Understanding and Implementing the Multiple Stress Creep Recovery (MSCR) Test and Specification

Mike Anderson, Asphalt Institute

Association of Modified Asphalt Producers
Annual Meeting
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Golf Score

$y = mx+b$

$R^2 = 0.75$

Instances of …

Acknowledgments

- Federal Highway Administration
  - John Bukowski
- Dr. John D'Angelo
- Asphalt Binder Expert Task Group
- Member Companies of the Asphalt Institute
  - Technical Advisory Committee

Discussion

- Background
- Basics of the MSCR test
- How do MSCR results (Jnr) relate to rutting?
- How can MSCR Recovery be used and what does it indicate?
- How does the proposed specification work?
- Educational activities
- Implementation activities

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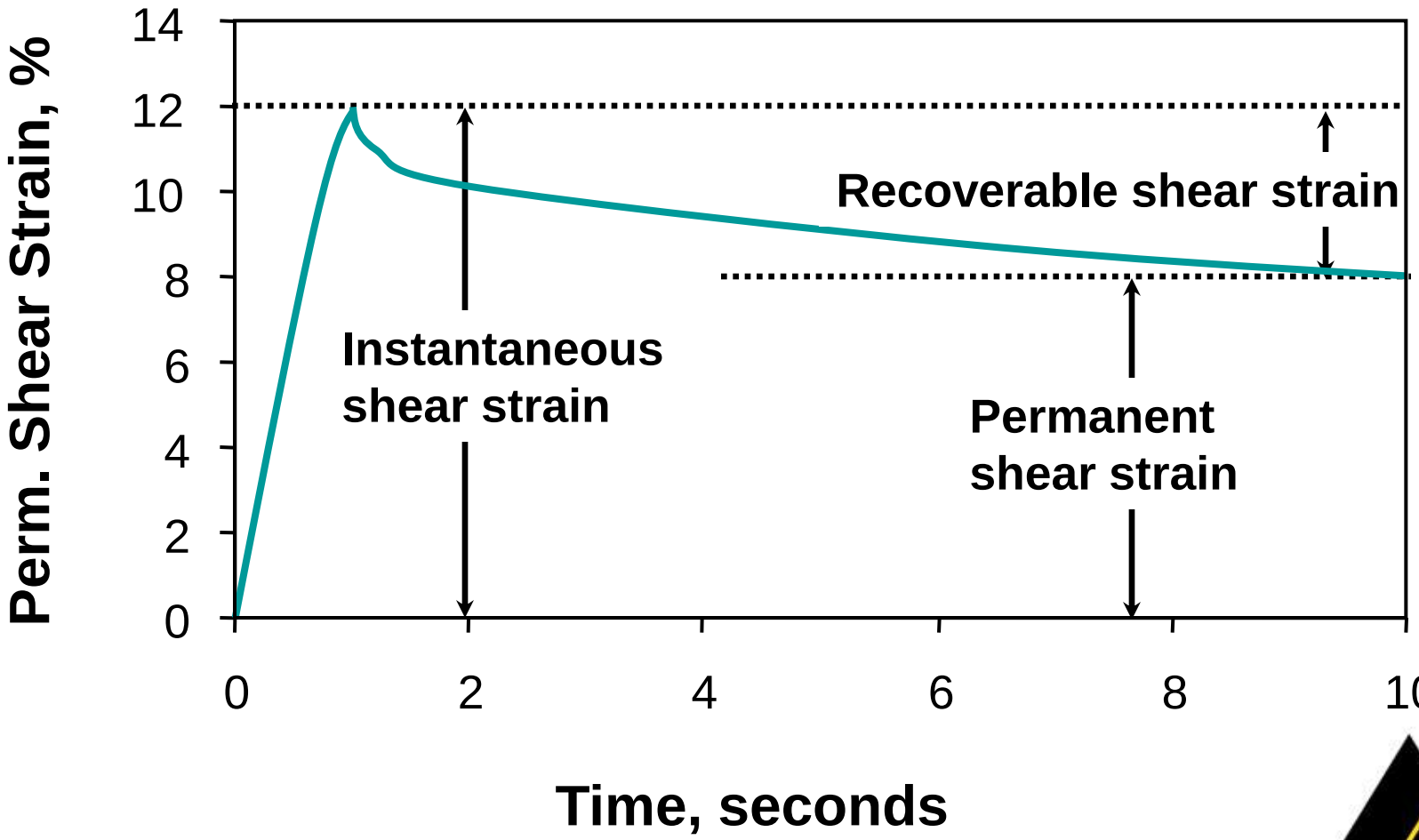
- **Educational activities**
- **Implementation activities**

Repeated Shear Creep



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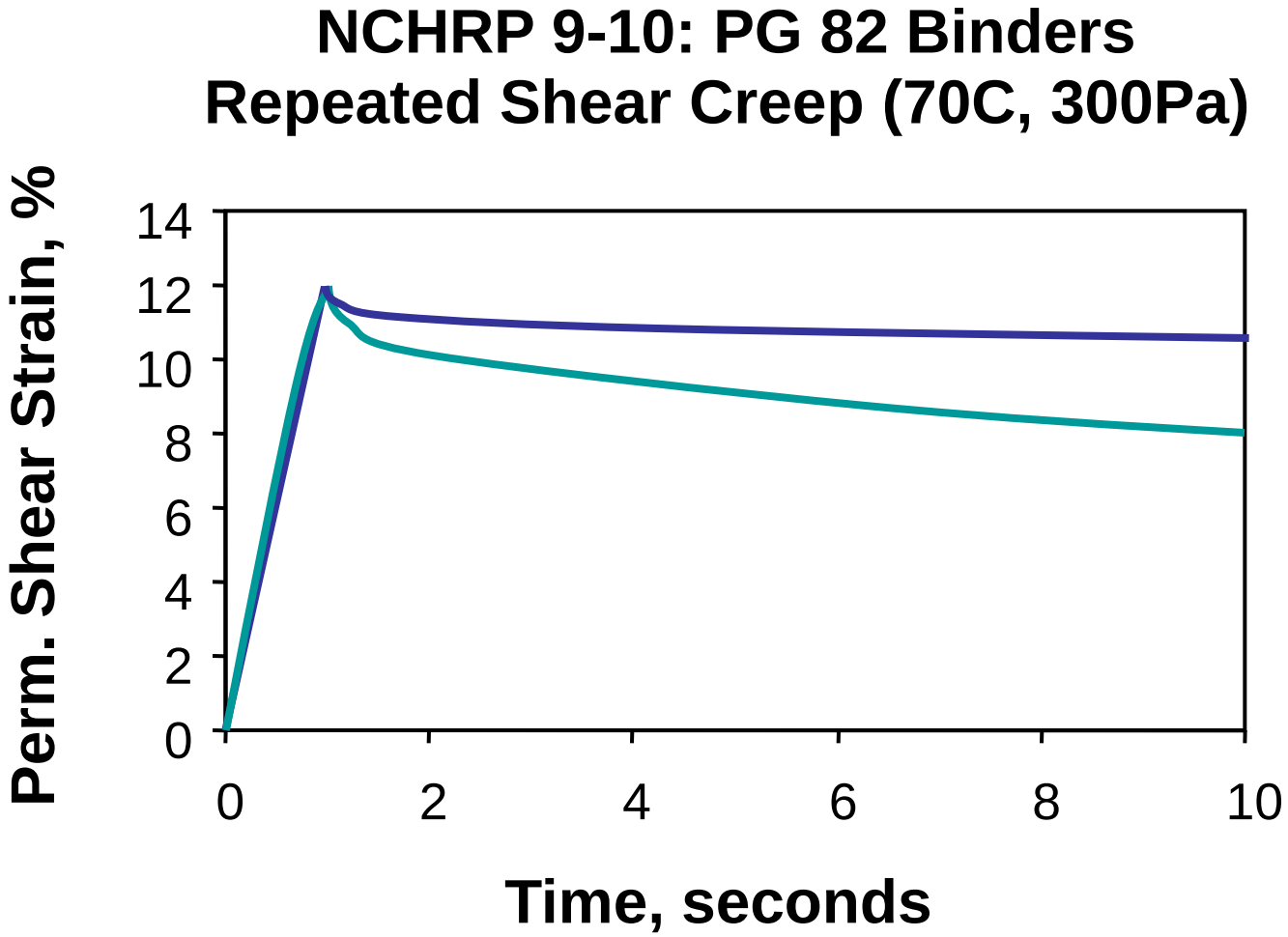
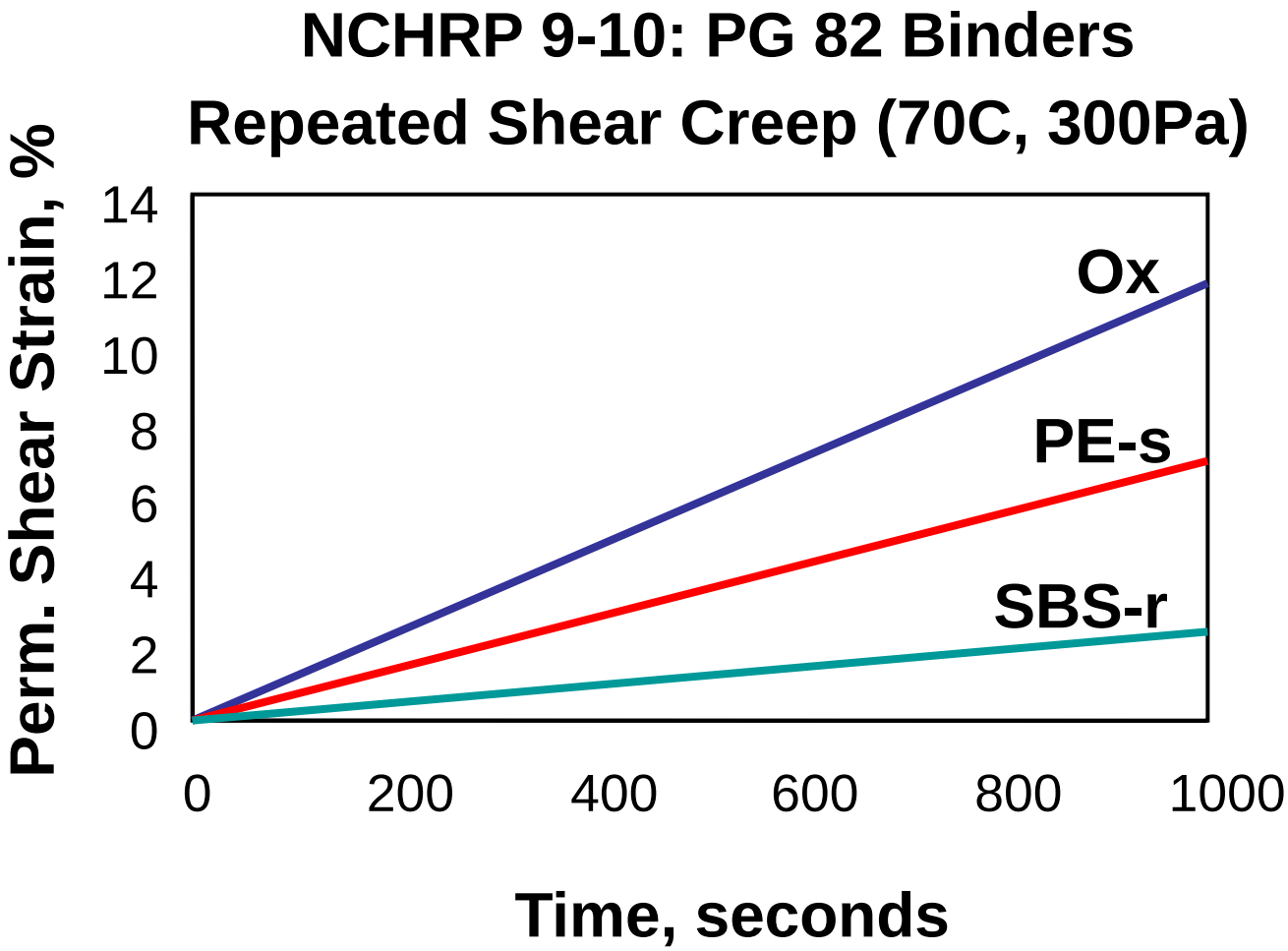
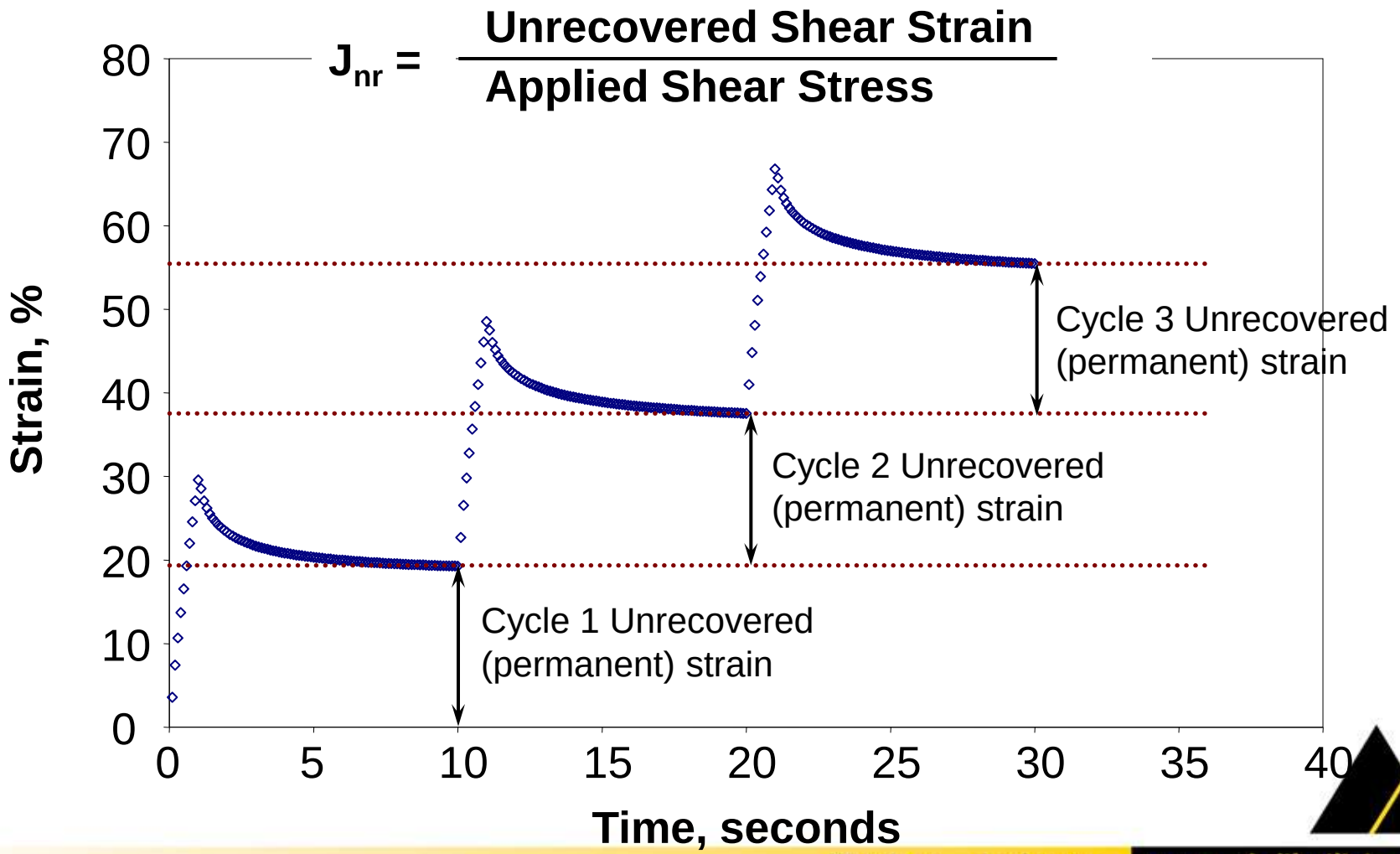


Repeated Shear Creep



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



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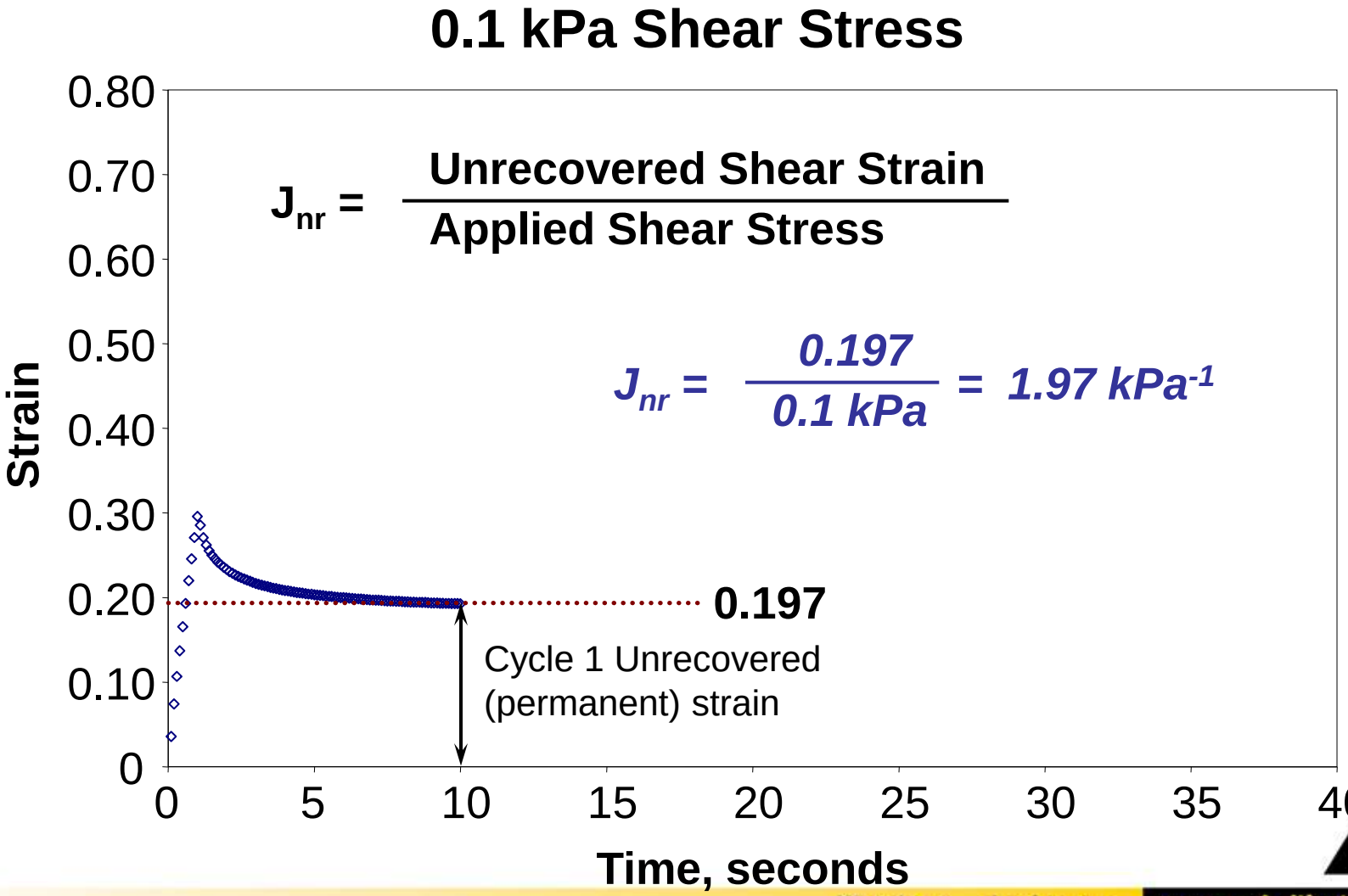
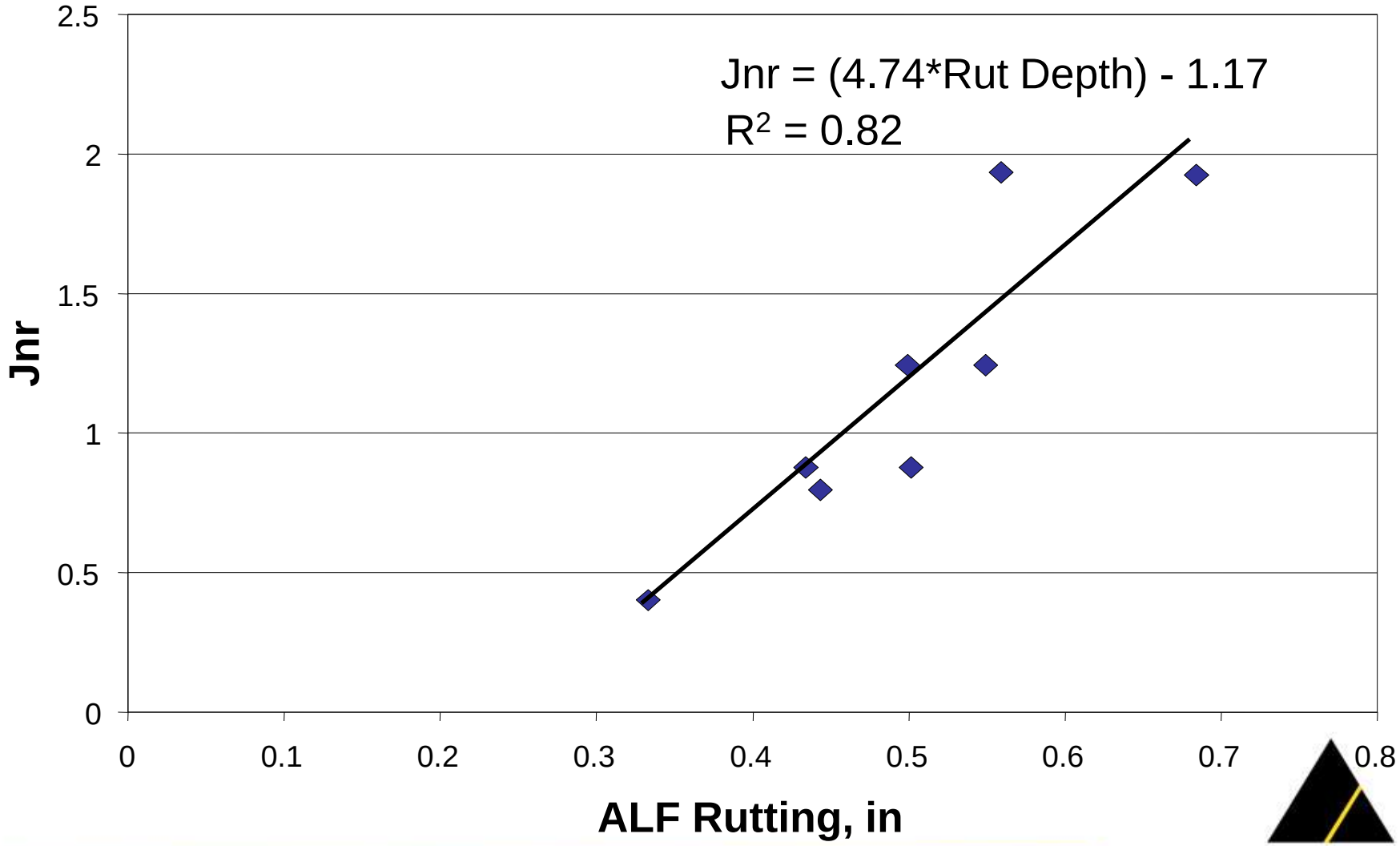


Relationship between Jnr and ALF Rutting 25.6kPa



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

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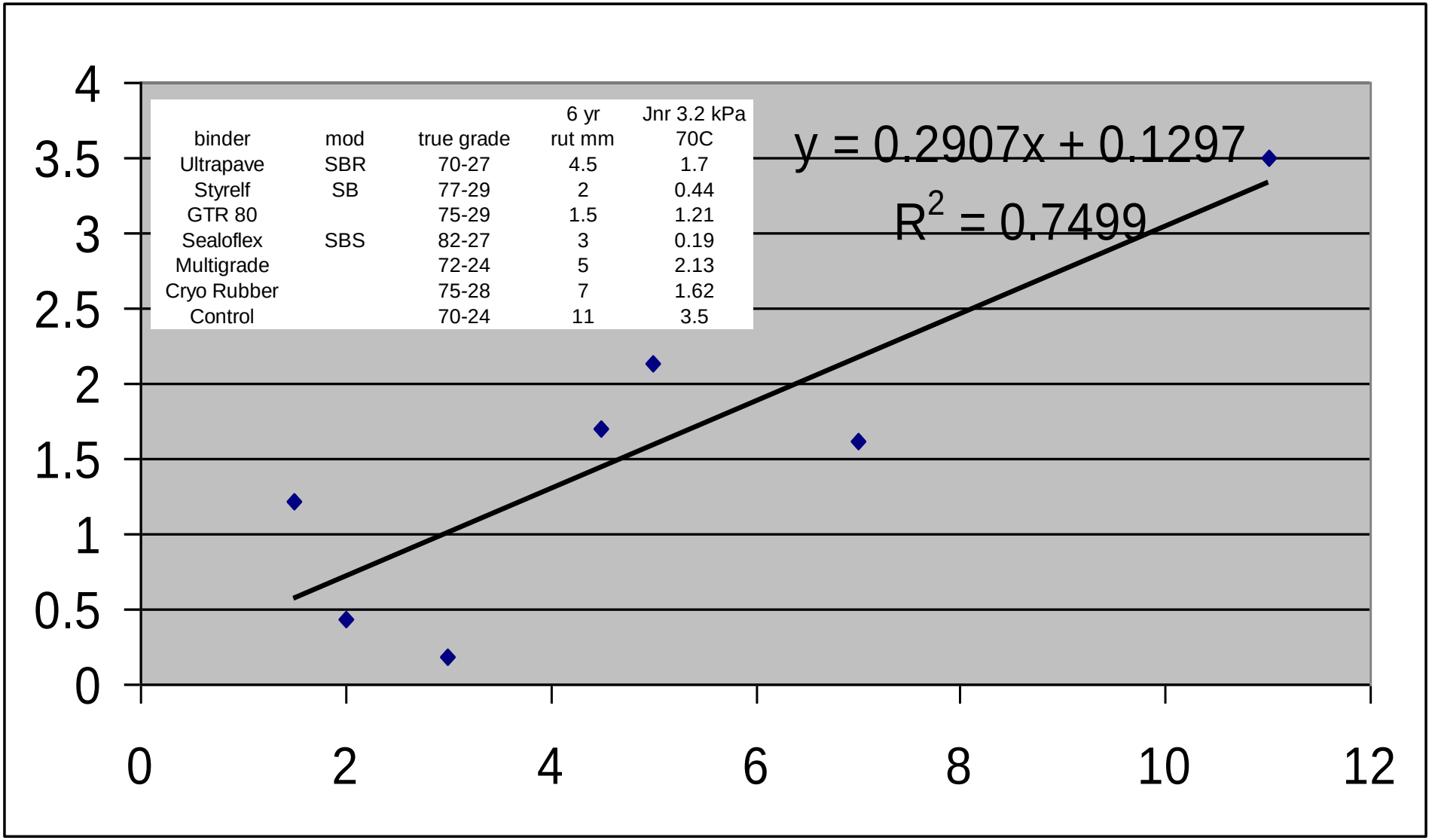


binder	mod	true grade	6 yr rut mm	Jnr 3.2 kPa 70C
Ultrapave	SBR	70-27	4.5	1.7
Styrelf	SB	77-29	2	0.44
GTR 80		75-29	1.5	1.21
Sealoflex	SBS	82-27	3	0.19
Multigrade		72-24	5	2.13
Cryo Rubber		75-28	7	1.62
Control		70-24	11	3.5

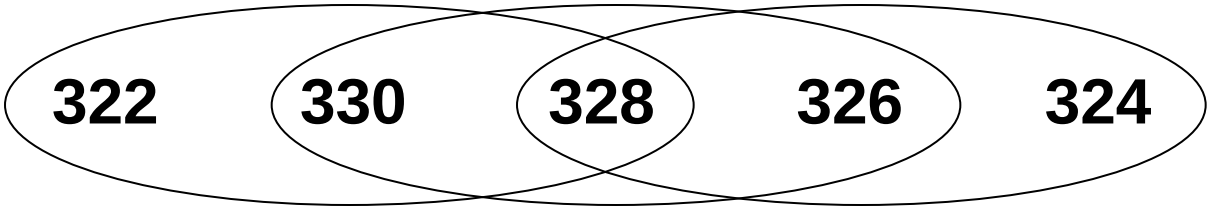
Kentucky 70-22 Study

- Kentucky PG 70-22 Study (1996)
  - Evaluate PG 70-22 asphalt binders produced by different methods
    - SBS (2)
    - SBR
    - Gel
    - Select Crude
  - I-64 near Winchester
    - Duplicate 1-mile test sections using each asphalt binder
    - Asphalt binder and mixture testing

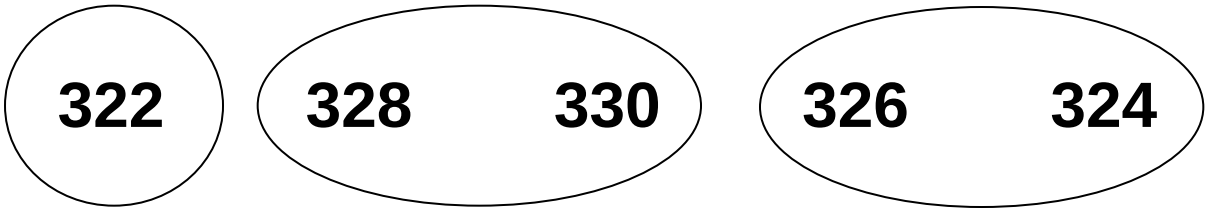
Kentucky 70-22 Study

Statistical Comparison

RSCH @58C, microstrain



J_{nr} @64C, kPa^{-1}



Low ⟷ *High*

Statistical Comparison by Binder Groups

- Group A
  - 322
    - Average J_{nr} = 0.195
    - Average γ_p = 9,750 microstrain

    Ave. MSCR $Rec_{3.2}$ = 18.8%
- Group B
  - 330, 328
    - Average J_{nr} = 0.580
    - Average γ_p = 12,125 microstrain

    Ave. MSCR $Rec_{3.2}$ = 11.4%
- Group C
  - 326, 324
    - Average J_{nr} = 1.78
    - Average γ_p = 17,250 microstrain

    Ave. MSCR $Rec_{3.2}$ = 5.2%*

M320 Table 3 (Proposed)

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Original					
DSR G*/sinδ Min 1.0	64				
RTFOT					
64 Standard MSCR3.2 <4.0	[(MSCR3.2 – MSCR 0.1)/ MSCR 0.1] < .75	64			
64 Heavy MSCR 3.2<2.0		64			
64 Very heavy MSCR3.2 <1.0		64			
PAV					
S grade DSR G*sinδ Max 5000	28	25	22	19	16
H & V grade DSR G*sinδ Max 6000	28	25	22	19	16

Low temp BBR and DTT remain unchanged

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.

What is % Recovered Strain?

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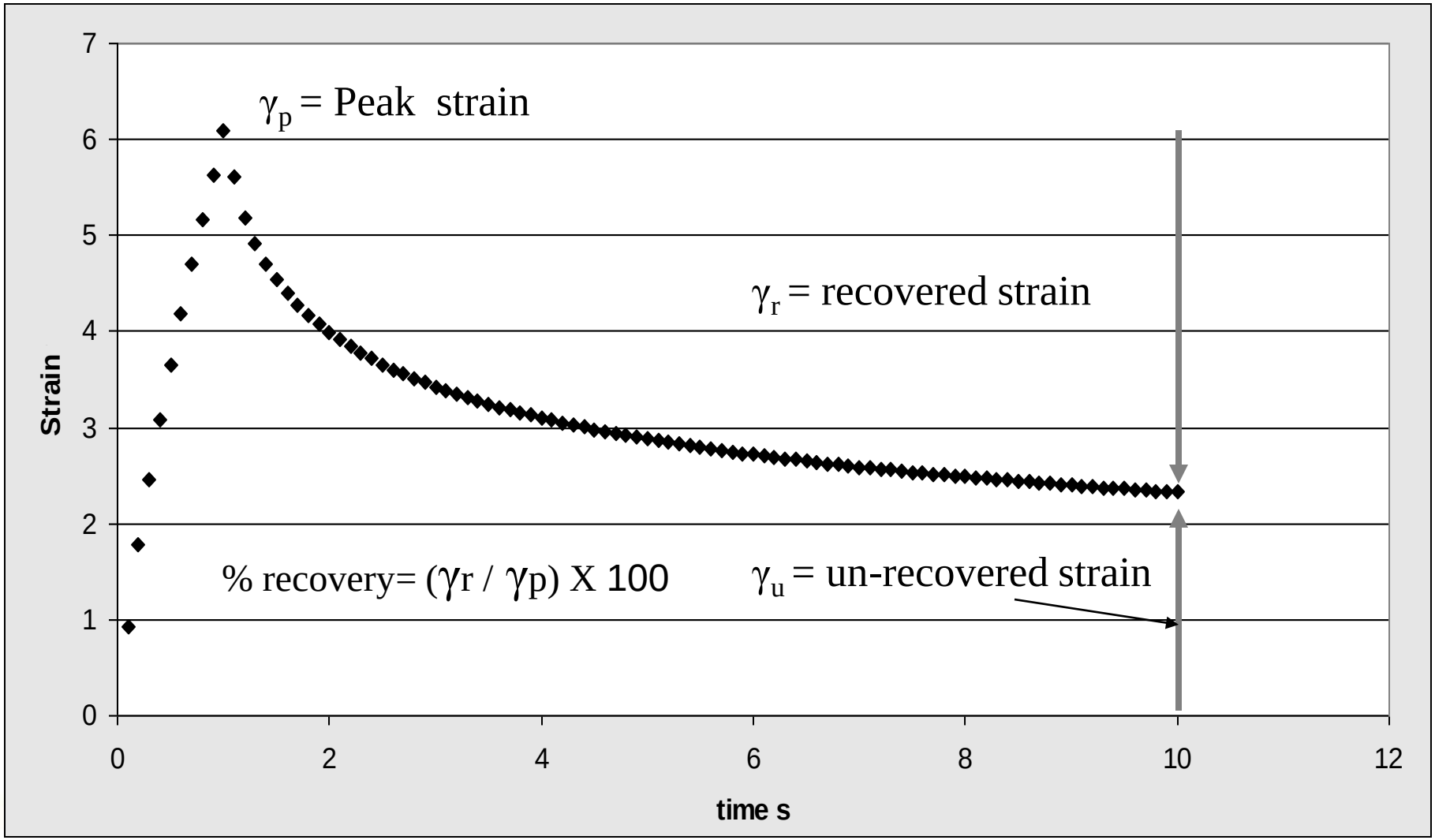
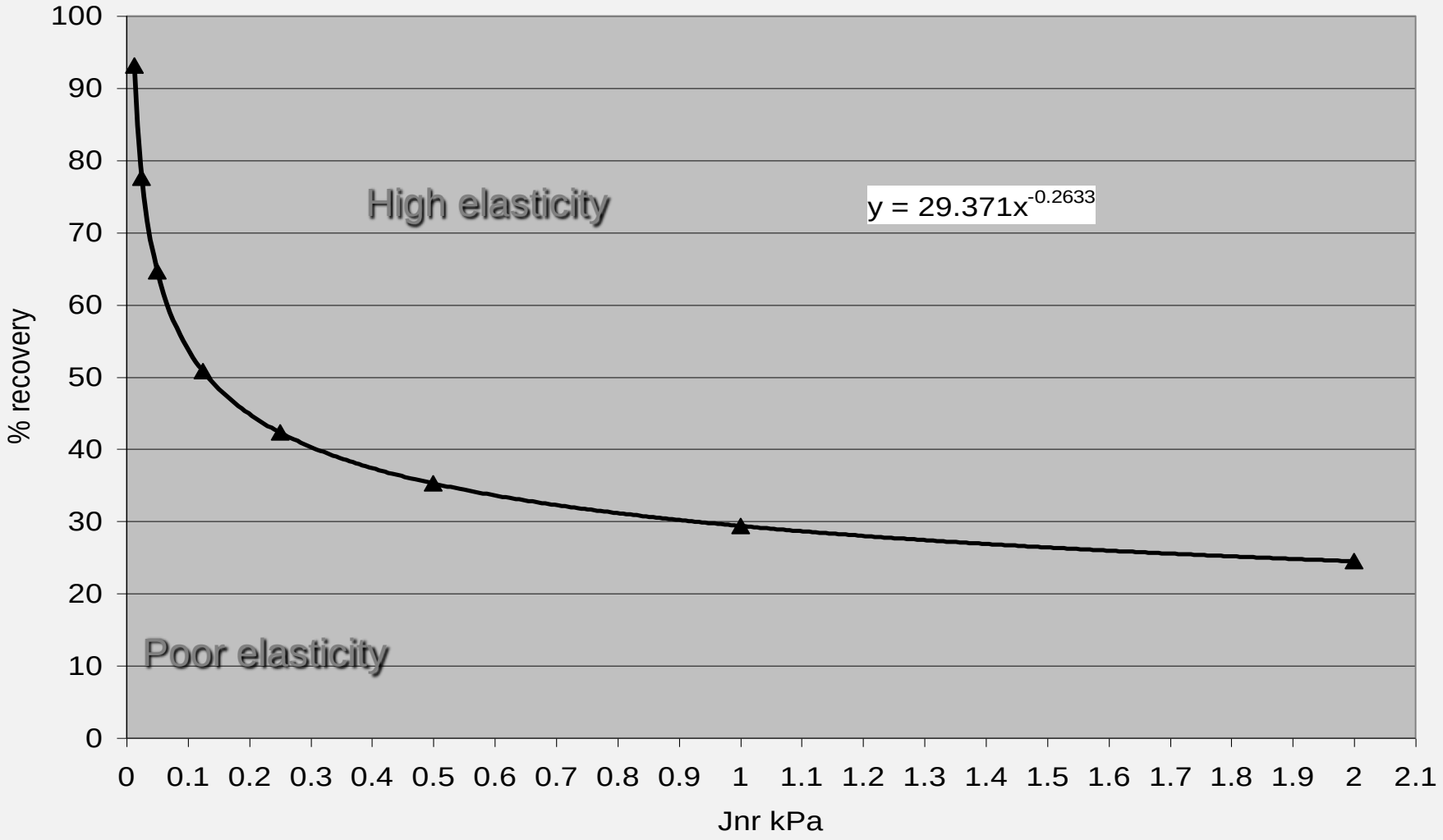


MSCR % recovery can be added to validate polymer modification



For agencies with concerns about a variable scale it can be adjusted to a stepped scale

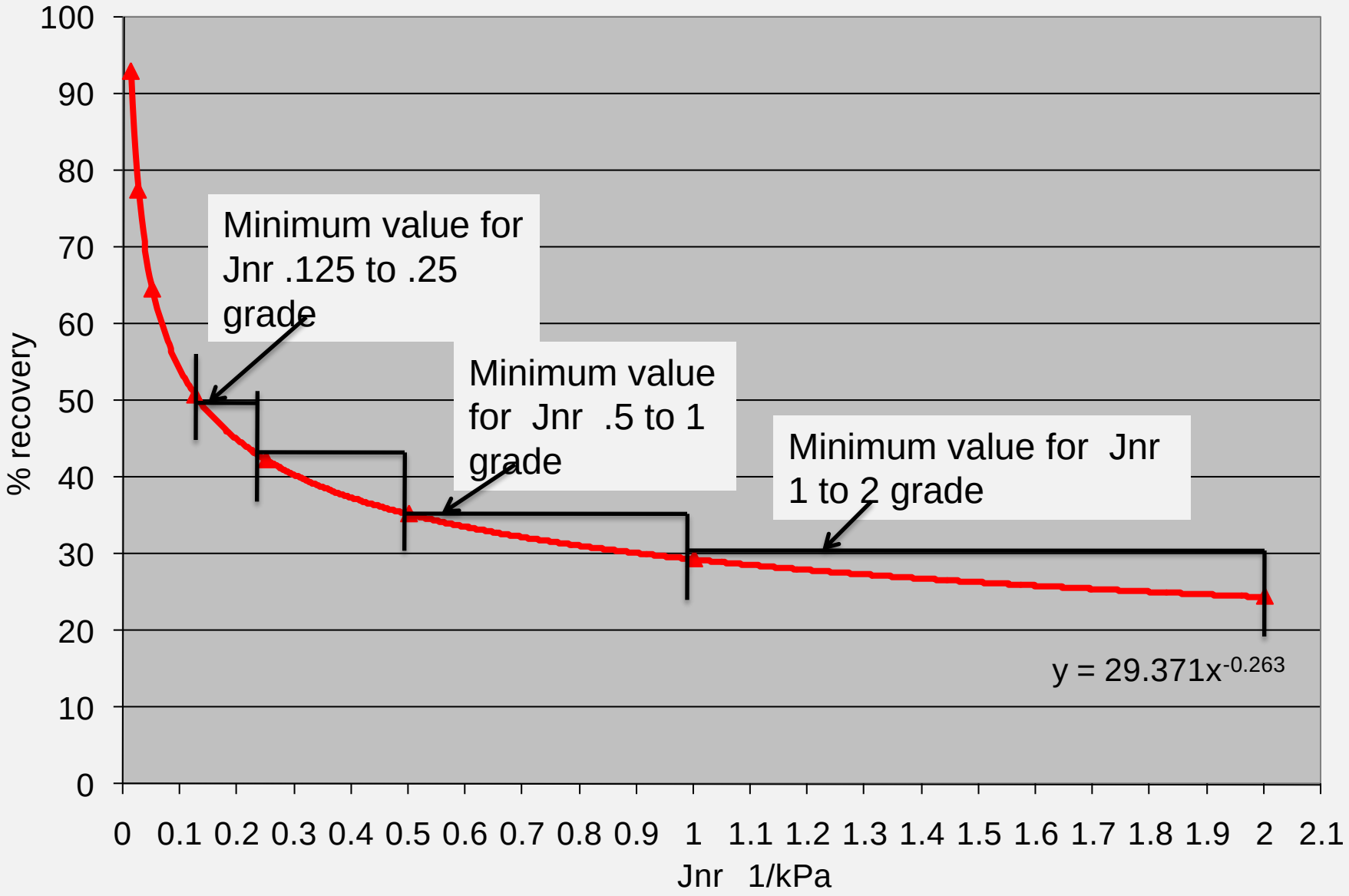


Table for MSCR % Recovery minimum values

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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%

Blending of binders and polymers Jnr, % recovery study

- PG 64-22 Base asphalt
- 4 % SBS polymer
  - Radial
  - Linear
- 0.5% PPA
- 2 blending temperatures

Polymer Network Affects Response

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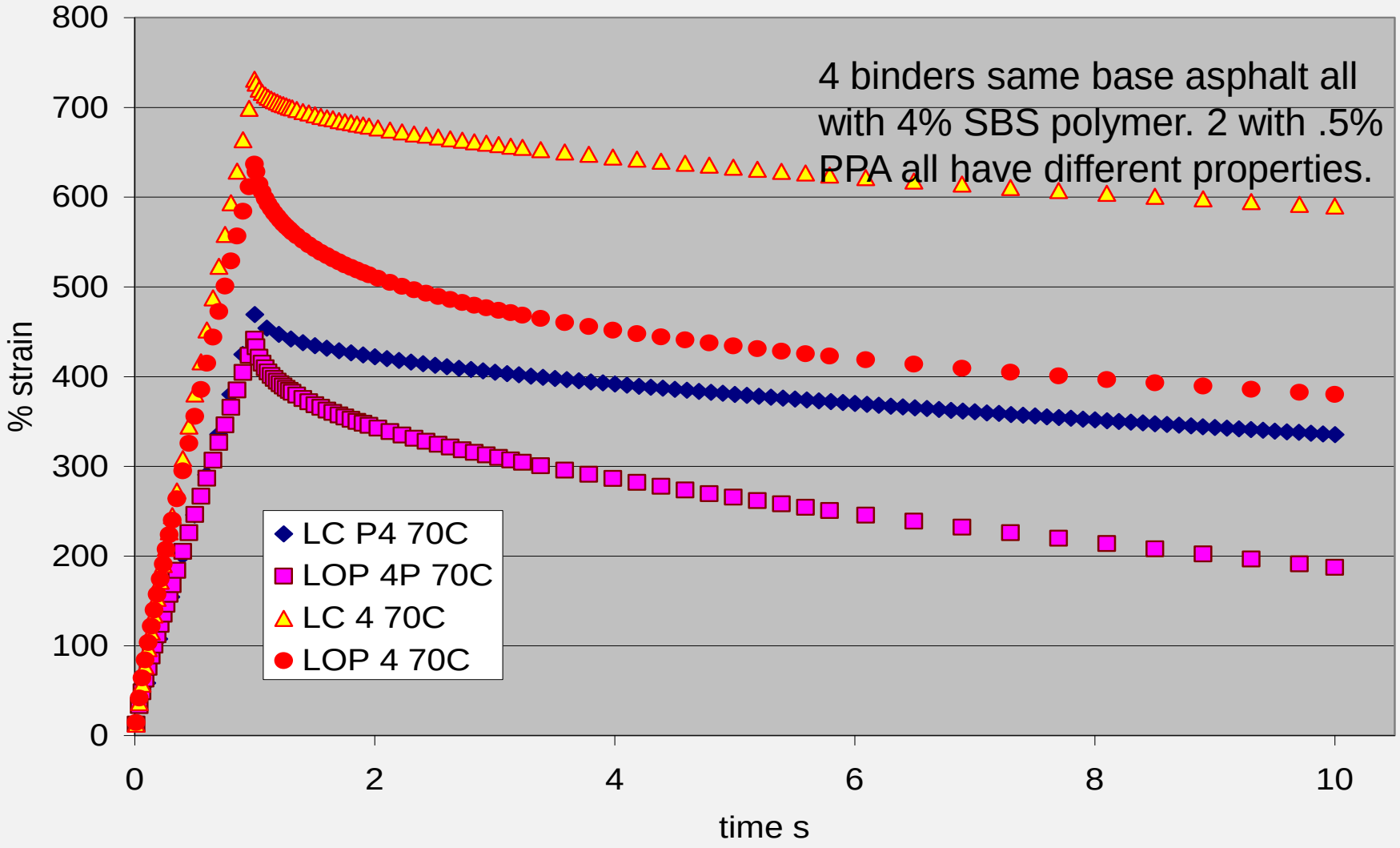

Effect of Polymer Network on Binder Response

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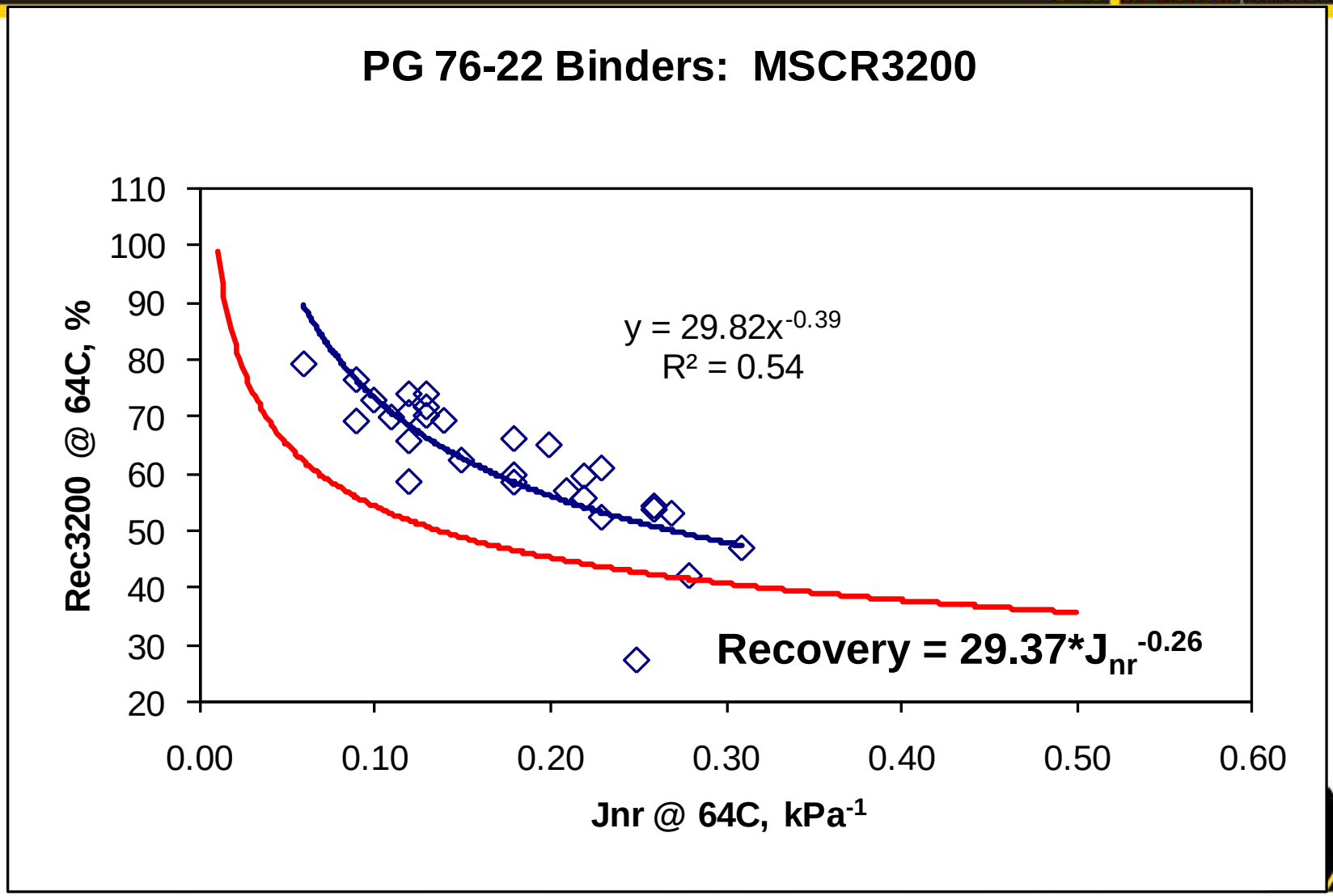
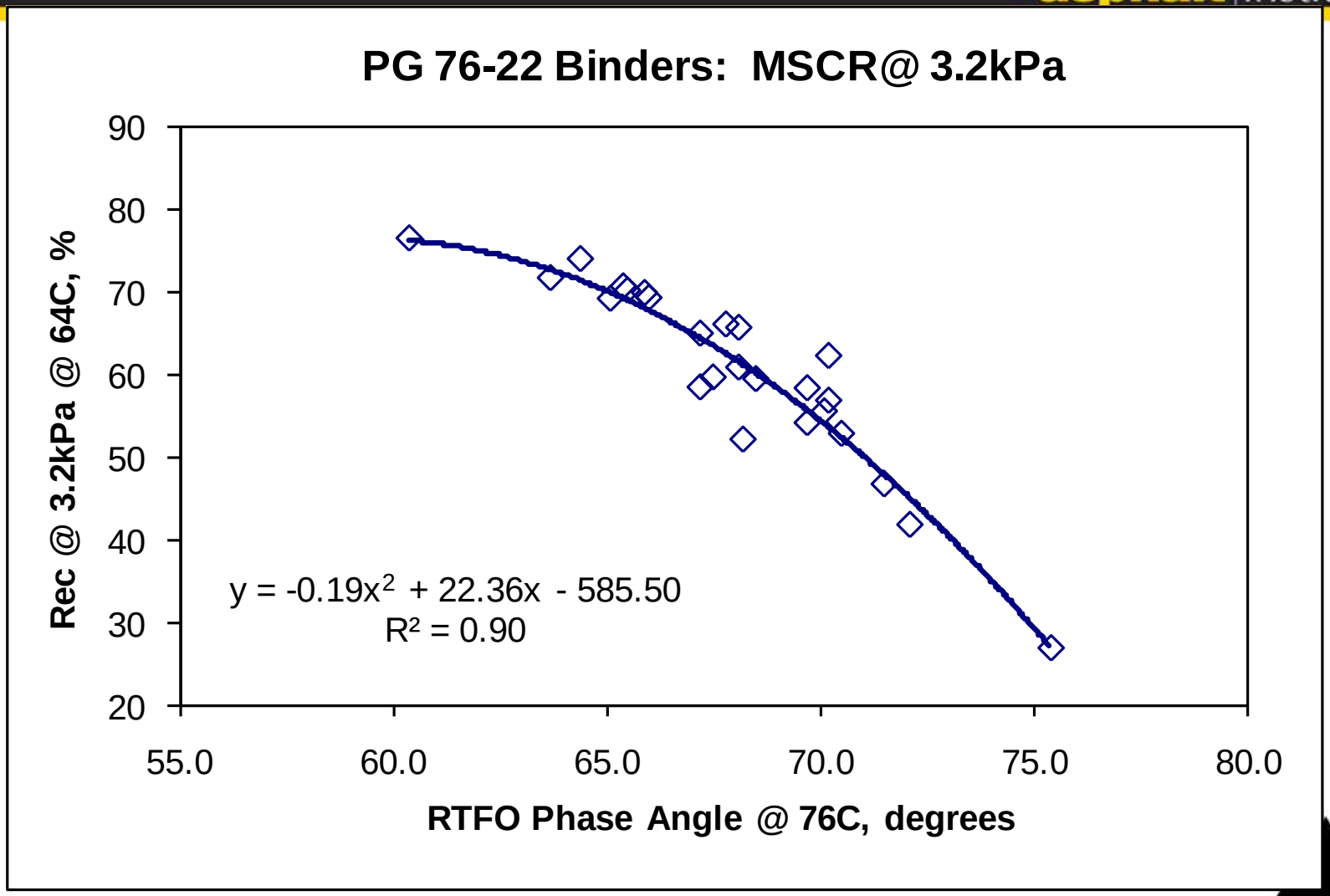
Sample ID	Continuous Grade	Polymer	Acid	Temp J_{nr} 3.2kPa = 1	ER	Temp C	% Recovery 3.2kPa
LC	66.7-24.1		0	56.4	5	64C	0
LC 4	75.7-22.3	4% SBS	0	65.1	73.8	70C	19.2
						76C	5.96
LC P4	81.2-22.2	4% SBS	0.50%	69.9	93.8	70C	28.4
						76C	20.55
LOP 4	76.6-25.2	4% SBS from Concentrate	0	69.1	86	70C	40.3
						76C	37.02
LOP 4P	81.6-24.5	4% SBS from Concentrate	0.50%	74.1	91.6	70C	52.05
						76C	42.52

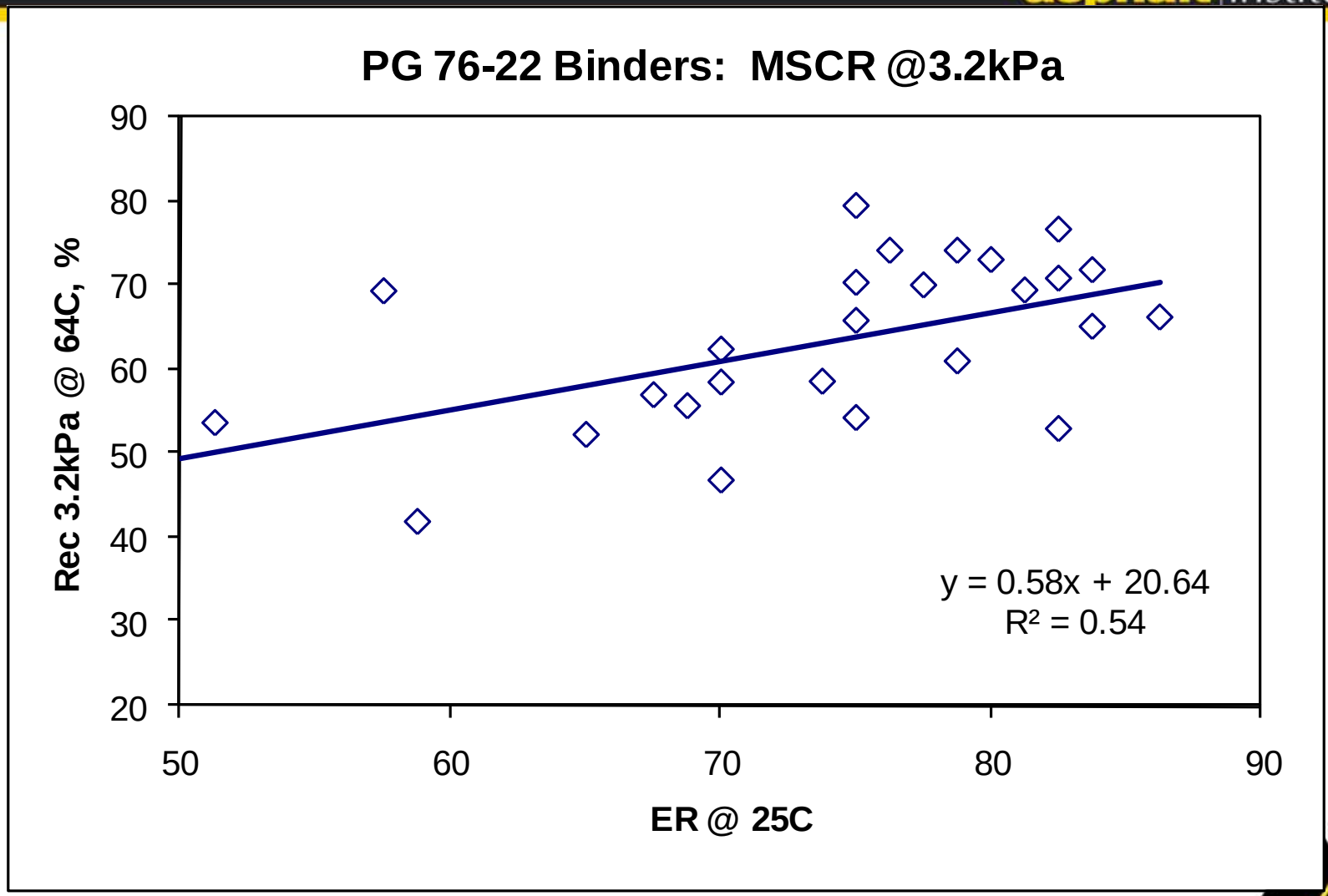
Validate Polymer Modification



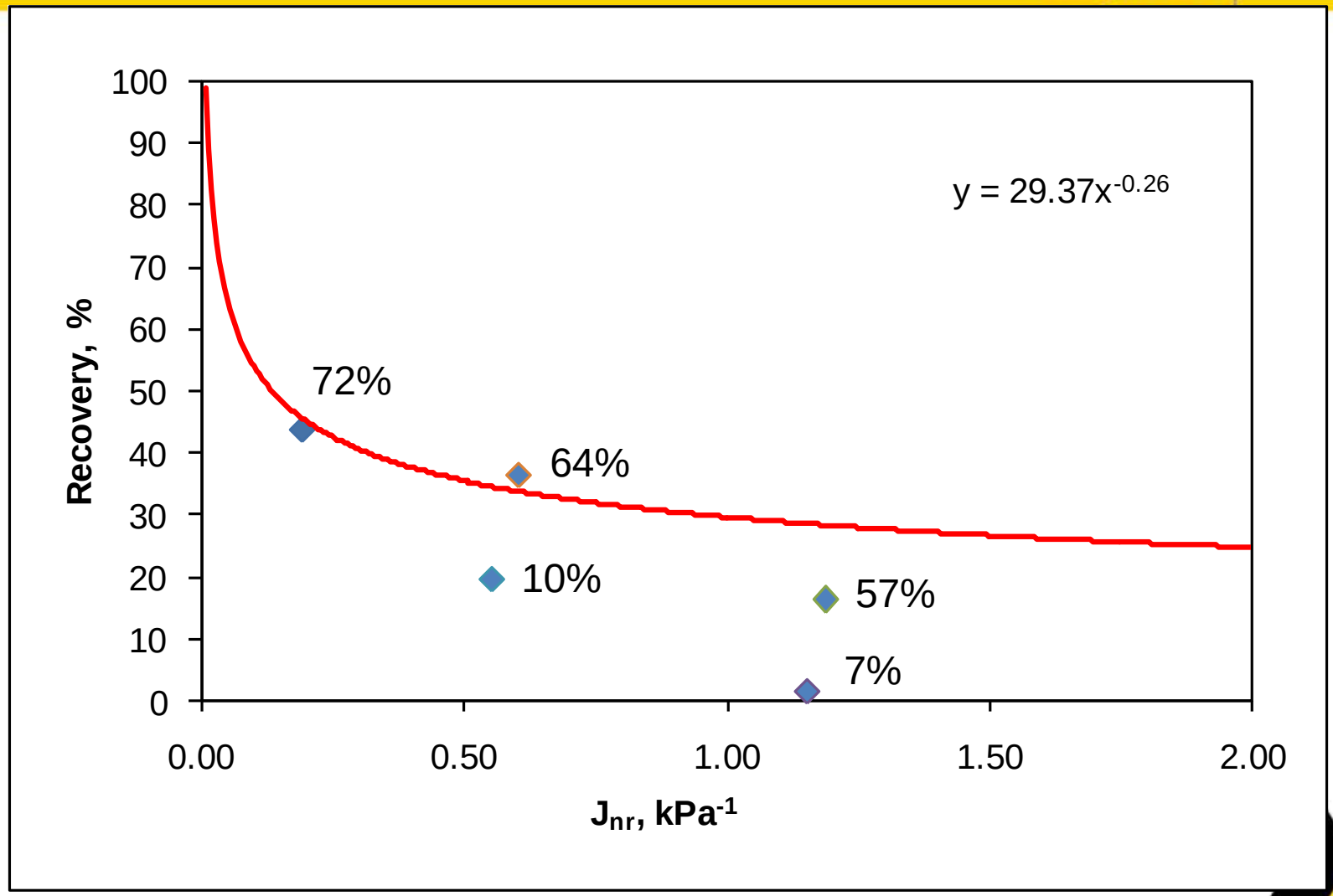
Correlation of MSCR Recovery and Phase Angle



Correlation of MSCR Recovery and Elastic Recovery



Kentucky PG 70-22 Study: Correlation of Jnr and Recovery



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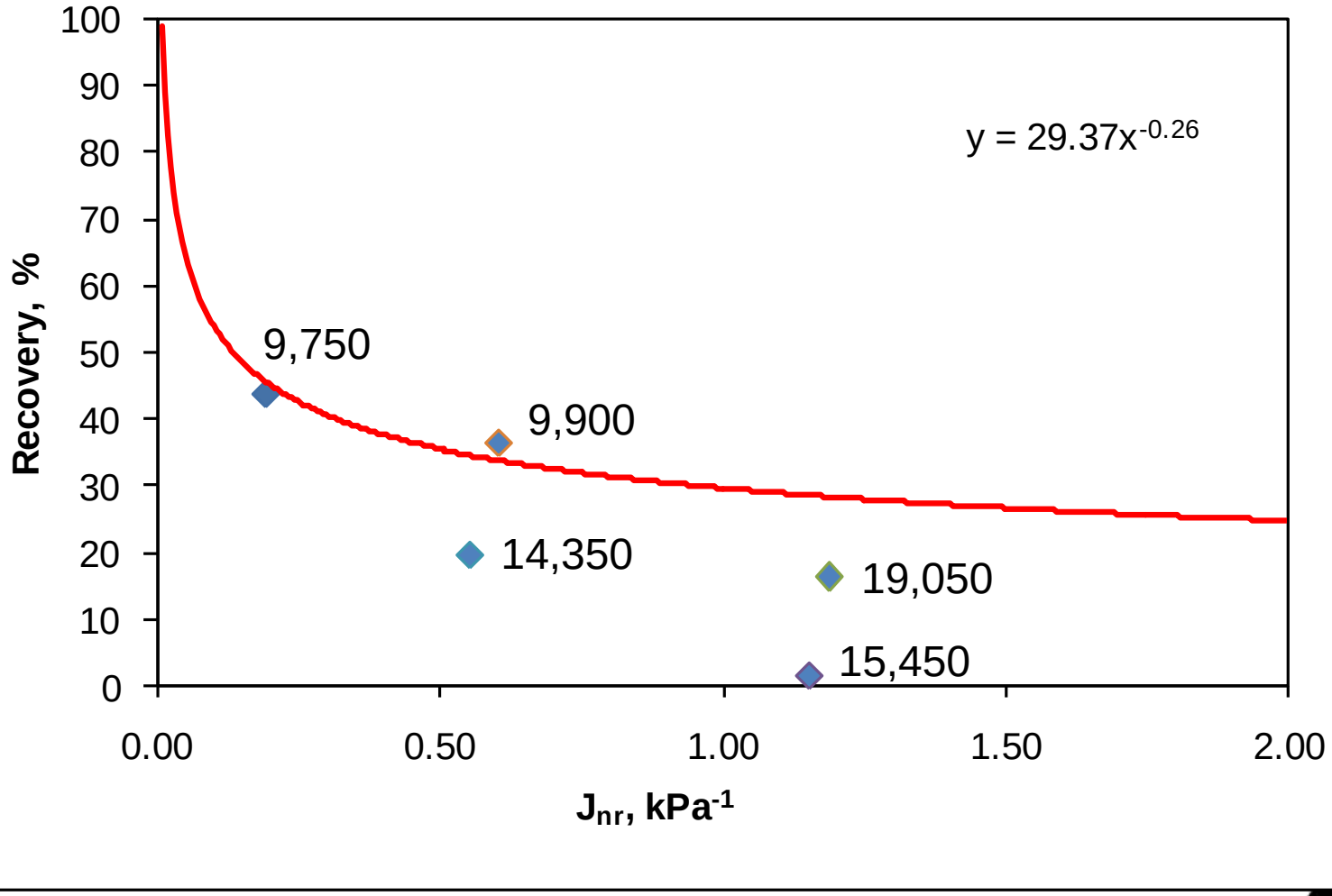

Comparison of Modified Asphalt Binders

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	CS_2H_4%SBS	CS_6H_2.5%SBS-X
M320 Table 1 Grade	PG 76-22	PG 76-22
Continuous Grade	PG 80.0-25.2	PG 79.9-27.9
Elastic Recovery	65%	68%
J_{nr} @ 0.1 kPa (64°C)	0.306 kPa^{-1}	0.353 kPa^{-1}
J_{nr} @ 3.2 kPa (64°C)	0.366 kPa^{-1}	0.452 kPa^{-1}
Stress Sensitivity	0.20	0.28
Recovery @ 0.1 kPa (64°C)	34.1%	42.2%
Recovery @ 3.2 kPa (64°C)	24.7%	30.8%
PAV G*sin δ @ 25°C	4271 kPa	3145 kPa
BBR Stiffness @ -12°C	183 MPa	158 MPa
BBR m-value @ -12°C	0.320	0.345

Fatigue Evaluation

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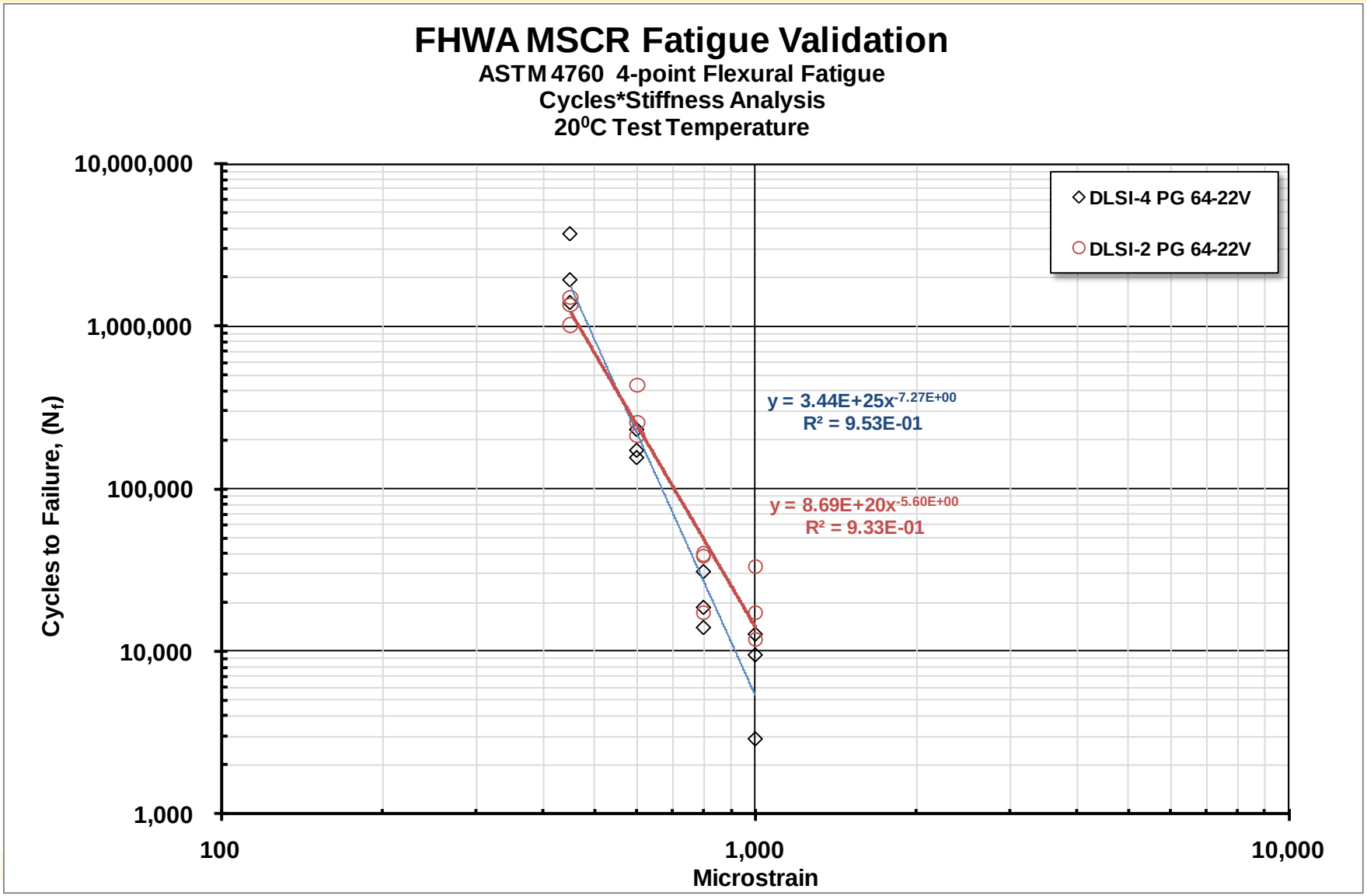


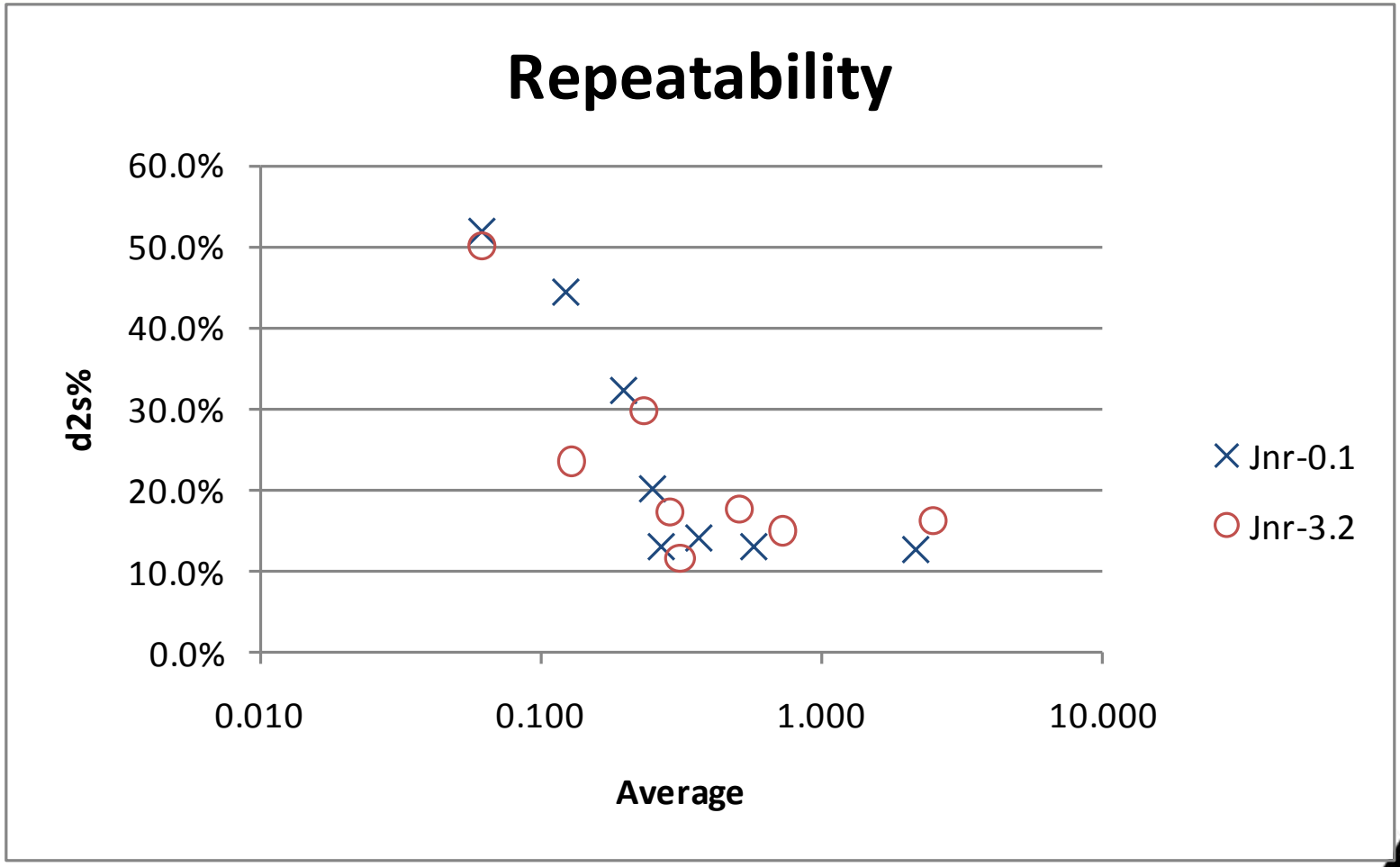
ILS Design

- Participating Labs
  - FHWA
    - Two Different Rheometers/Technicians
  - MTE Services
  - Paragon Technical Services
  - PRI Asphalt Technologies
  - Kraton Polymers
  - Nevada Department of Transportation
  - Asphalt Institute

ILS Design – Materials

- Asphalt Binders
  - Verification
    - PG 76-22
  - Experiment
    - PG 64-22
    - PG 64-34
    - PG 70-28
    - PG 70-34
    - PG 76-22 (2)

Repeatability and Reproducibility



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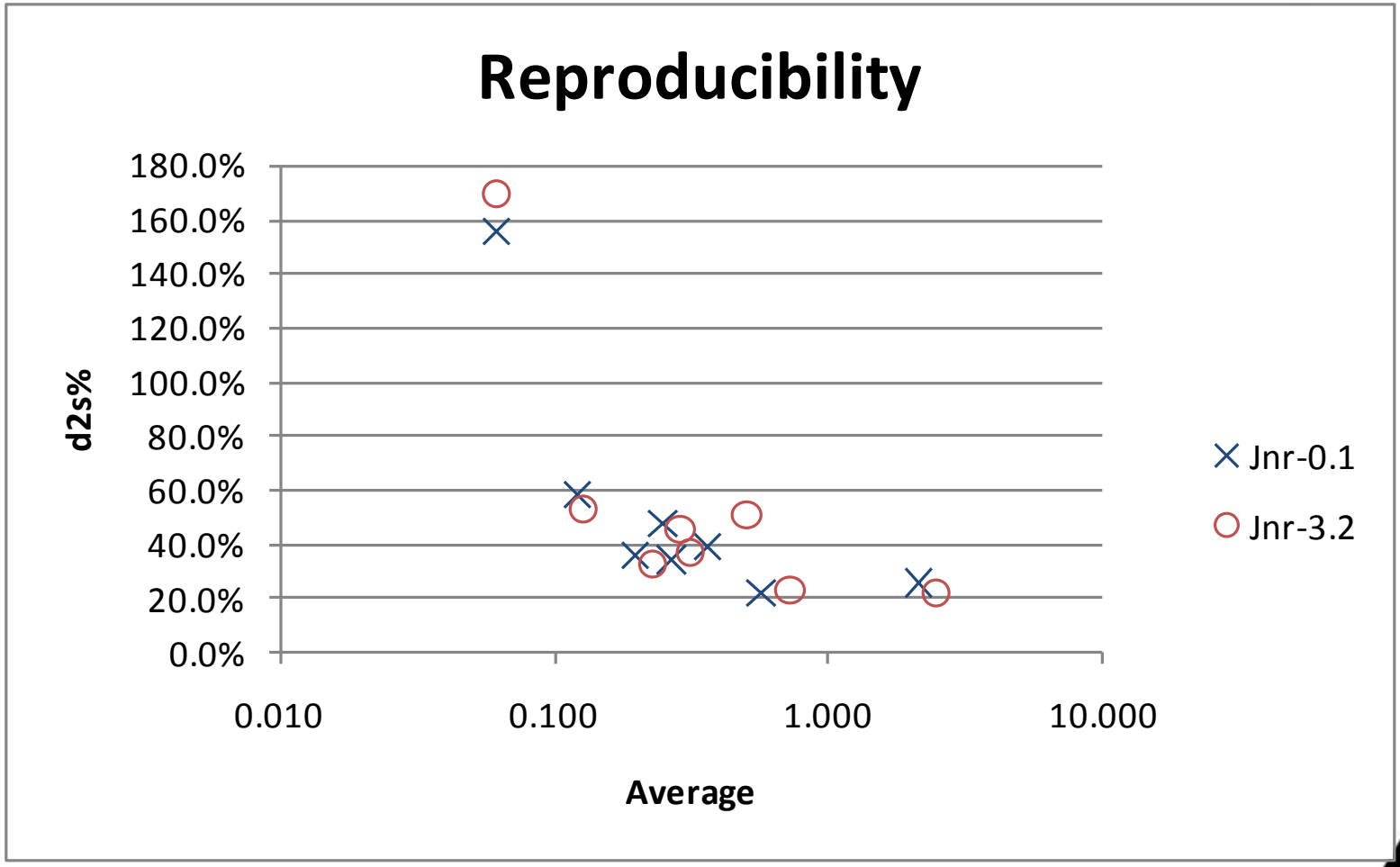

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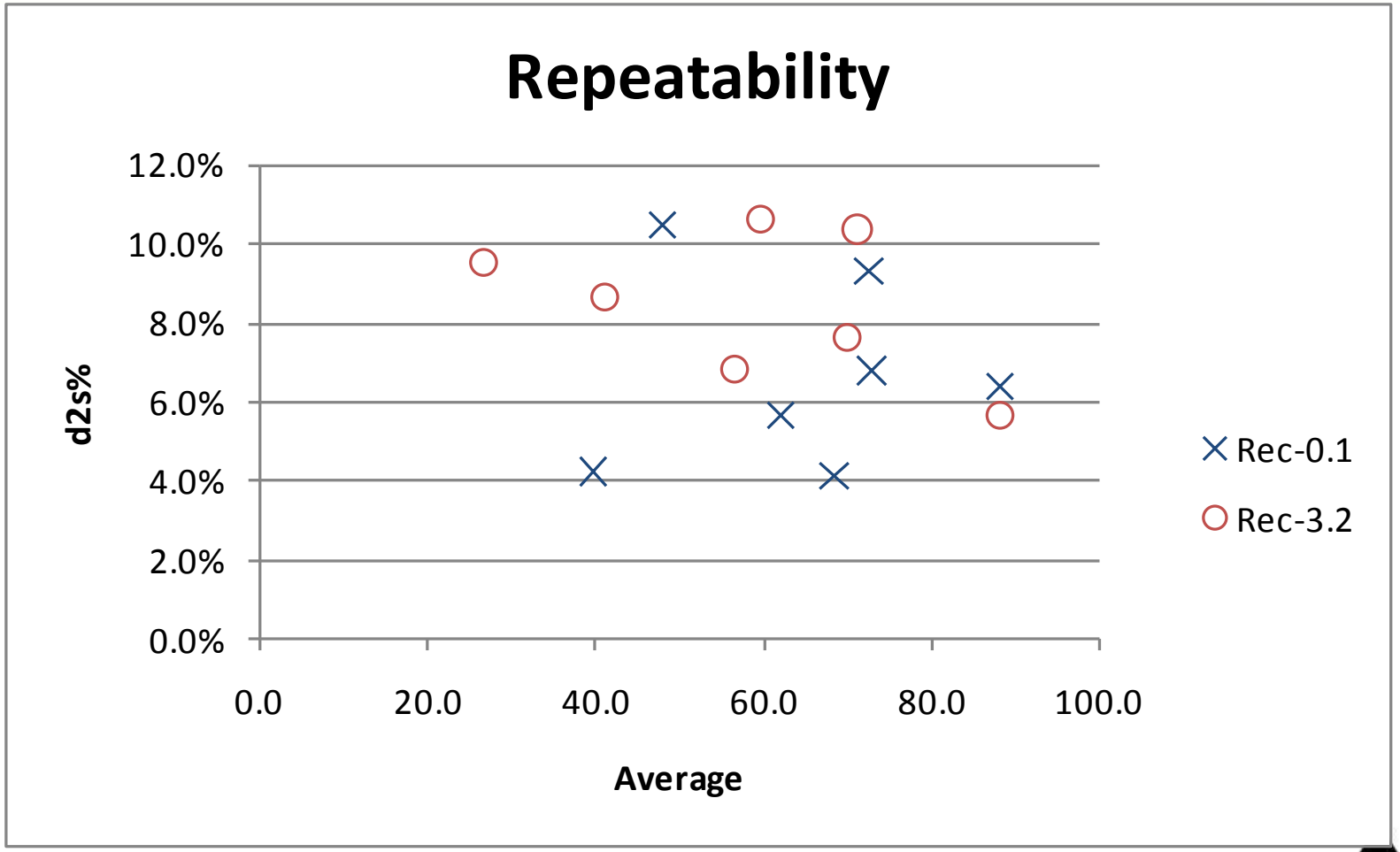

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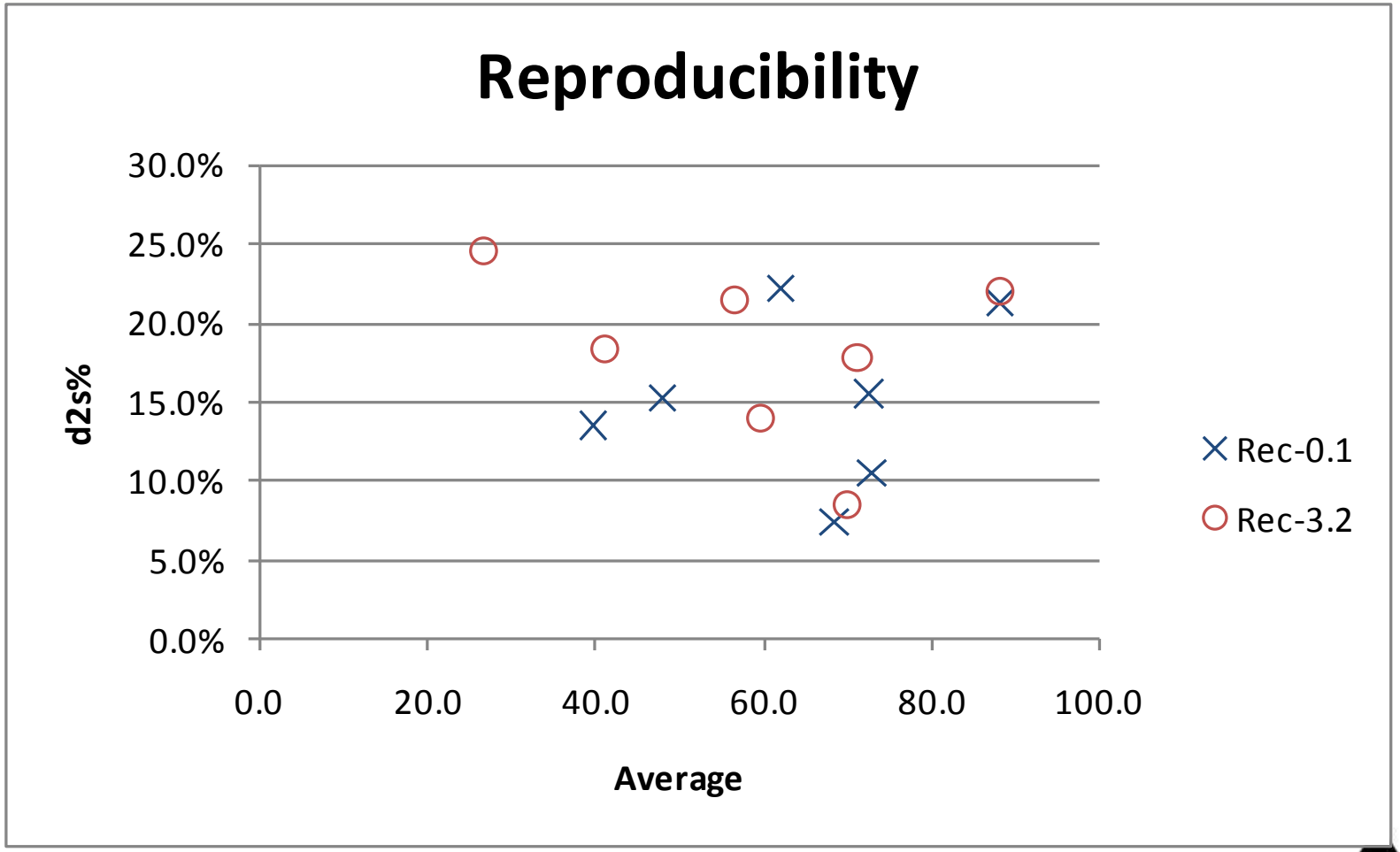

Repeatability and Reproducibility

- Precision
  - Variability in Recovery is unaffected by Recovery magnitude
    - Average repeatability and reproducibility for Precision Statement

Repeatability and Reproducibility

- Precision
  - Variability in J_{nr} appears to be a function of J_{nr} magnitude
    - Suggests tiered Precision Statement

      J_{nr} >1.00 kPa^{-1}

      J_{nr} > 0.25 kPa^{-1} and ≤ 1.00 kPa^{-1}

      J_{nr} > 0.10 kPa^{-1} and ≤ 0.25 kPa^{-1}

      J_{nr} ≤ 0.10 kPa^{-1}

Note: only one asphalt binder was tested that fit into the highest (J_{nr} >1.00 kPa^{-1}) and lowest (J_{nr} ≤ 0.10 kPa^{-1}) levels. More data will be needed to validate both the levels and the reported variability.

Repeatability

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Condition	*Coefficient of Variation (1s%)*[a]	*Acceptable Range of Two Test Results (d2s%)*[a]
Single-Operator Precision:		
$Recovery_{0.1kPa}$ (%)	2.4%	6.7%
$Recovery_{3.2kPa}$ (%)	3.0%	8.5%
$J_{nr@0.1kPa}$ (kPa^{-1})		
>1.00	4.6%	12.8%
0.25 - 1.00	5.4%	15.2%
0.10 - 0.25	13.7%	38.3%
≤ 0.1[b]	n/a	n/a
$J_{nr@3.2kPa}$ (kPa^{-1})		
>1.00	5.7%	16.0%
0.25 - 1.00	5.5%	15.3%
0.10 - 0.25	9.5%	26.6%
≤ 0.1[b]	n/a	n/a

Reproducibility

Condition	*Coefficient of Variation (1s%)*[a]	*Acceptable Range of Two Test Results (d2s%)*[a]
Multilaboratory Precision:		
$Recovery_{0.1kPa}$ (%)	5.4%	15.0%
$Recovery_{3.2kPa}$ (%)	6.5%	18.1%
$J_{nr@0.1kPa}$ (kPa^{-1})		
>1.00	9.1%	25.6%
0.25 - 1.00	12.7%	35.6%
0.10 - 0.25	16.7%	46.8%
≤ 0.1[b]	n/a	n/a
$J_{nr@3.2kPa}$ (kPa^{-1})		
>1.00	7.9%	22.0%
0.25 - 1.00	13.9%	39.0%
0.10 - 0.25	15.2%	42.6%
≤ 0.1[b]	n/a	n/a

[a] These limits represent the 1s% and d2s% limits described in ASTM Practice C670.

[b] For J_{nr} below 0.1 kPa^{-1} high variability is likely due to the very low measured strain magnitude. If an asphalt binder has a J_{nr} below 0.1 kPa^{-1} at a specified temperature, then consideration should be given to testing at a temperature that is 6°C higher.

Educational Activities

- MSCR Workshops
  - *Understanding and Implementing the MSCR Test and Specification*
  - Rocky Mountain Asphalt User Producer Group
    - March 2009
  - Northeast Asphalt User Producer Group
    - September 2009
    - Webcast, Recorded
      - www.ct.gov/dot video on demand

Educational Activities

- MSCR Workshops
  - *Understanding and Implementing the MSCR Test and Specification*
  - Background
    - Why do we need a new high temperature parameter?
  - Justification
    - How does the MSCR test meet the needs?
  - Basics
    - How do the MSCR test and specification work?
  - Testing Considerations
    - If it is important in T315 then it is important in TP70

Educational Activities

- MSCR Workshops
  - *Understanding and Implementing the MSCR Test and Specification*
  - Other UPGs?
    - May not be necessary with streaming video availability
  - Proposed TRB Webinar
    - AFK20
    - State DOT participation
    - 60 minute condensed version

Educational Activities

- Technical Bulletin/Brief
  - Use and Purpose of the MSCR test and specification
    - 4-page designed bulletin
- On-Demand Video Presentations
  - Re-create videos similar to NEAUPG Workshop

Implementation Activities

- Precision of AASHTO TP70
  - Presented to ETG
  - Forwarded to ASTM, AASHTO
  - Technical report
- Communication with DSR Manufacturers
  - User interface and reporting

Implementation Activities

- Implementation Guidance Document
  - For user agencies
    - Describing how to implement the MSCR test and specification
    - Why?
      - 17 years since the last major national specification changes

Implementation Guidance: AASHTO M320

- Table 3
  - Recommended specification for all asphalt binders
    - Expect Table 1 to eventually be deleted
  - Approval and Publication in 2009

Implementation Guidance: AASHTO M320

- Implementation
  - Beginning in 2010…
    - Determine climatic high temperature
    - Users and producers conduct Table 3 shadow testing

Implementation Guidance: AASHTO M320

- Implementation
  - Beginning in 2010…
    - Require producers to supply Table 3 test data and identify grade
      - MSCR (AASHTO TP70) on RTFO-aged binder
        - » Conducted at climate temperature
        - » Report J_{nr} at 3.2 kPa, J_{nr} Diff, Recovery at 3.2 kPa
      - G*sin δ on PAV-aged binder at actual intermediate temperature
        - » Some users already require this
      - G*/sin δ on original binder at actual climatic high temperature (optional)

Implementation Guidance: AASHTO M320

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- Implementation
  - Beginning in 2011…
    - Replace the use of AASHTO M320 Table 1 with Table 3

Implementation Guidance: AASHTO M320

- Notes to User Agencies
  - **Shadow testing** is only indicative of current products and formulations. Products are likely to change once the full specification is implemented.
  - AASHTO M320 Table 3 should be used in its current form without modification.

Implementation Guidance: AASHTO M320

- Notes to User Agencies
  - **MSCR Recovery** is not included in Table 3 as a specification, but could be used by agencies to indicate elastomeric modification.
    - Will not recommend any changes to current agency policy regarding “Plus” tests.
      - If a user agency is not currently requiring “Plus” tests for the identification of elastomeric modification in Table 1, then they shouldn’t necessarily require MSCR recovery in Table 3.

Implementation Guidance: AASHTO M320

- Notes to User Agencies
  - **MSCR Recovery**, if required, should replace other “Plus” tests that are intended to have a similar purpose.
    - Recommend against requiring Elastic Recovery, Force Ductility, or Toughness and Tenacity tests. MSCR Recovery can be used to replace these tests. Separation tests may still be required.
    - User agencies should not expect to see a strong correlation between MSCR Recovery and Table 1 “Plus” tests.

Implementation Guidance: AASHTO M320

- Notes to User Agencies
  - **Regional Implementation** is preferred.
    - Piecemeal implementation will create need for multiple tanks or production of the asphalt binder grade with the most restrictive specifications

Implementation Guidance: AASHTO M320

- Notes to User Agencies
  - Table 3 is an improvement to the current system (Table 1)
    - Provides a parameter (J_{nr}) that is better correlated with rutting potential
    - Can be used with modified and unmodified asphalt binders.
      - Eliminates the need for additional tests to properly characterize modified asphalt binders

Thanks!