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Using the Multiple-Stress Creep-Recovery (MSCR) Test

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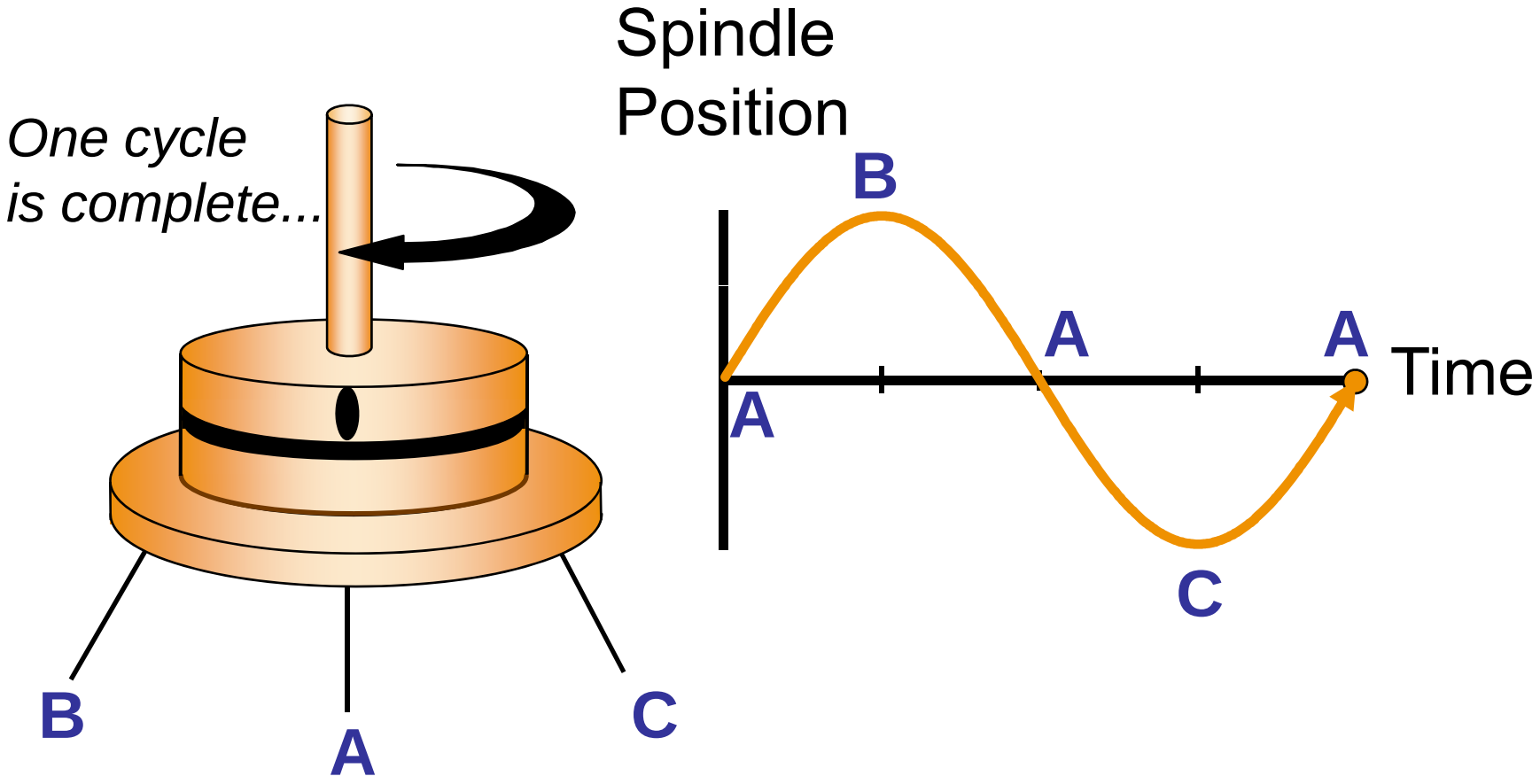
Acknowledgments

- DTFH61-08-H-00030
  - Cooperative Agreement between the FHWA and the Asphalt Institute
- John A. D'Angelo
- Asphalt Binder ETG
- Member Companies of the Asphalt Institute
  - Technical Advisory Committee

Discussion

- Background
- Basics of the MSCR test
- 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?
- Educational and implementation activities

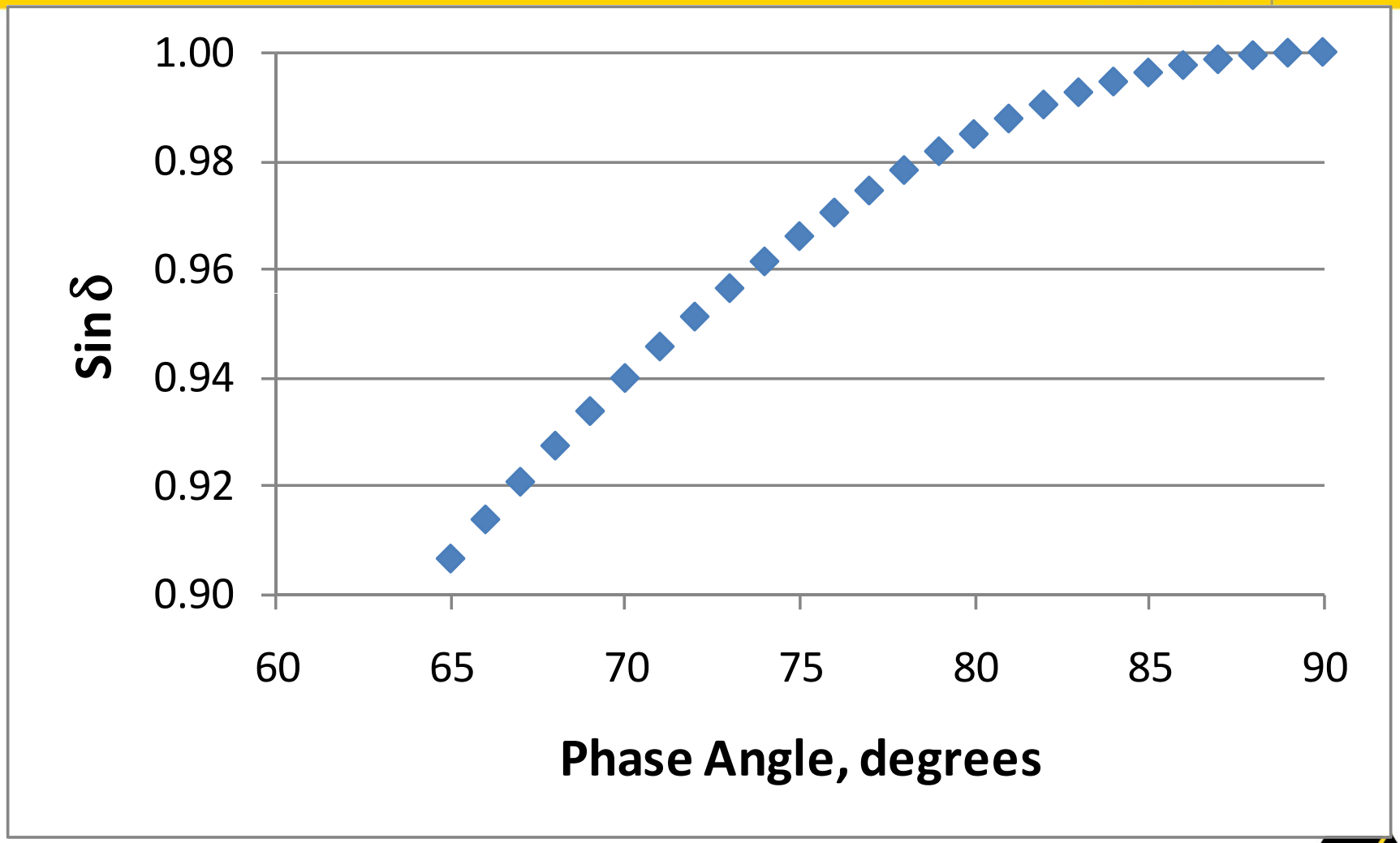
DSR Operation: AASHTO T315



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

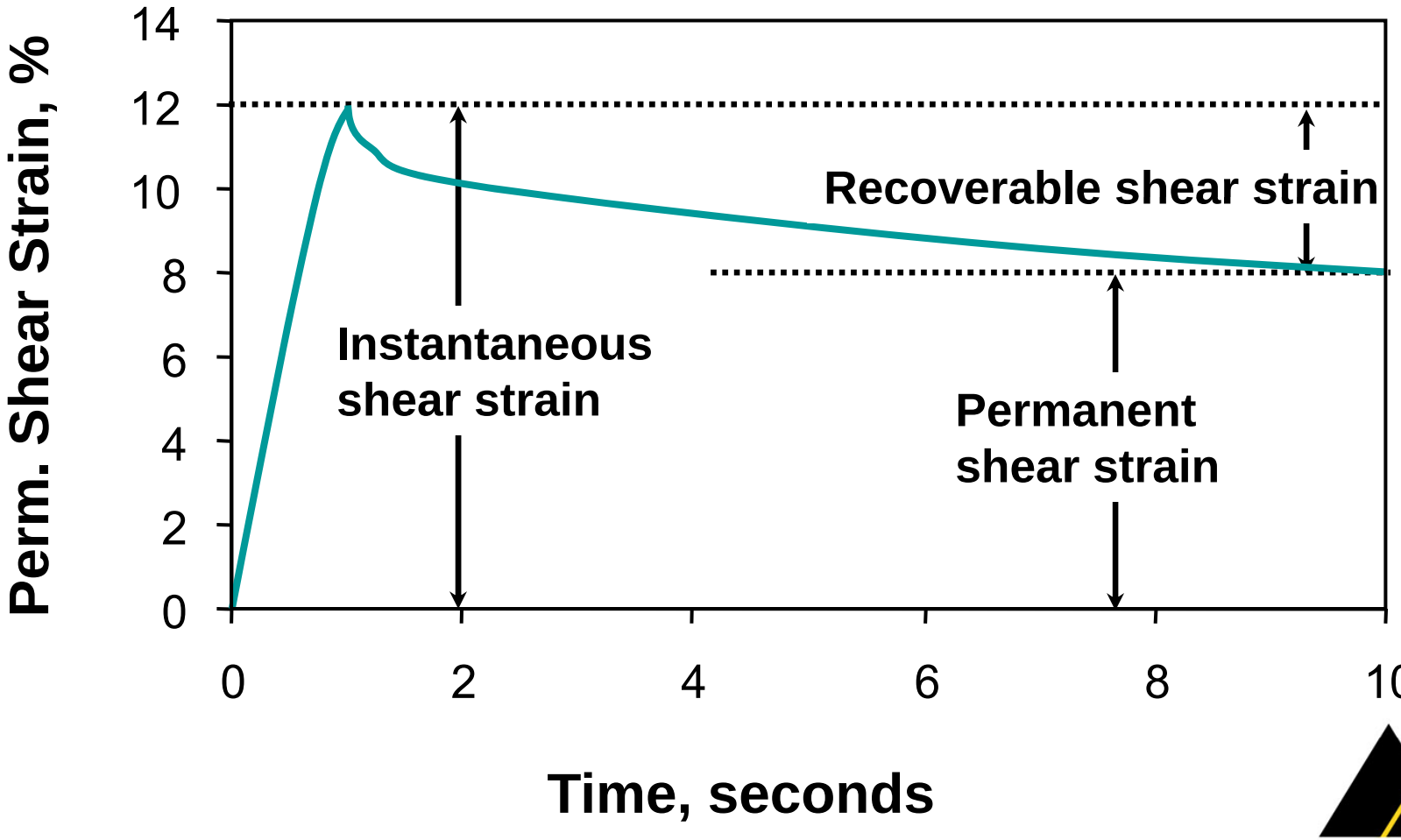
Effect of Phase Angle



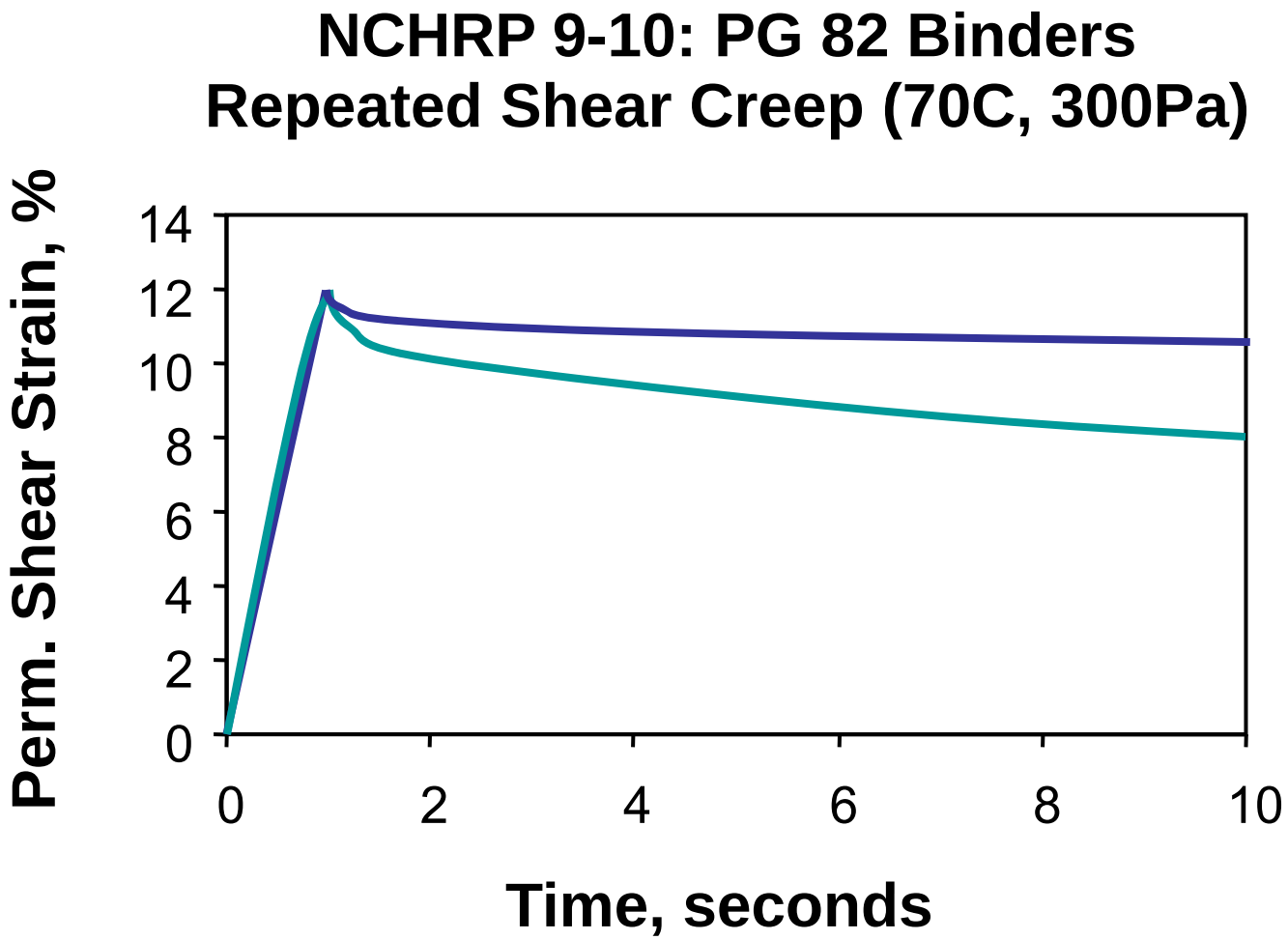
High Temperature Testing

- 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

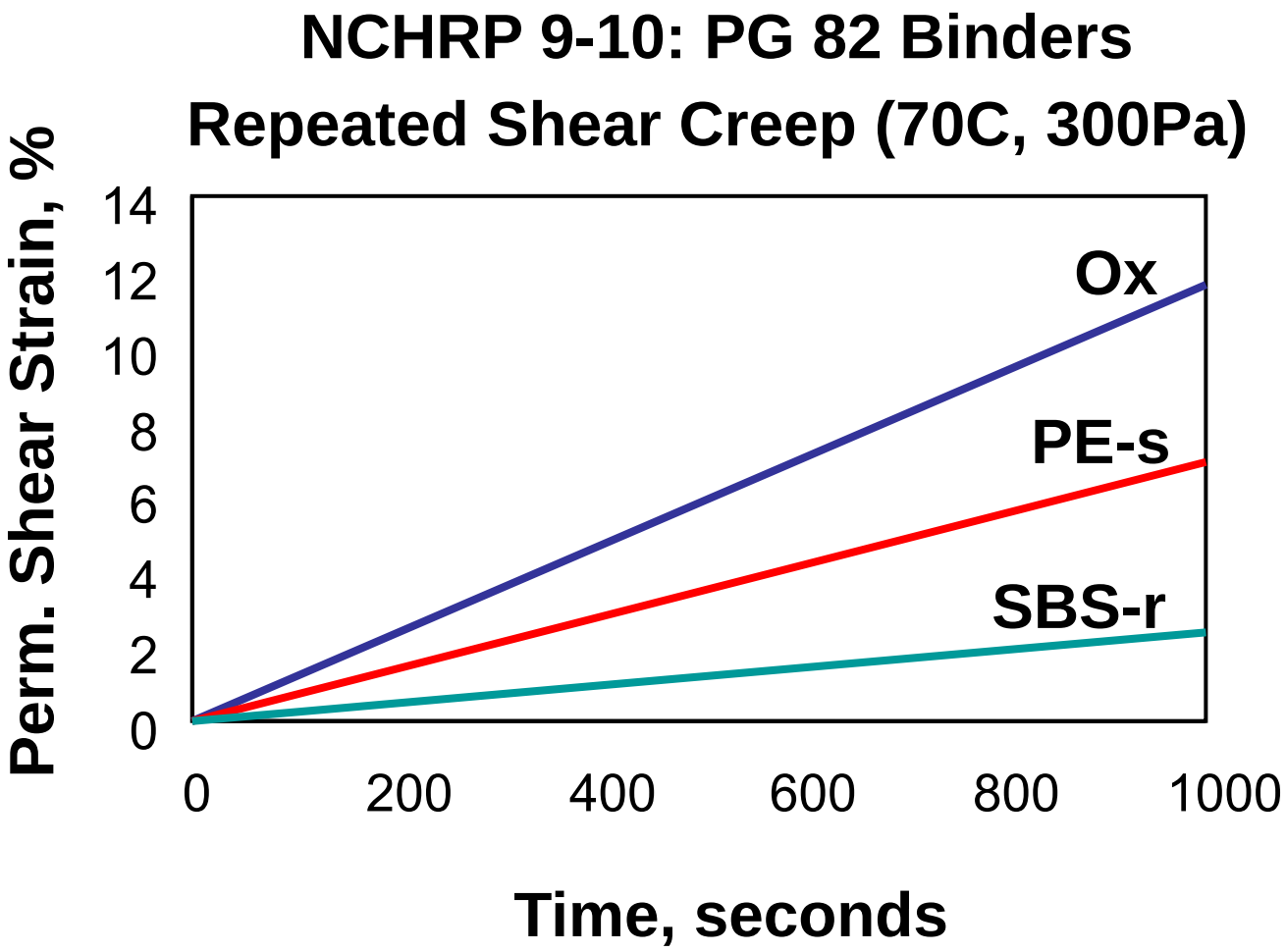
Repeated Shear Creep



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

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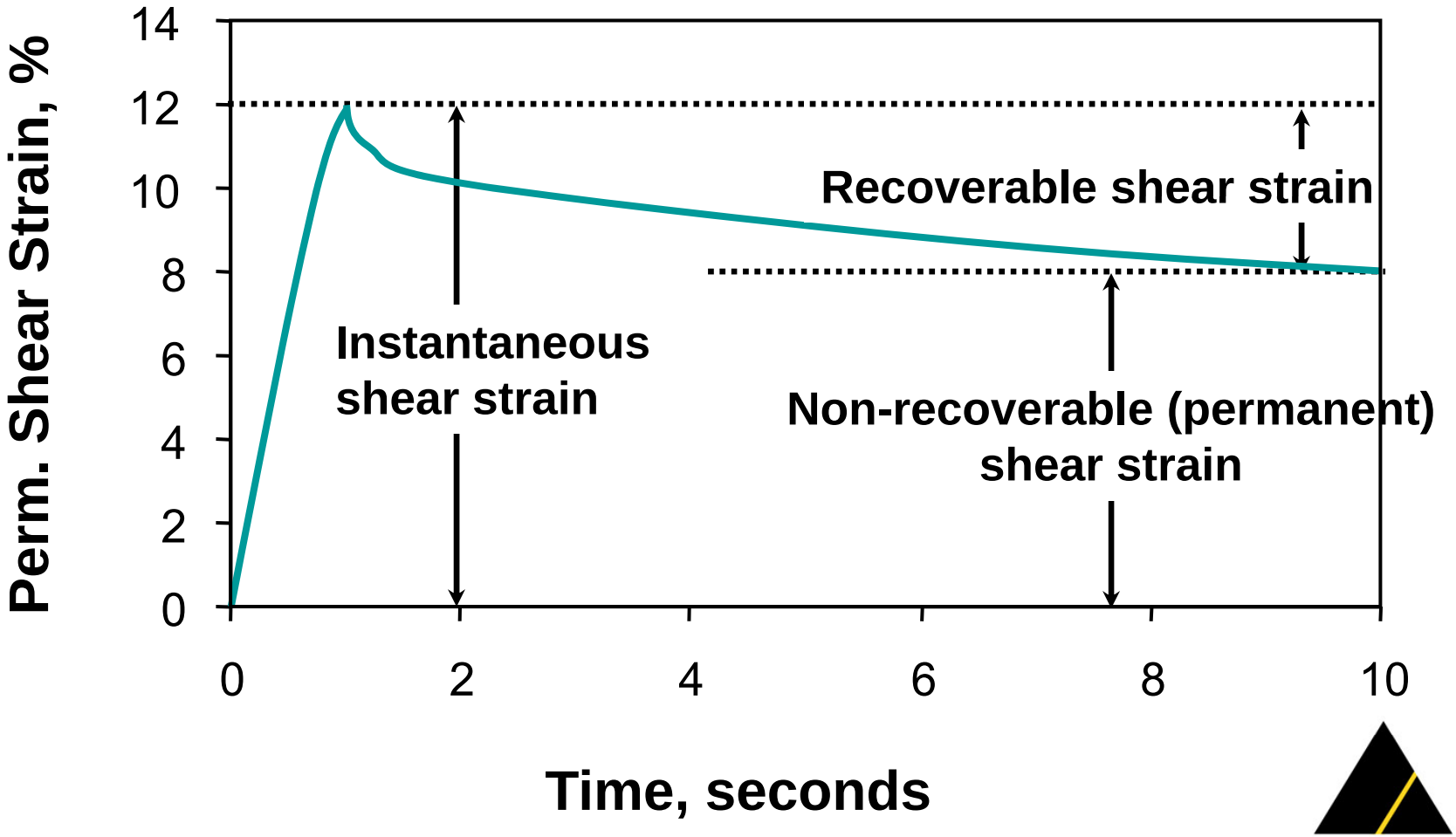
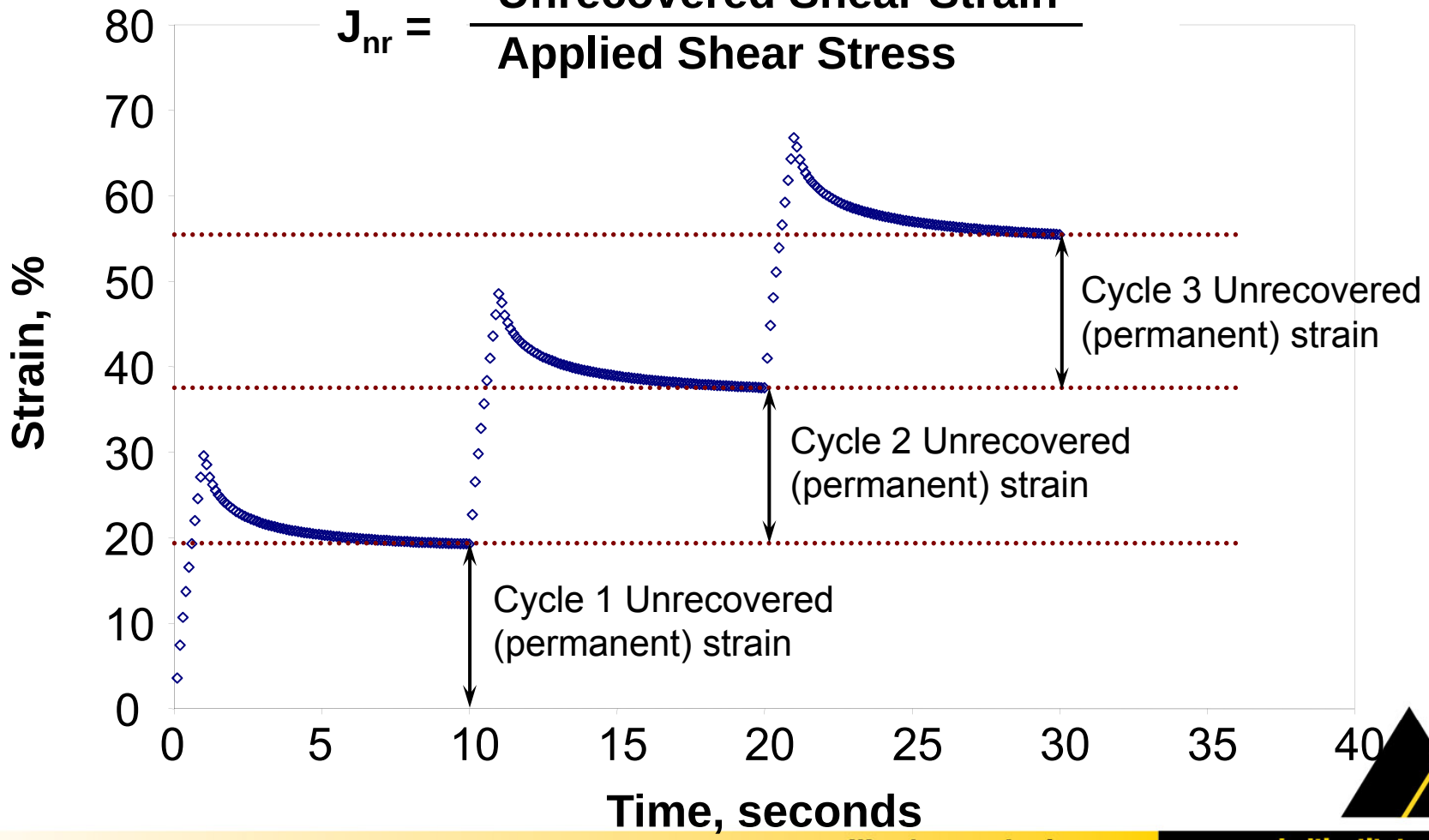
- Calculate Non-recoverable Creep Compliance (J_{nr})
  - Non-recoverable shear strain divided by applied shear stress
    - "J" = "compliance"
    - "nr" = "non-recoverable"
- Calculate Recovery for each Cycle, Stress
  - Difference between strain at end of recovery period and peak strain after creep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

MSCR

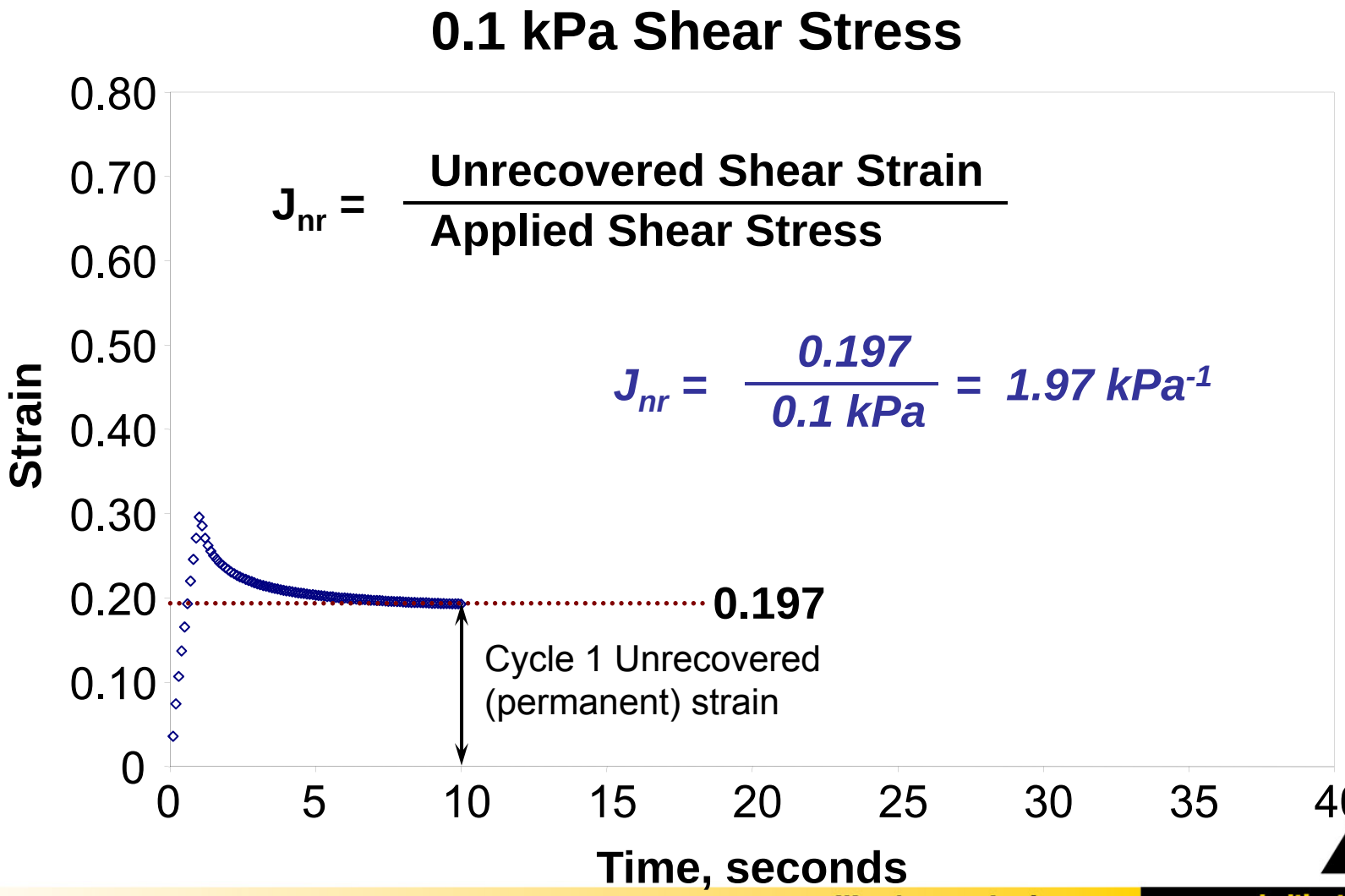

Perm. Shear Strain, %
14
12
10
8
6
4
2
0
0
2
4
6
8
10
Time, seconds
Instantaneous shear strain
Recoverable shear strain
Non-recoverable (permanent) shear strain

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

$$J_{nr} = \frac{\text{Unrecovered Shear Strain}}{\text{Applied Shear Stress}}$$



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



Relationship between Jnr and ALF Rutting 25.6kPa

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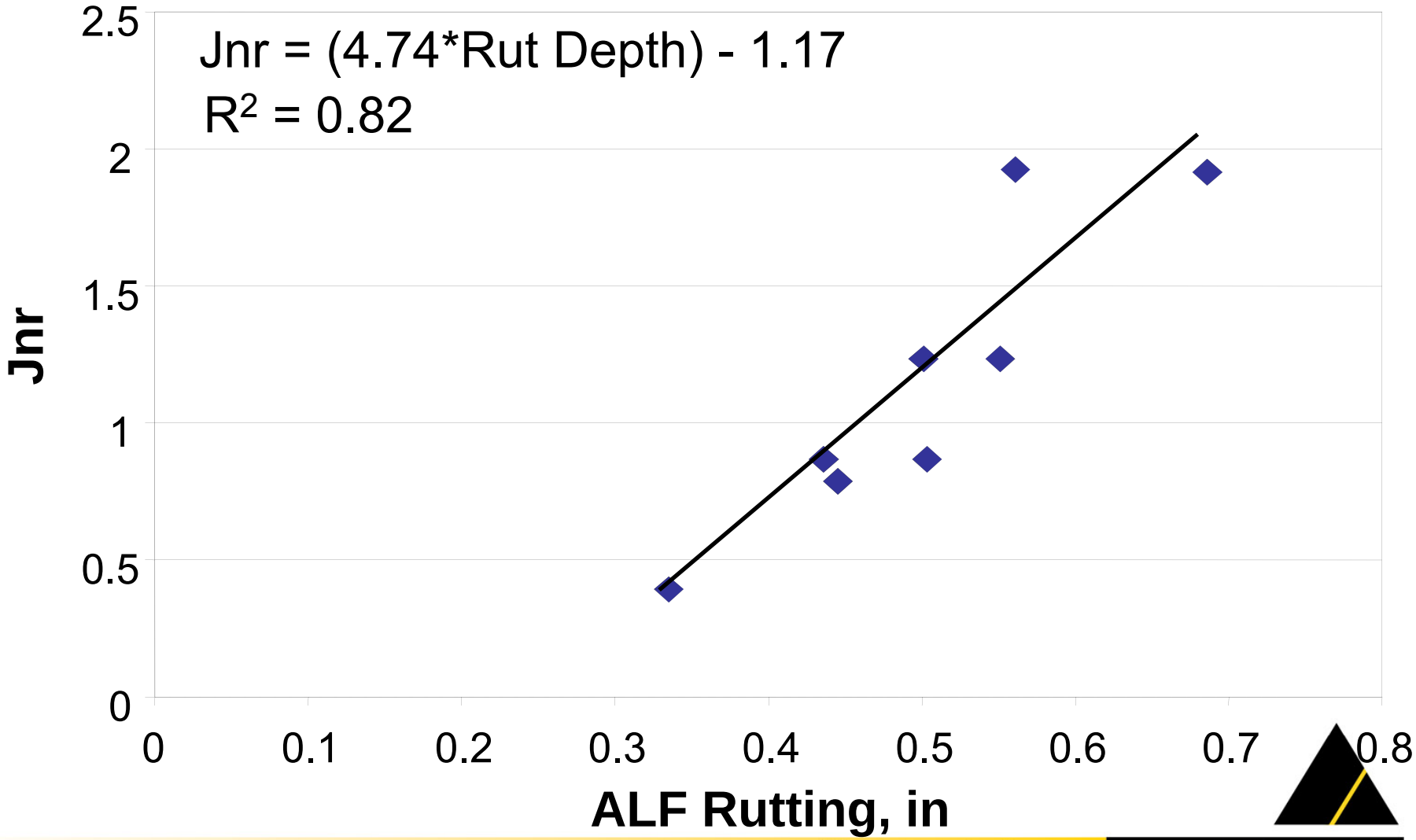

Mississippi I55: 6yr rutting J_{nr} 3.2 kPa

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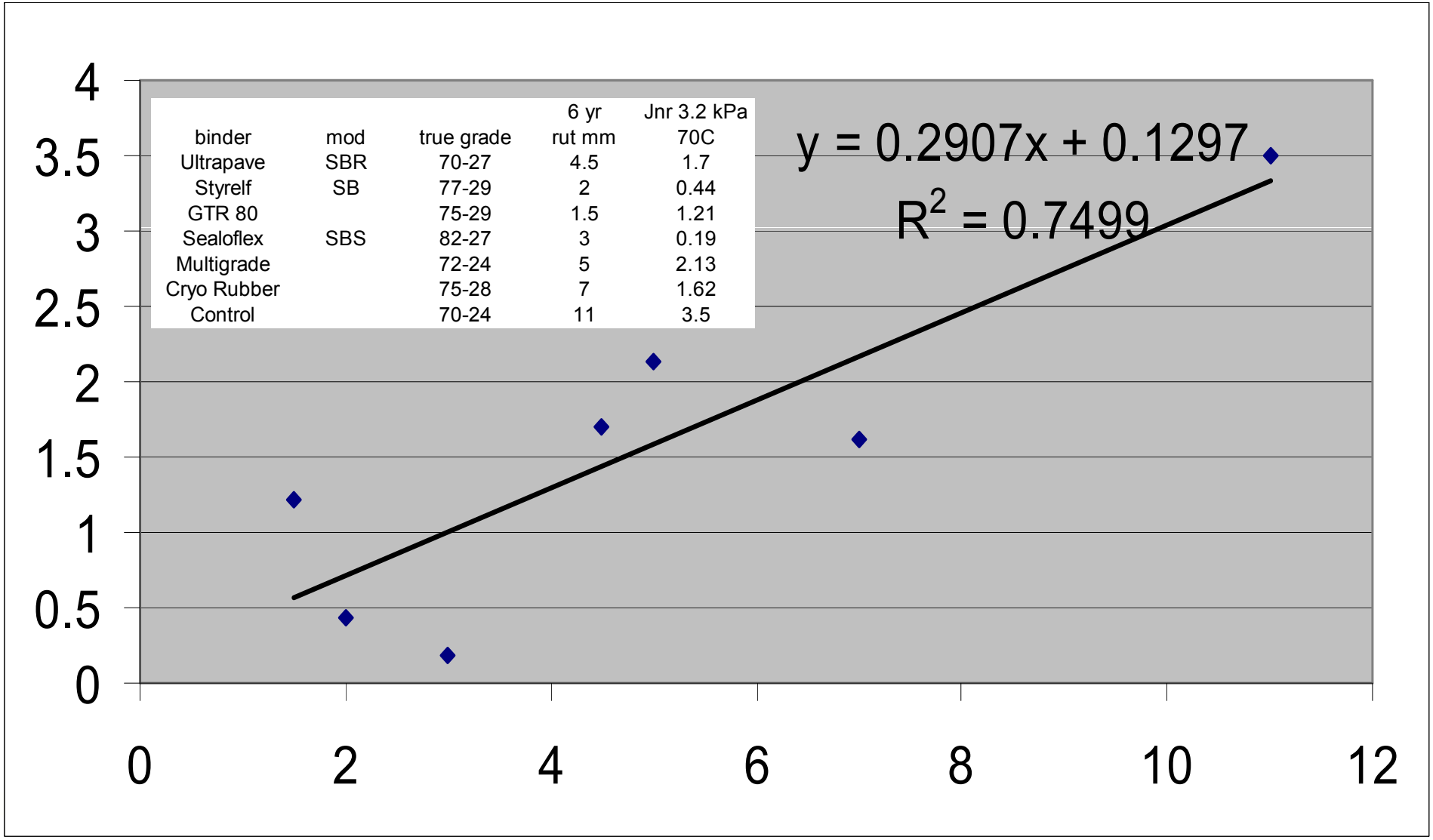

binder	mod	true grade	6 yr rut mm	Jnr 3.2 kPa 70C
Ultrapave	SBR	70-27	4.5	1.7
Styrelf	SB	77-29	2	0.44
GTR 80		75-29	1.5	1.21
Sealoflex	SBS	82-27	3	0.19
Multigrade		72-24	5	2.13
Cryo Rubber		75-28	7	1.62
Control		70-24	11	3.5

MSCR: What is % Recovery?

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- 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

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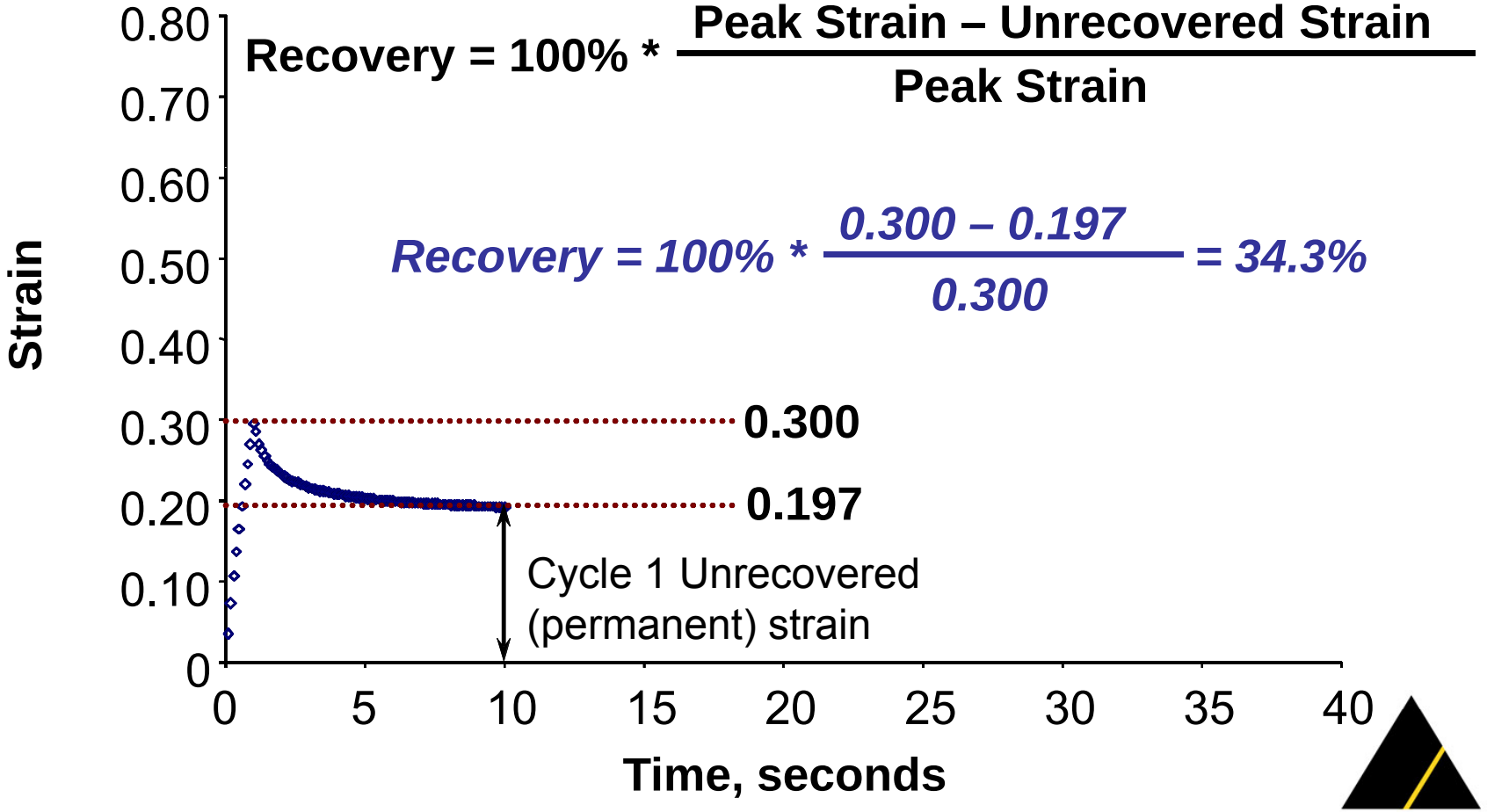
3.2 kPa Shear Stress

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

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



MSCR Recovery: Validate Polymer Modification

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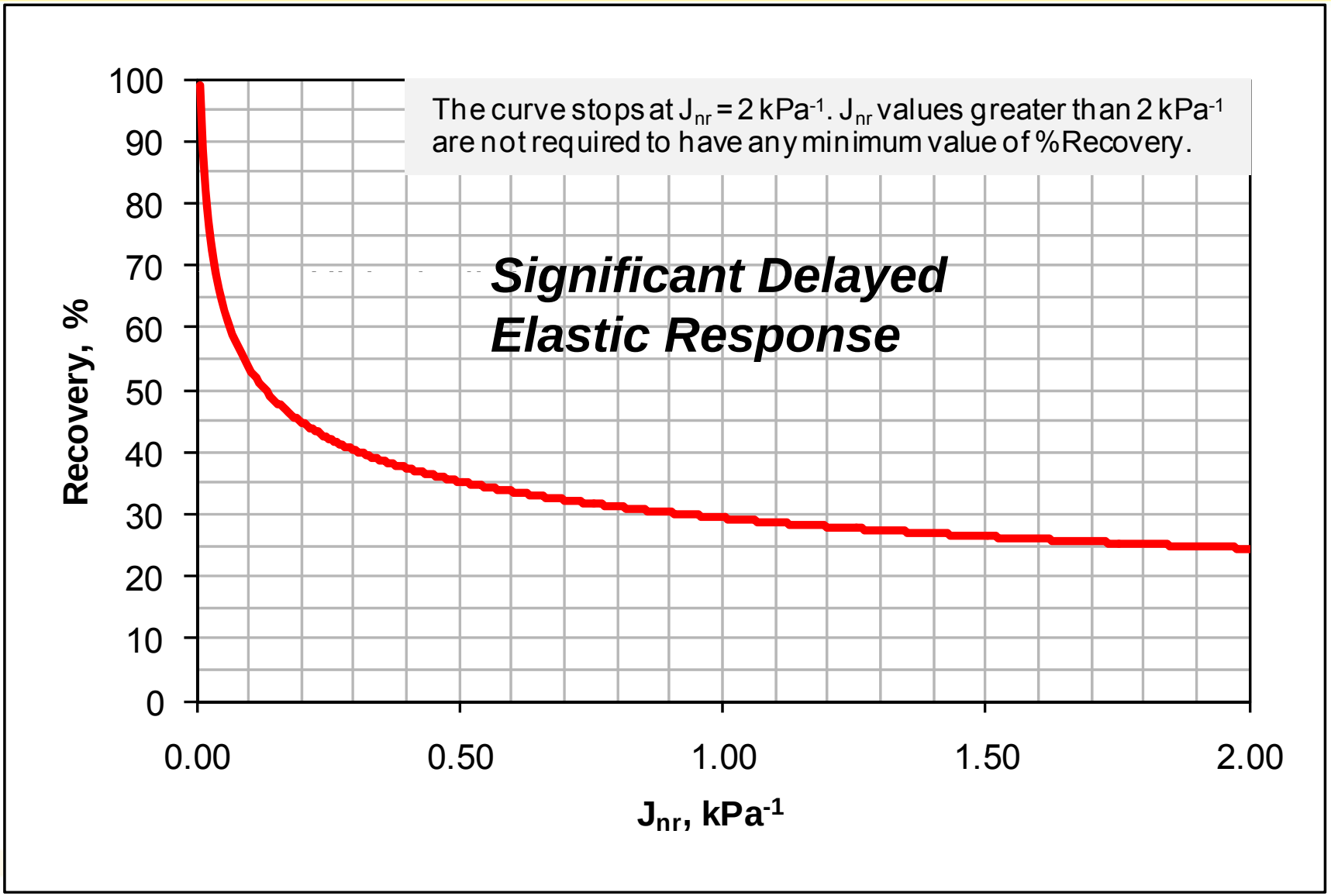

Table for MSCR % Recovery: Minimum Values

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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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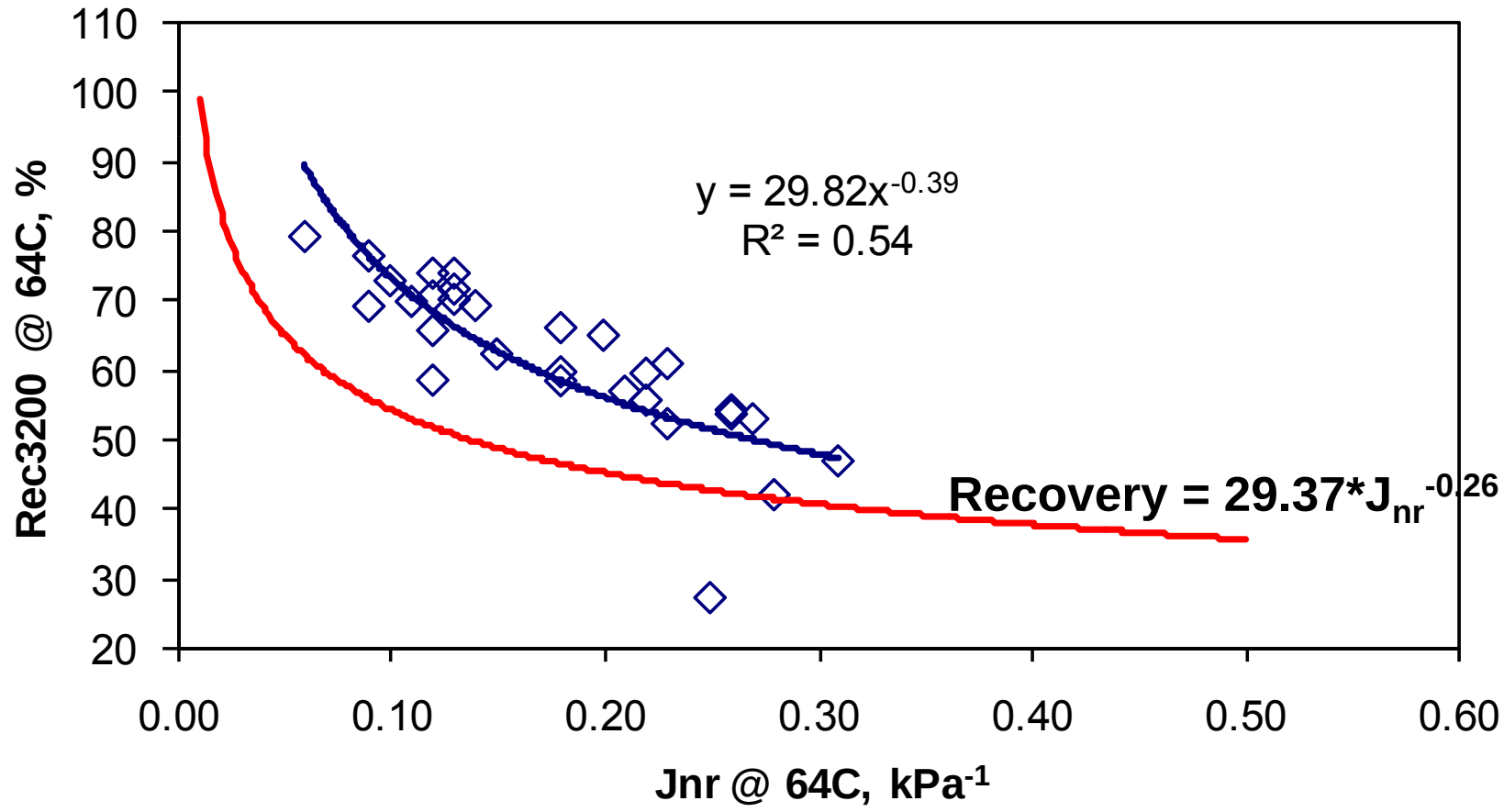

Evaluation of the MSCR Test for Canadian Asphalt Binders

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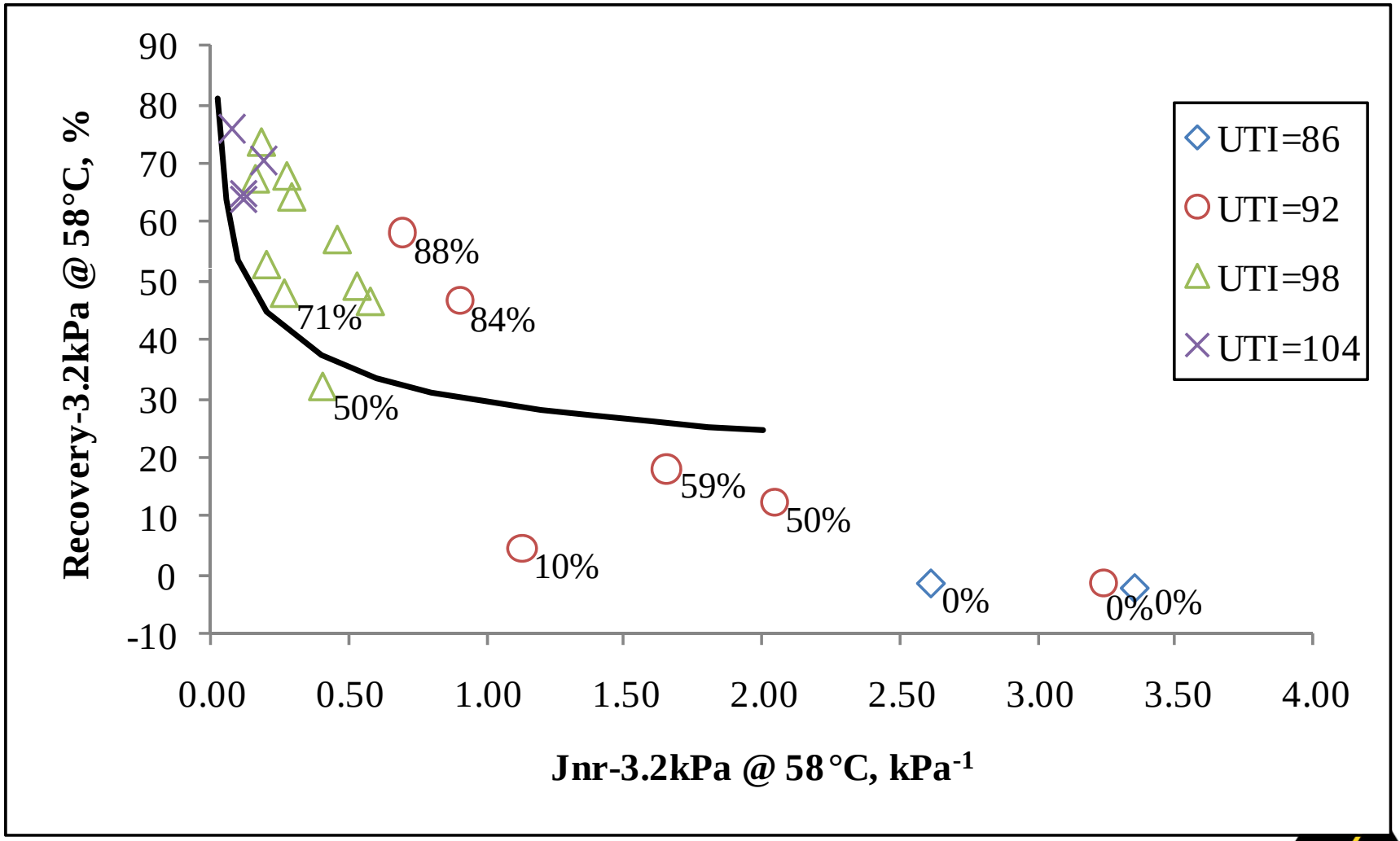

AASHTO MP19

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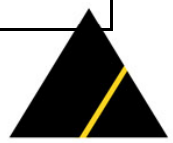
	PG 64					
	-10	-16	-22	-28	-34	-40
	Original Binder					
DSR (T315) – temp @ 10 rad/s $G^*/\sin\delta \geq 1.00$ kPa	64					
	RTFO-Aged Binder					
MSCR (TP70) – temp All Grades: Jnr,Diff ≤ 75% "S" Grade: Jnr-3.2 ≤ 4.0 kPa^{-1} "H" Grade: Jnr-3.2 ≤ 2.0 kPa^{-1} "V" Grade: Jnr-3.2 ≤ 1.0 kPa^{-1} "E" 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

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

AASHTO MP19

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- 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

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

PG 64-22V 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 64-22V Asphalt Binder

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- 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 64-22V 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

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- Telephone survey in 2010 and since indicate that there are barriers to state MSCR implementation
  - Inadequate DSR equipment/software
  - Lack of resources to perform transitional tests
  - Lack of guidance from suppliers and other states
  - Uncertainty about effect on binder supply and modification

Implementation: SEAUPG

- Task Force agreed to conduct survey of 14 SEAUPG states
  - Determine current capabilities to run MSCR
  - Determine need for training
  - Find out what barriers exist to testing and/or implementation

Survey Results - Barriers

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- 9 of 14 states said biggest barrier was concerns over correlation between existing PG Plus and new MSCR criteria
- Comment:
  - Satisfied with the PG 76-22 polymer modified binder performance. There is a perception that moving to MSCR test may result in lower polymer loading and reduction in binder performance.

Survey Results - Training

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- 11 of 14 states said they could use some type of training
  - 8 requested classroom training
  - 9 requested laboratory training
  - Comments:
    - More important than training is keeping abreast of progress around the country
    - Internet based training would be preferred since travel is restricted

Implementation Activities

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

Binder AR (PG 64-22): Jnr-3.2 at 64°C

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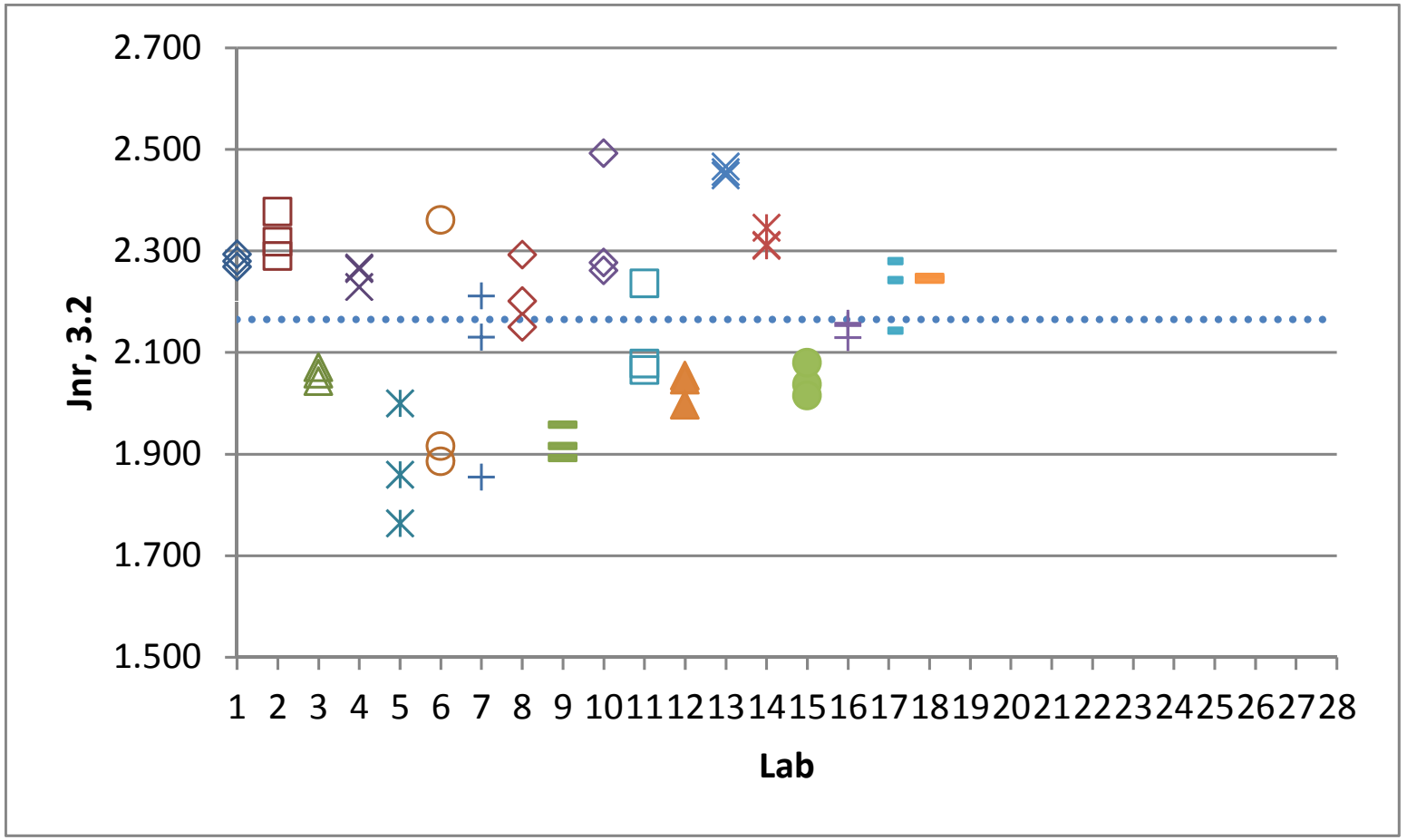

Repeatability and Reproducibility Estimates (before removal of outliers)

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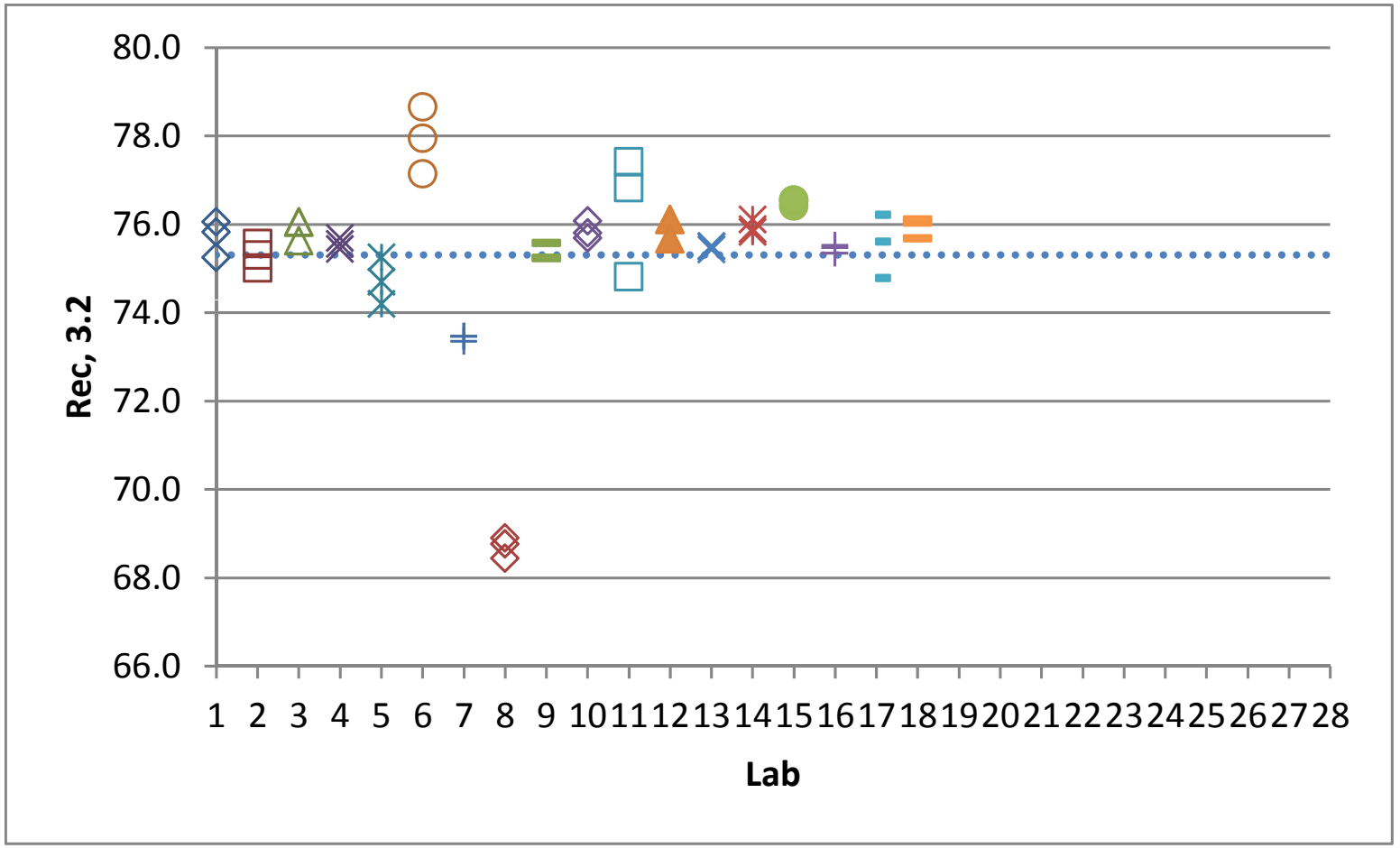
Jnr (3.2 kPa) @ 64°C

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-}bar}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
AO	PG 64-22	4.73445	0.30437	0.28046	0.38090	0.78530	1.06651	5.9%	16.6%	8.0%	22.5%
BO	PG 76-22	0.31478	0.03366	0.01686	0.03636	0.04722	0.10182	5.4%	15.0%	11.6%	32.3%
CO	PG 70-22	1.09091	0.09018	0.05083	0.09928	0.14234	0.27797	4.7%	13.0%	9.1%	25.5%
AR	PG 64-22	2.16532	0.15582	0.09492	0.17403	0.26578	0.48729	4.4%	12.3%	8.0%	22.5%
BR	PG 76-22	0.13844	0.01514	0.00591	0.01589	0.01654	0.04448	4.3%	11.9%	11.5%	32.1%
CR	PG 70-22	0.42219	0.03845	0.01743	0.04100	0.04880	0.11479	4.1%	11.6%	9.7%	27.2%

Binder BR (PG 76-22): Rec-3.2 at 64°C



Repeatability and Reproducibility Estimates (before removal of outliers)

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Recovery (3.2 kPa) @ 64°C

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-}bar}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
AO	PG 64-22	-0.70138	1.16245	0.27286	1.18361	0.76402	3.31411	-38.9%	-108.9%	-168.8%	-472.5%
BO	PG 76-22	69.86953	2.04476	0.50367	2.08571	1.41028	5.83998	0.7%	2.0%	3.0%	8.4%
CO	PG 70-22	35.33316	1.45239	0.89656	1.62644	2.51037	4.55404	2.5%	7.1%	4.6%	12.9%
AR	PG 64-22	0.85334	0.98338	0.13352	0.98941	0.37387	2.77035	15.6%	43.8%	115.9%	324.6%
BR	PG 76-22	75.30791	1.86344	0.46241	1.90130	1.29475	5.32365	0.6%	1.7%	2.5%	7.1%
CR	PG 70-22	47.66866	1.67845	0.70757	1.77510	1.98119	4.97028	1.5%	4.2%	3.7%	10.4%

Implementation Assistance

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- 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

Educational Activities

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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

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 64-22 E"

Implementation

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Some agencies may be reluctant to implement MSCR fully, since the names by which they refer to binder types will necessarily change.

"PG 64-22 H" instead of "PG 70-22," for a possible example

AI's "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification."

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

Thanks!

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