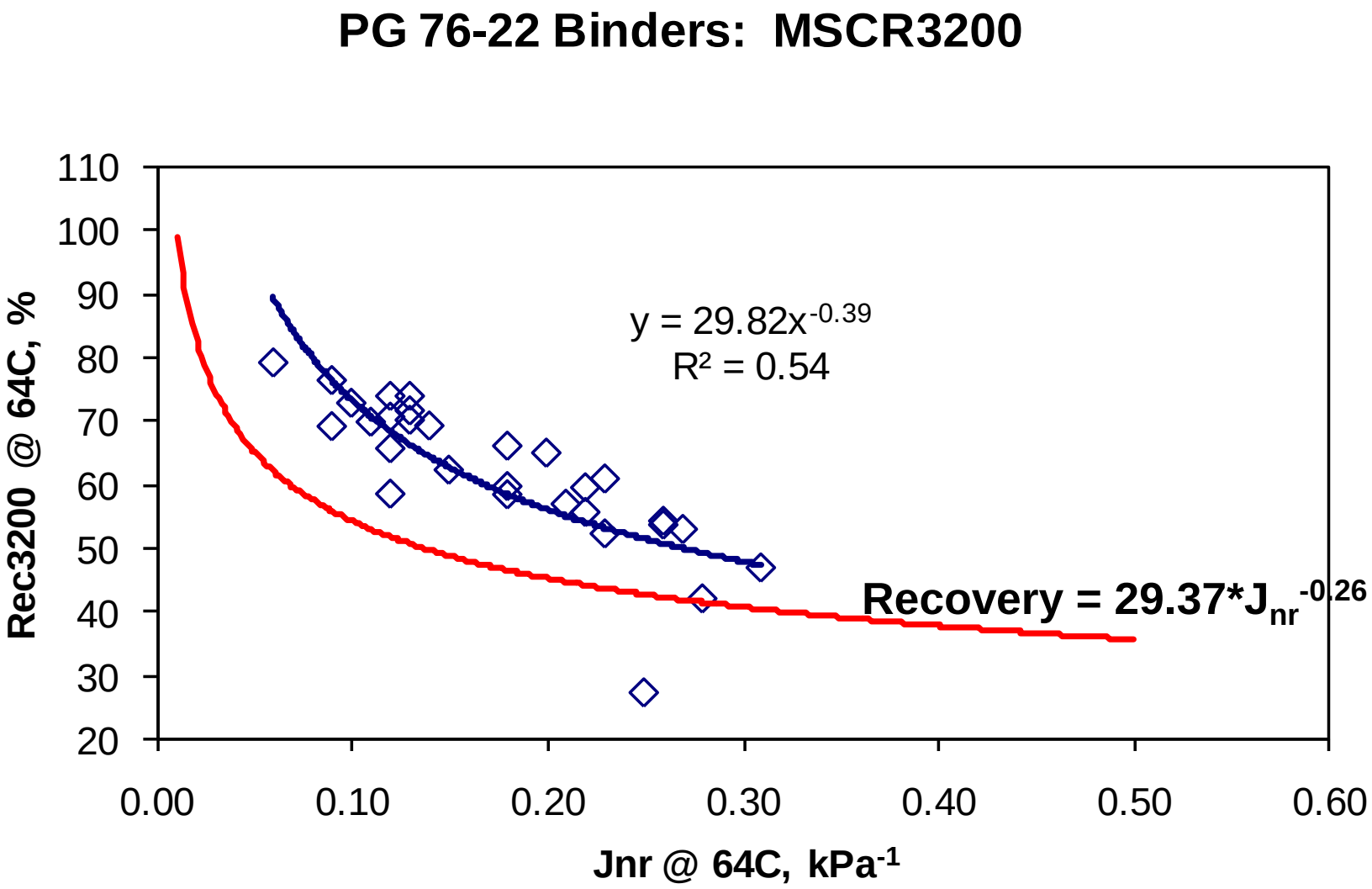

Evaluation of the MSCR Test for Canadian Asphalt Binders

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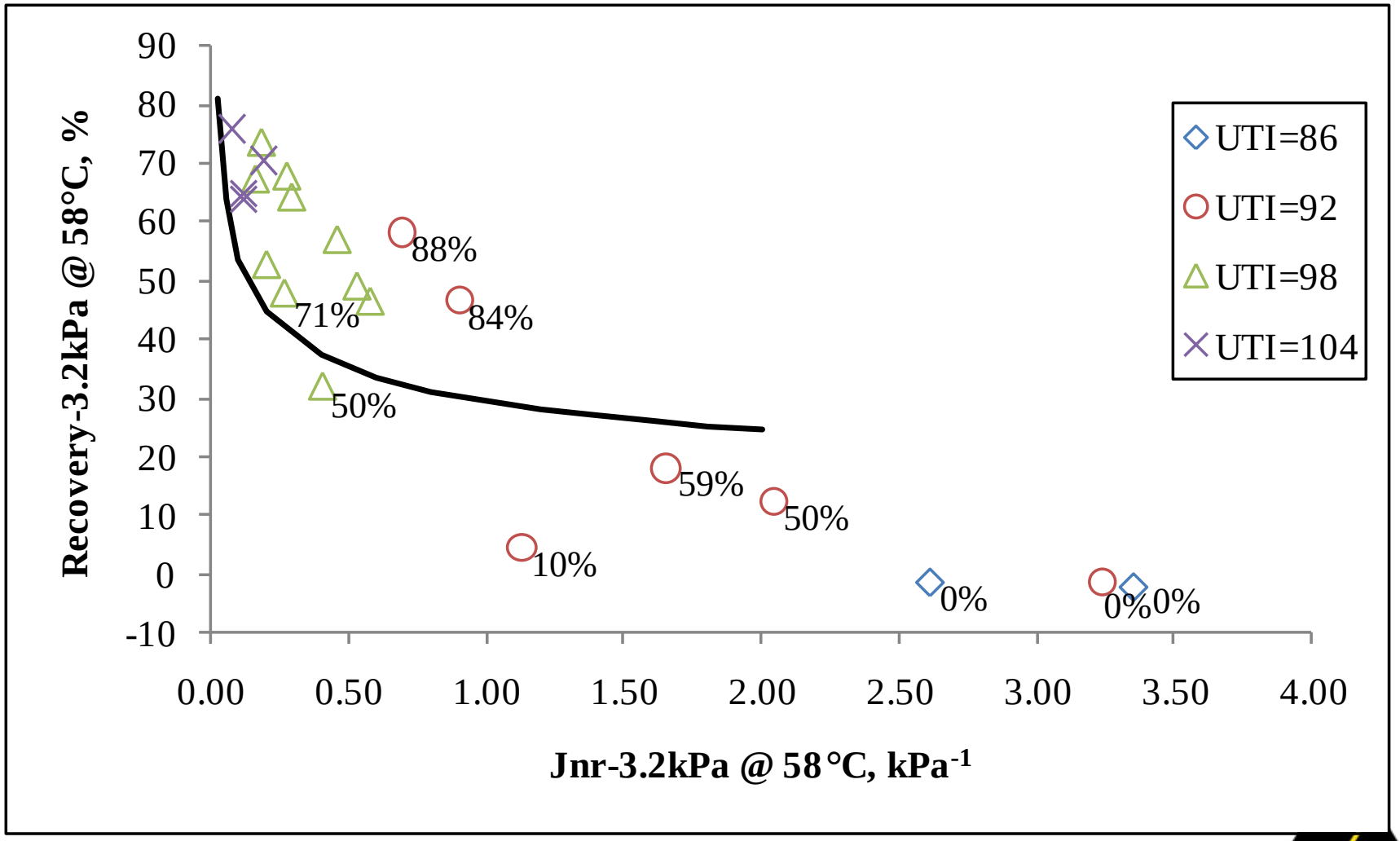

AASHTO MP19

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	PG 64					
	-10	-16	-22	-28	-34	-40
	Original Binder					
DSR (T315) – temp @ 10 rad/s $G^*/\sin\delta \geq 1.00$ kPa	64					
	RTFO-Aged Binder					
MSCR (TP70) – temp All Grades: Jnr,Diff ≤ 75% "S" Grade: Jnr-3.2 ≤ 4.0 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 MP19

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	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 MP19

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

AASHTO MP19

- 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 MP19

- 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 δ must be ≥ 1.00 kPa @ 64°C

PG 64V-22 Asphalt Binder

- RTFO Aged Binder
  - RTFO Mass Change
    - Must be ≤ 1.00%
  - MSCR (AASHTO TP70)
    - 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

Implementation Activities

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

Implementation Assistance

- Educational
  - FHWA Technical Brief (FHWA-HIF-11-038)
  - Asphalt Institute
    - Guidance Document, “Implementation of the Multiple Stress Creep Recovery Test and Specification”
    - Guidance Document, “Using the MSCR Test with the AASHTO M320 Specification”
    - www.asphaltinstitute.org

Implementation Assistance

- Educational
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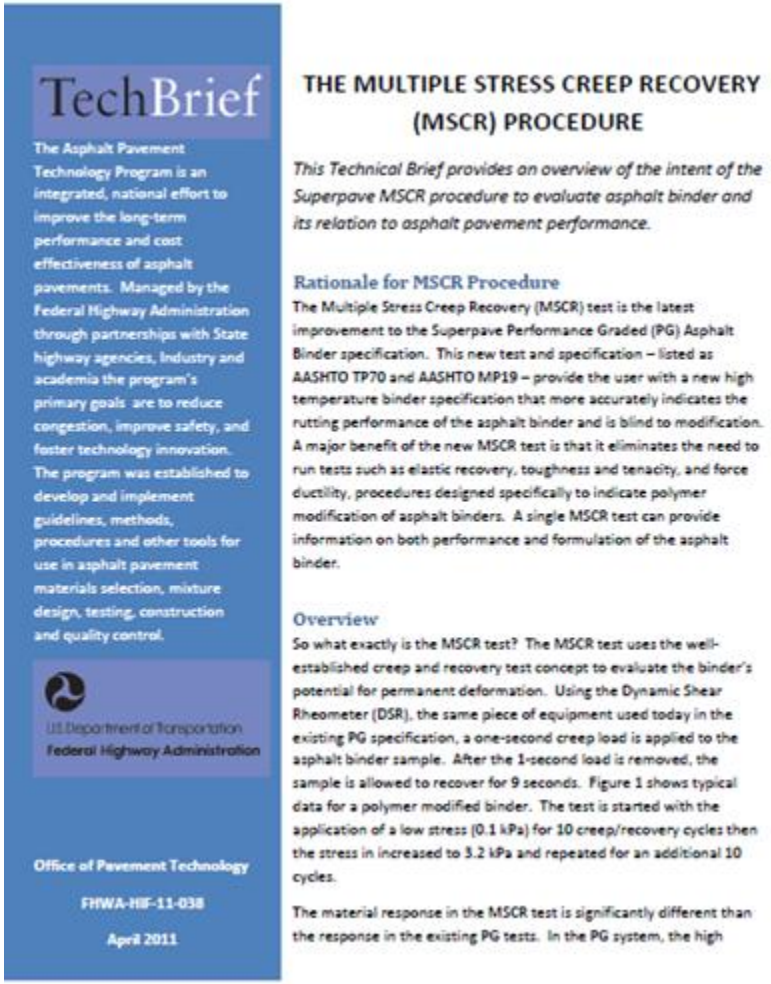

TechBrief

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

Implementation of the MSCR Test and Specification

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FHWA-HIF-10-XXX

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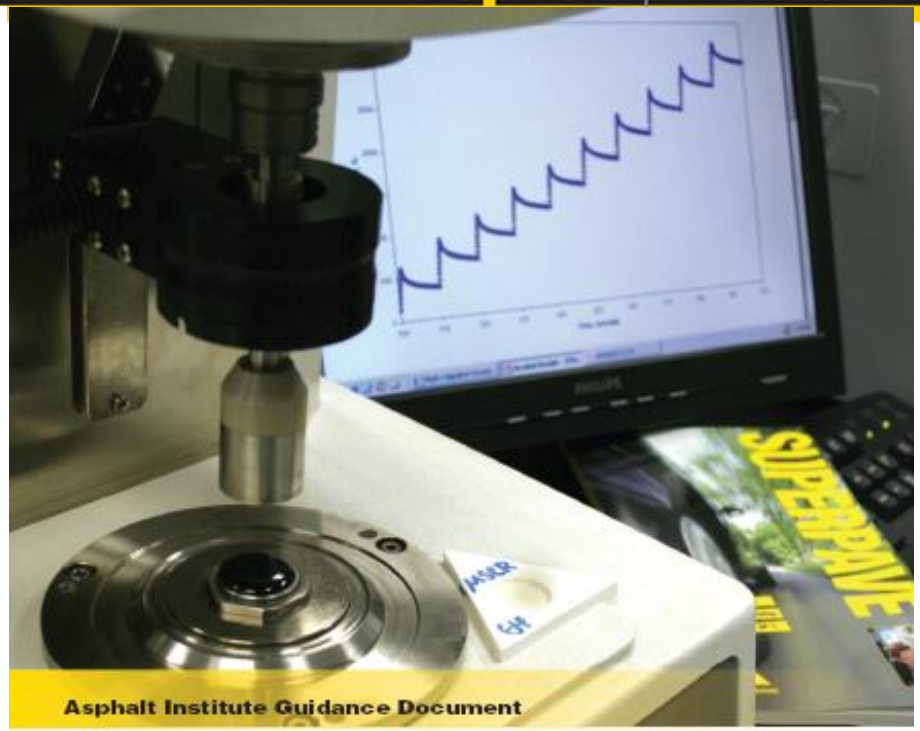

Asphalt Institute Guidance Document

Implementation of the Multiple Stress Creep Recovery Test and Specification

The purpose of this 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 Multiple Stress Creep Recovery (MSCR) test. The MSCR test replaces the existing AASHTO M320 Dynamic Shear Rheometer (DSR) test used for characterizing the high temperature performance properties of an asphalt binder after short-term aging. 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.

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Educational Activities

- "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

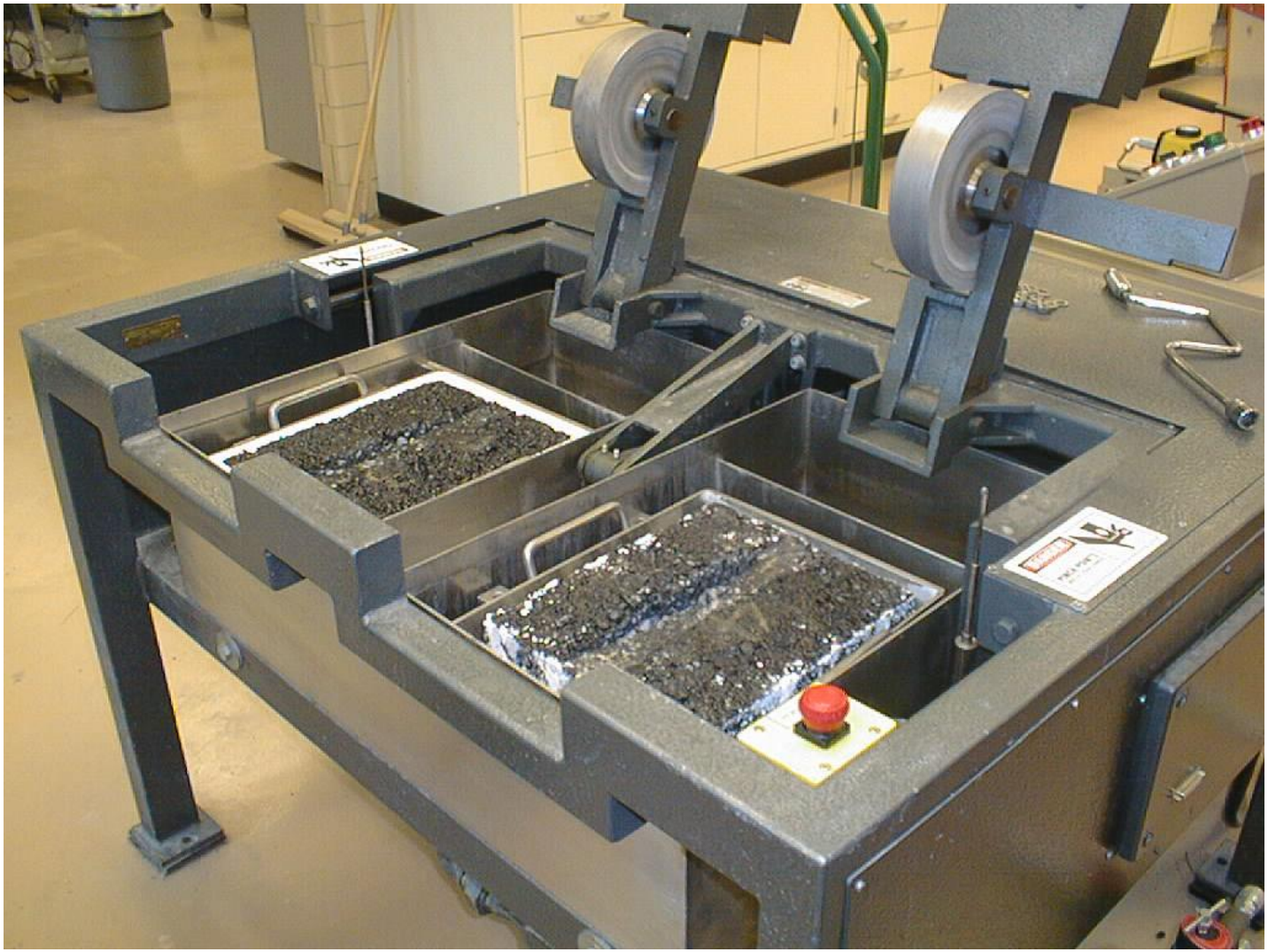
Implementation

Recognize that the refineries that serve your state may also serve bordering states.

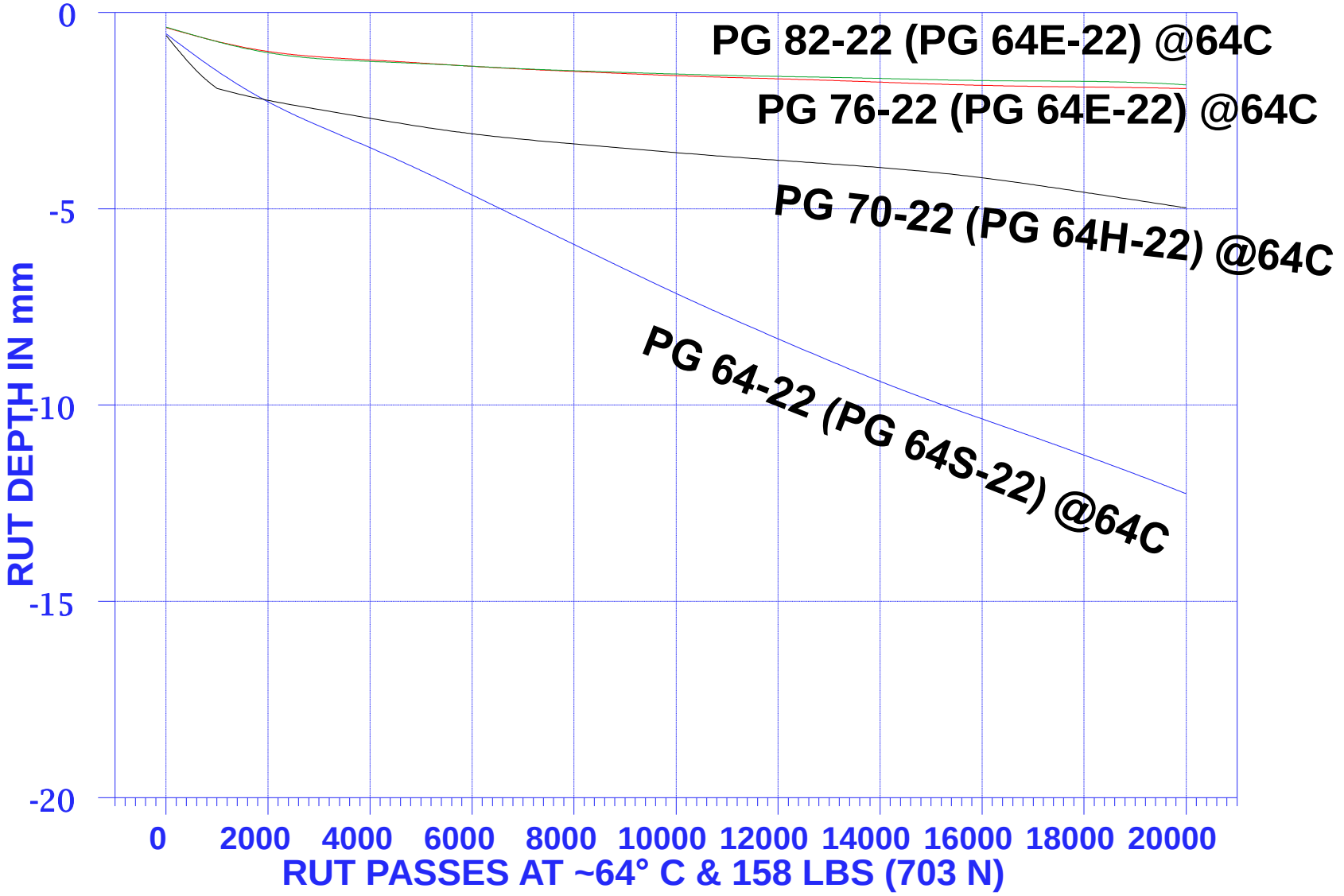
This may be a good reason to work with other states to implement regionally

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

Dry Hamburg Testing



TESTED IN HAMBURG
DRY AT ~ 64° C, 158# LOAD, E-10 FINE LIMESTONE BLEND



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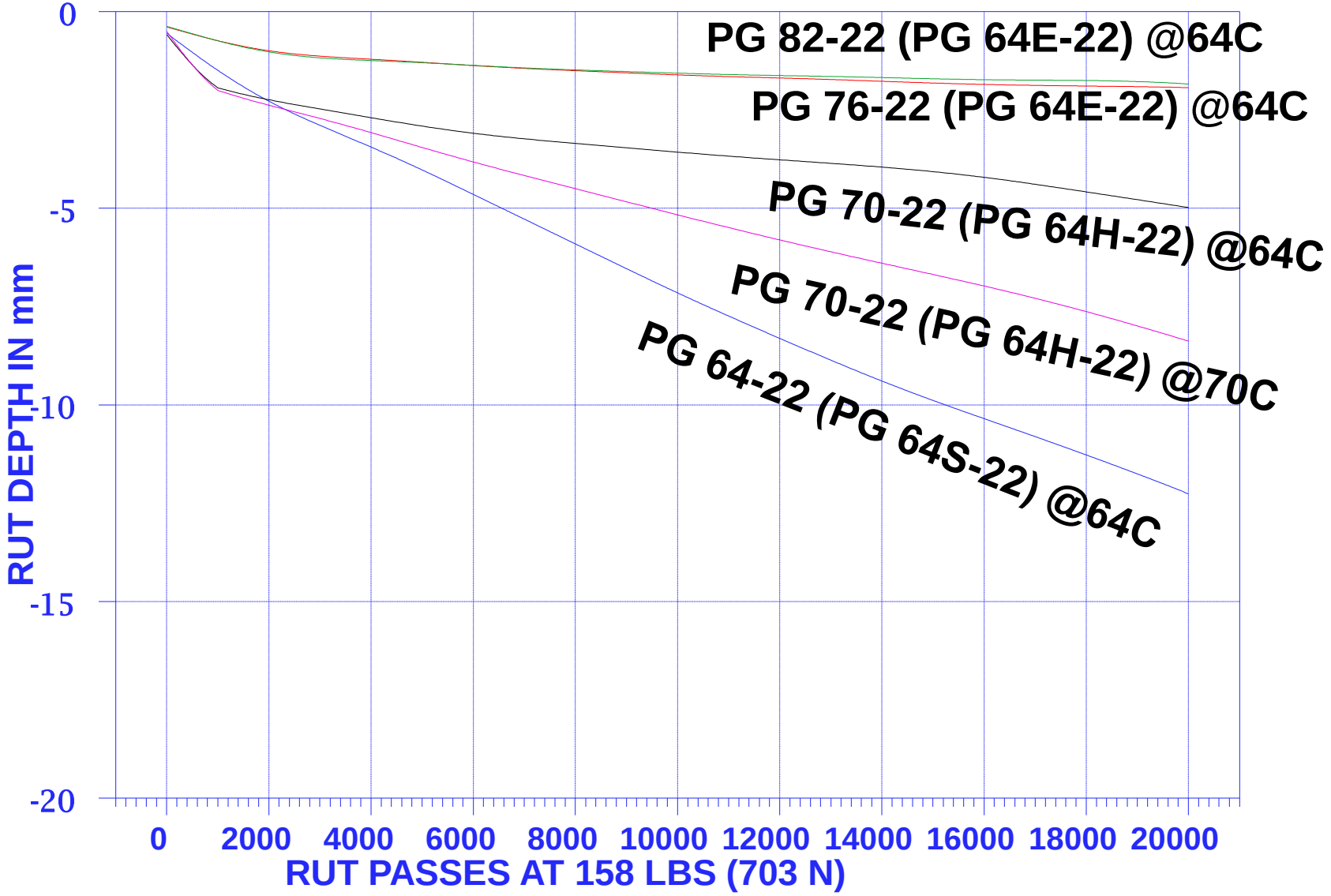

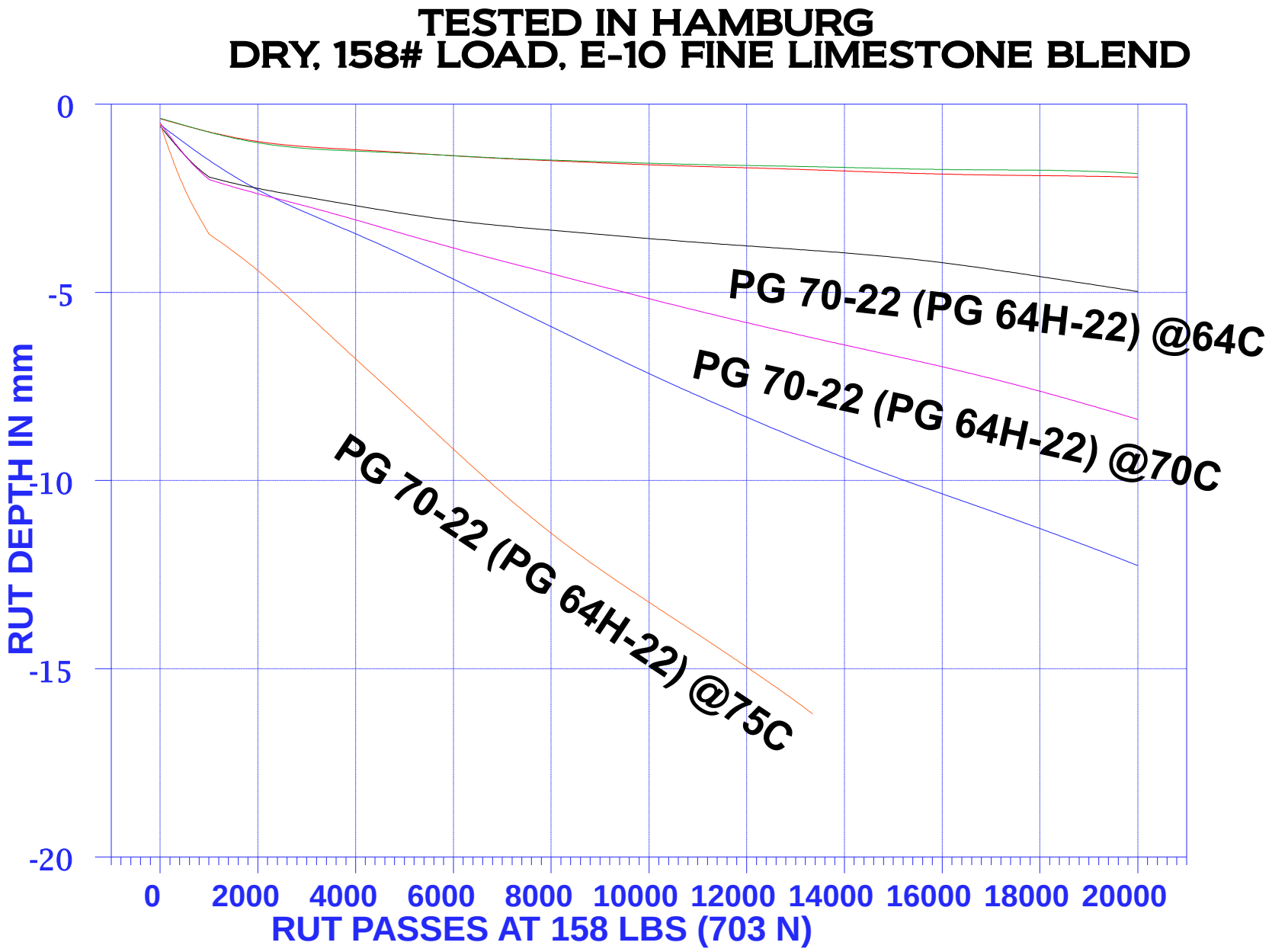
TESTED IN HAMBURG
DRY, 158# LOAD, E-10 FINE LIMESTONE BLEND
RUT DEPTH IN mm
0
-5
-10
-15
-20
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
RUT PASSES AT 158 LBS (703 N)
PG 70-22 (PG 64H-22) @64C
PG 70-22 (PG 64H-22) @70C
PG 70-22 (PG 64H-22) @75C

MTE Rutting Study: Dry Hamburg WI E10 Fine Mix

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PG GRADE (M320)	PG GRADE (MP19)	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

Why MSCR?

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

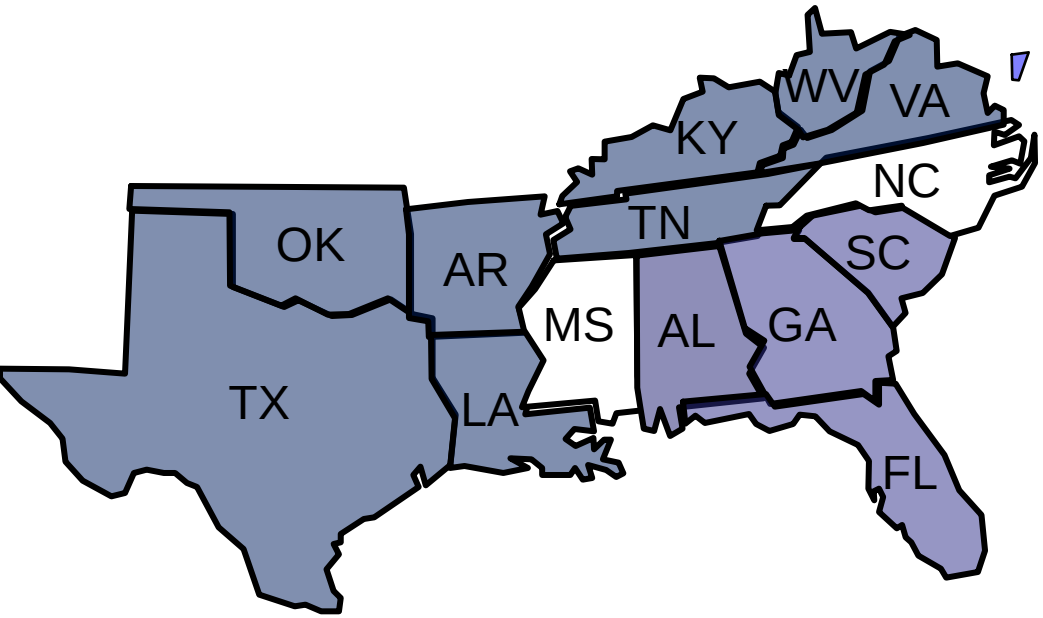
Why MSCR?

- 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

MSCR Implementation

- SEAUPG
  - MSCR Task Force of Binder Subcommittee
    - Formed in 2010
    - Periodic WebEx Meetings 2011 and 2012
    - Established to evaluate possibility of using MSCR Recovery as a replacement for current PG Plus tests (Elastic Recovery, Phase Angle)

Current 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

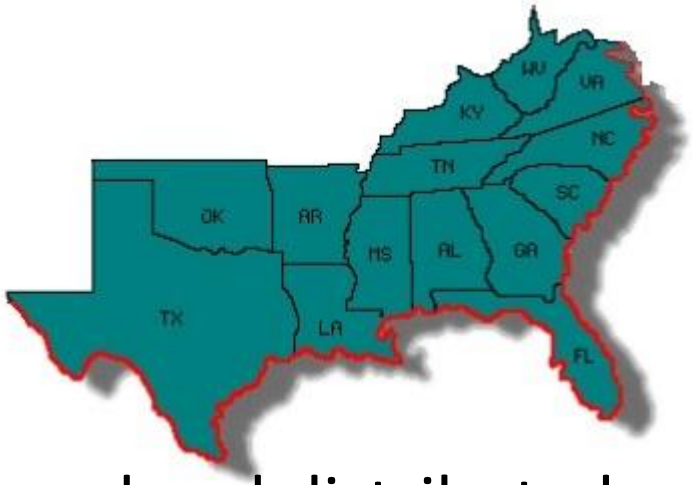
States use Phase Angle

States do not have a PG Plus test

Summary – PG Plus Tests

- In the 12 SEAUPG states that have PG Plus, there are 8 different PG Plus test procedures
  - One procedure for Phase Angle
  - Seven procedures for Elastic Recovery

SEAUPG



- A guidance document to help the states with the evaluation process itself was developed and distributed.
- An Excel spreadsheet was developed and distributed to help document each state's comparison testing, and also included graphs which are automatically populated as data is input
- Reporting on results at SEAUPG Annual Meeting in November 2012.

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

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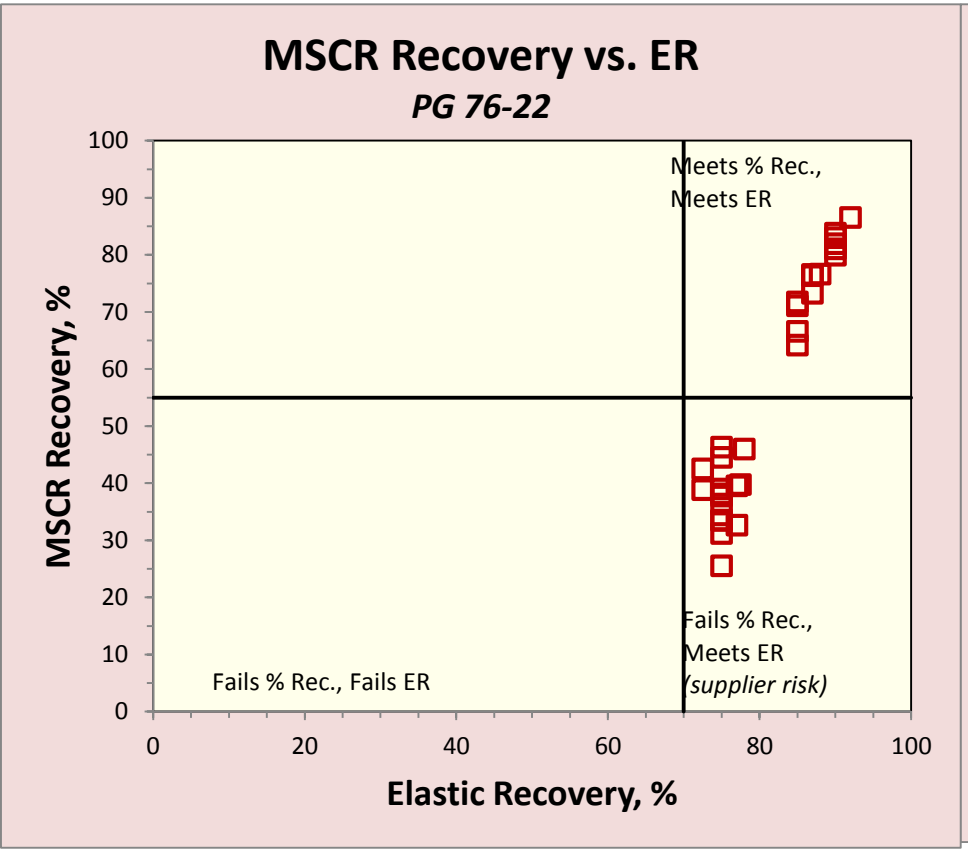

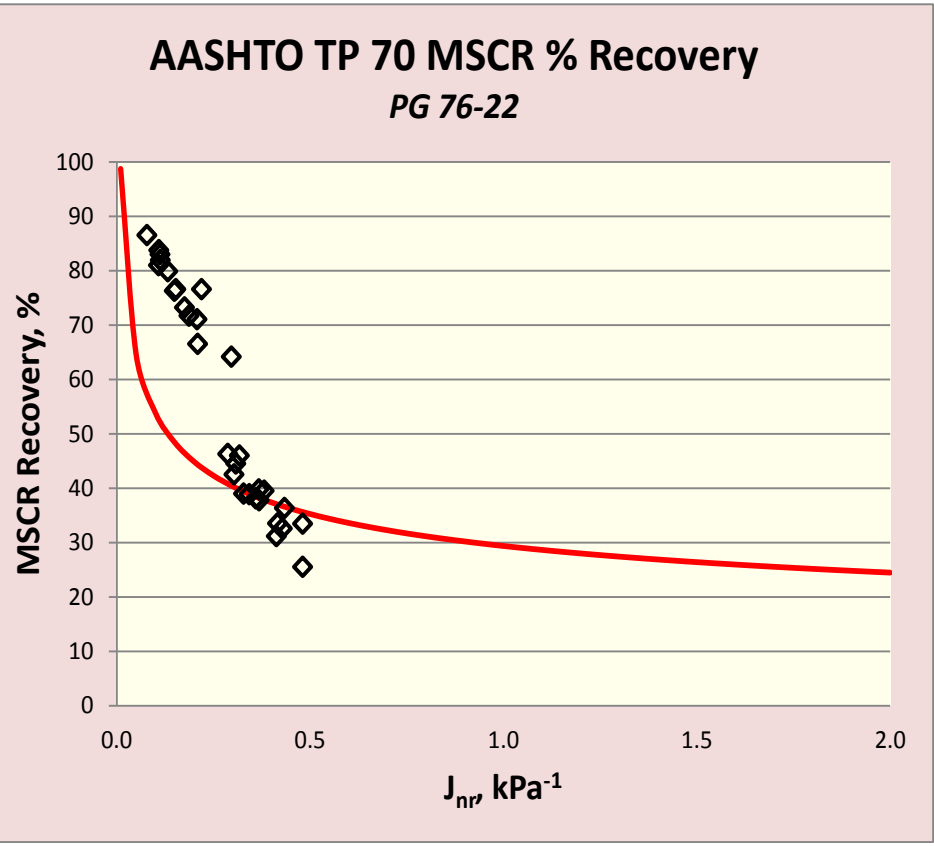

SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 1

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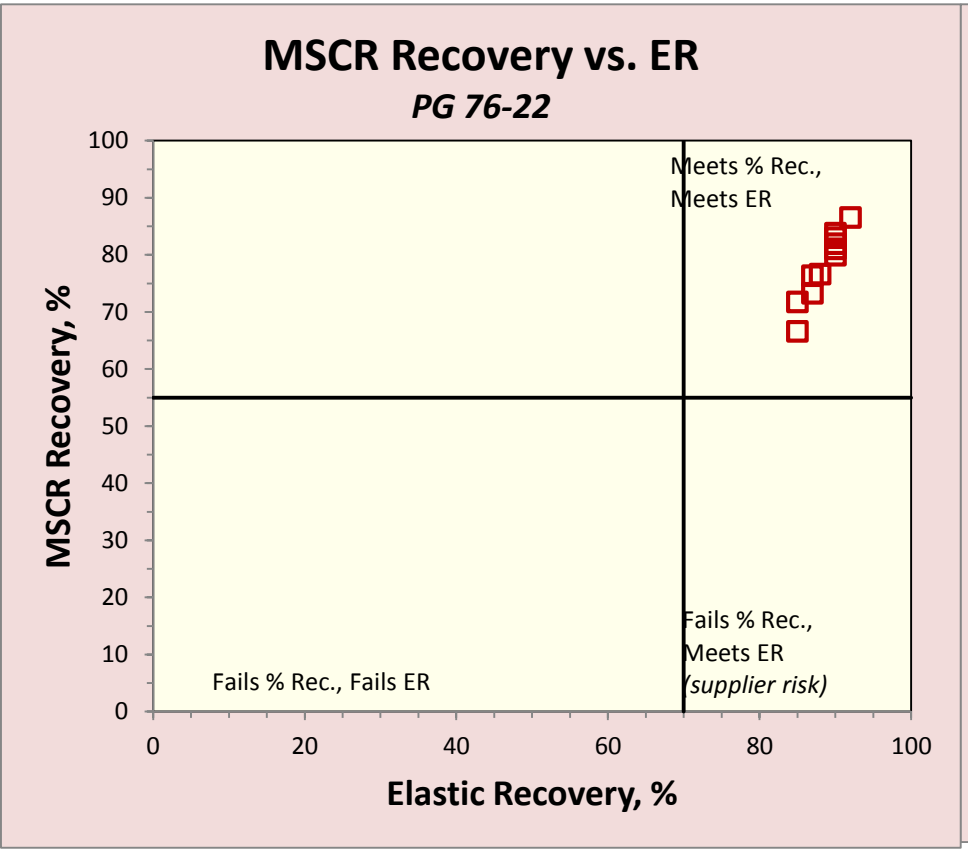

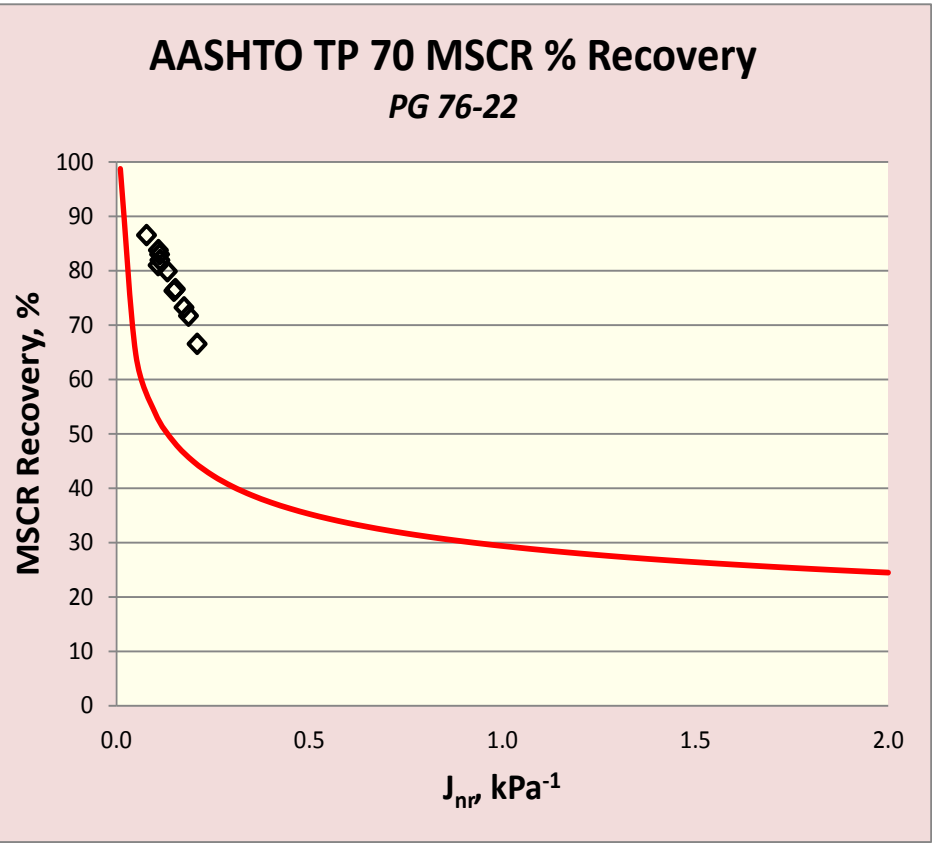

SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 2

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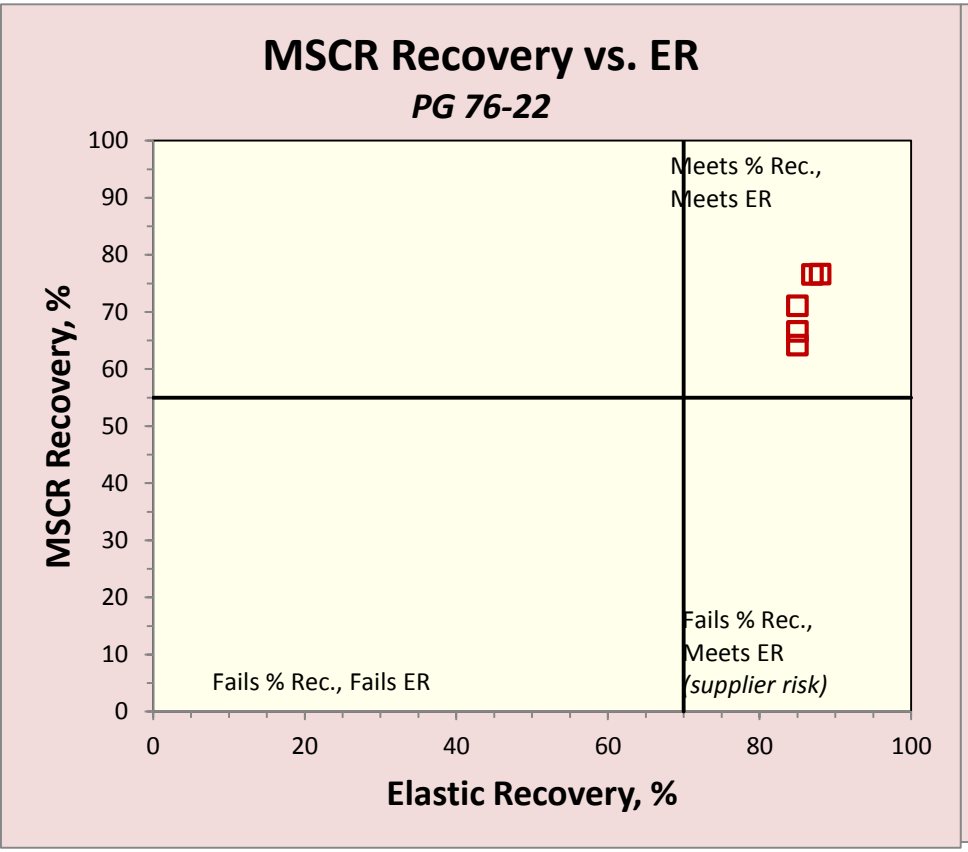

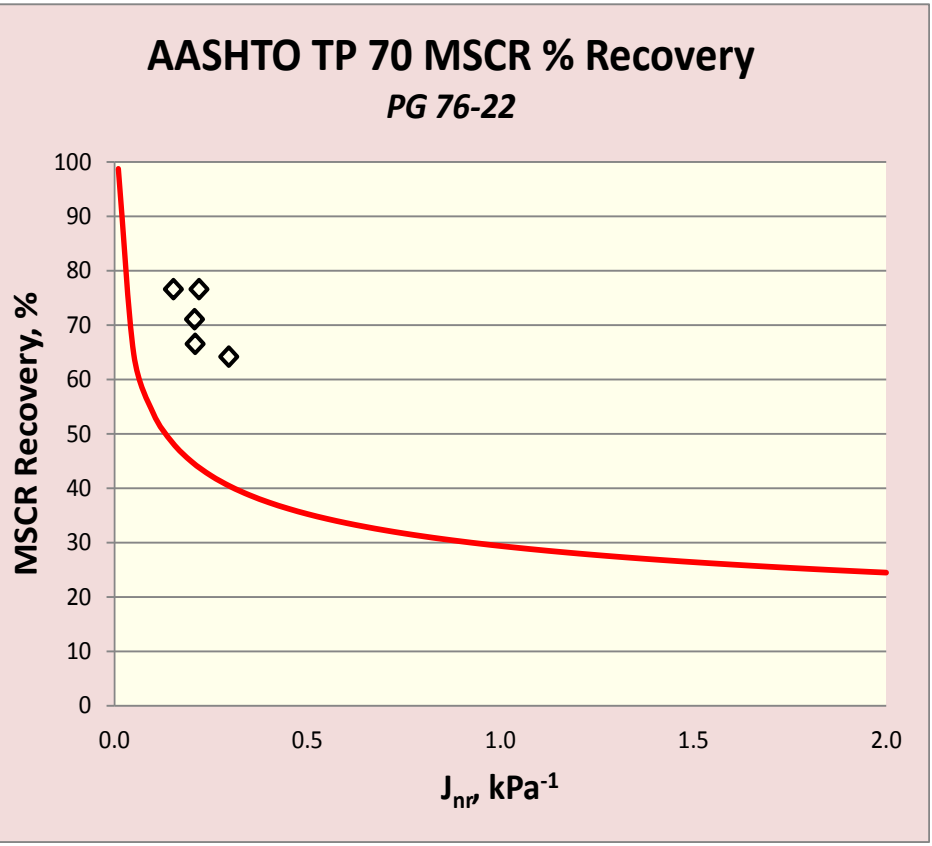

SEAUPG MSCR Evaluation: User 1 – PG 76-22 Binder Source 3

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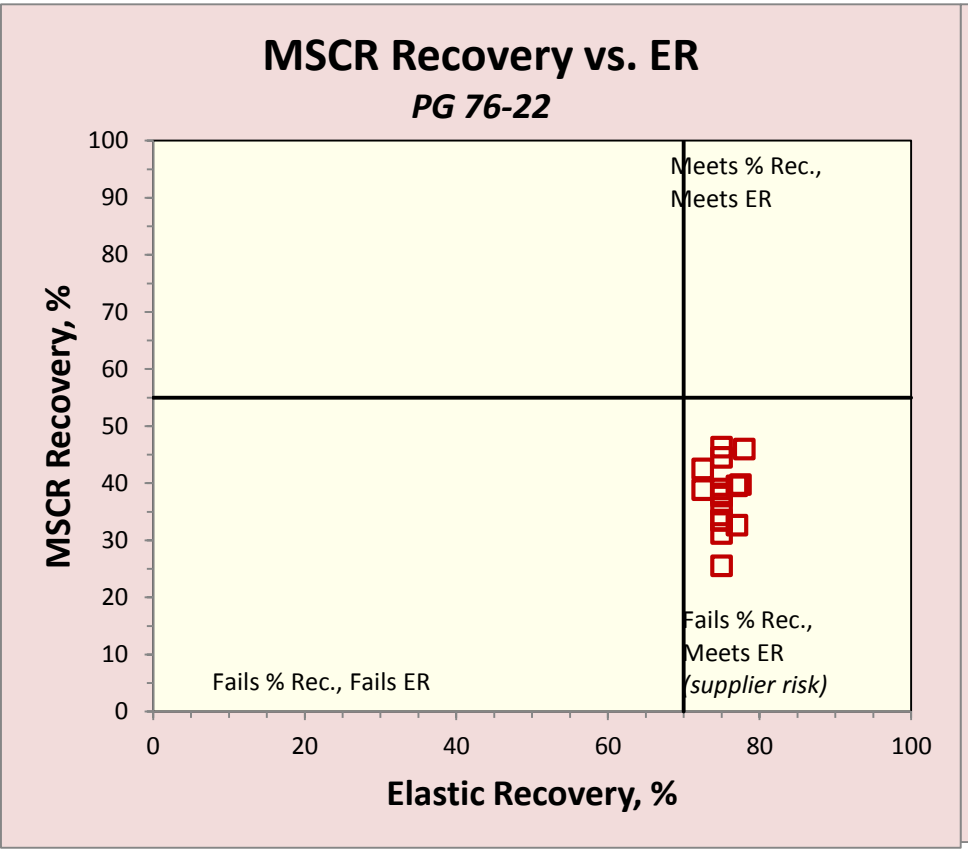

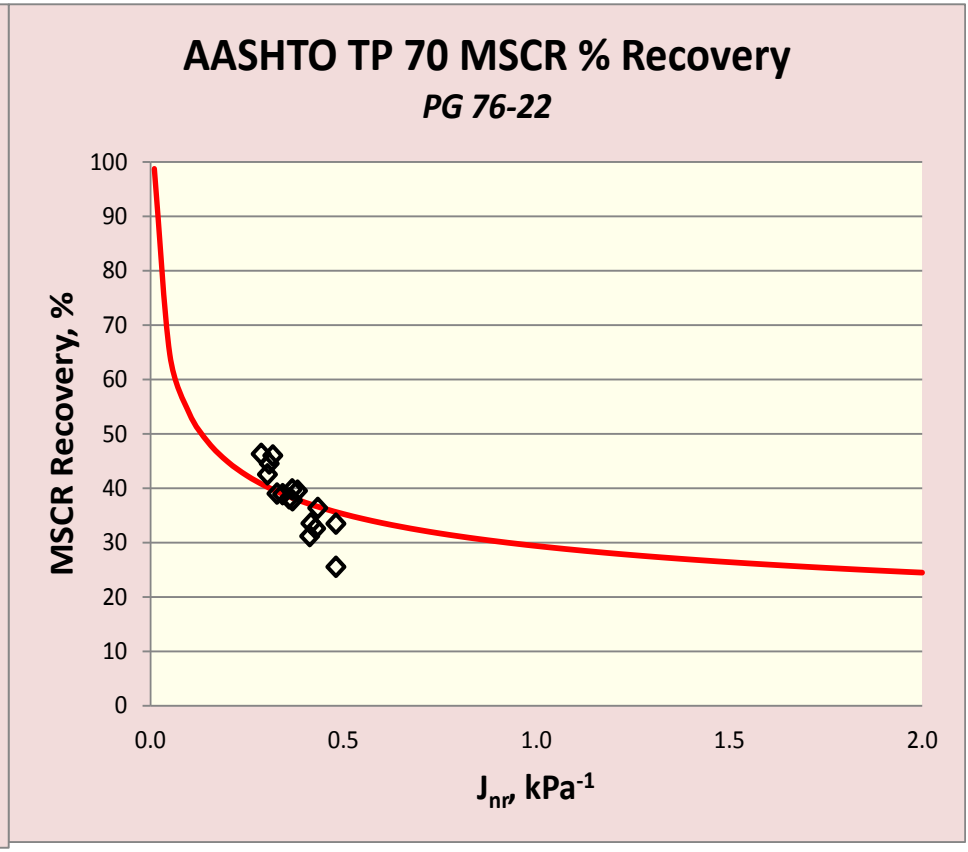

SEAUPG MSCR Evaluation: User 4 – All PG 76-22 Binders

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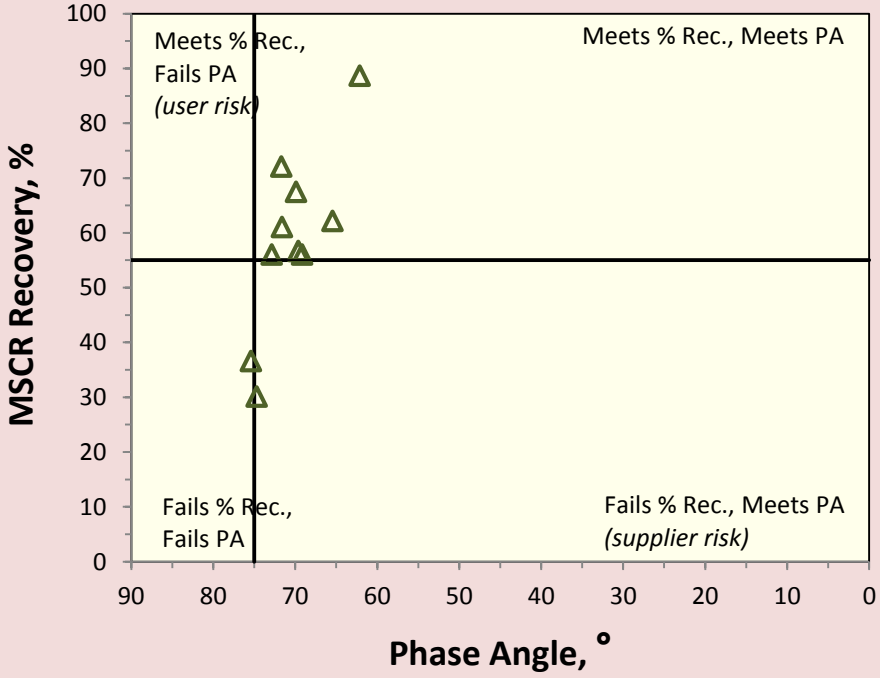
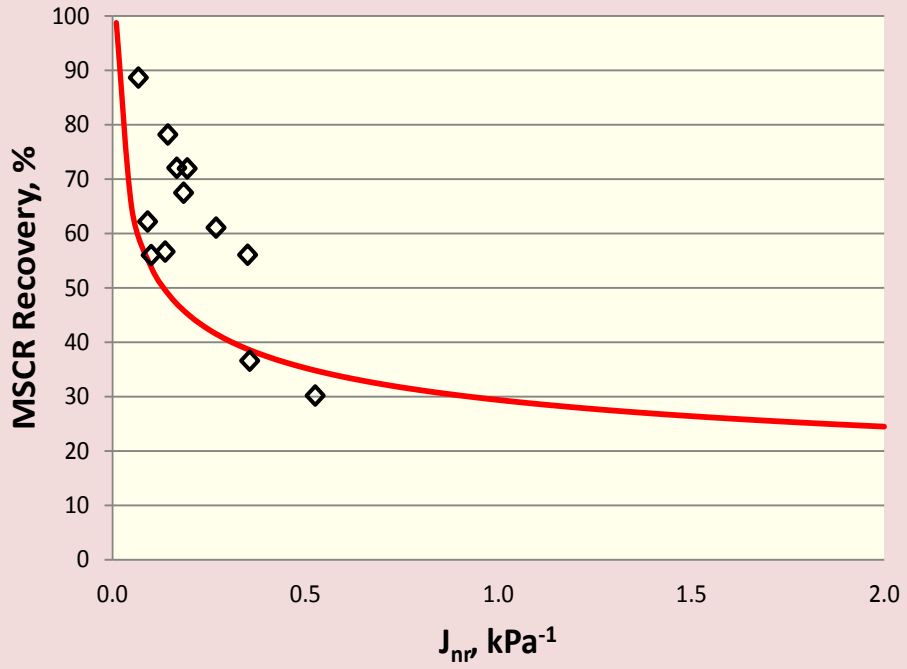
MSCR Recovery vs. Phase Angle

PG 76-22



AASHTO TP 70 MSCR % Recovery

PG 76-22



Thanks!

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