MULTIPLE STRESS CREEP RECOVERY TEST FOR ASPHALT BINDERS

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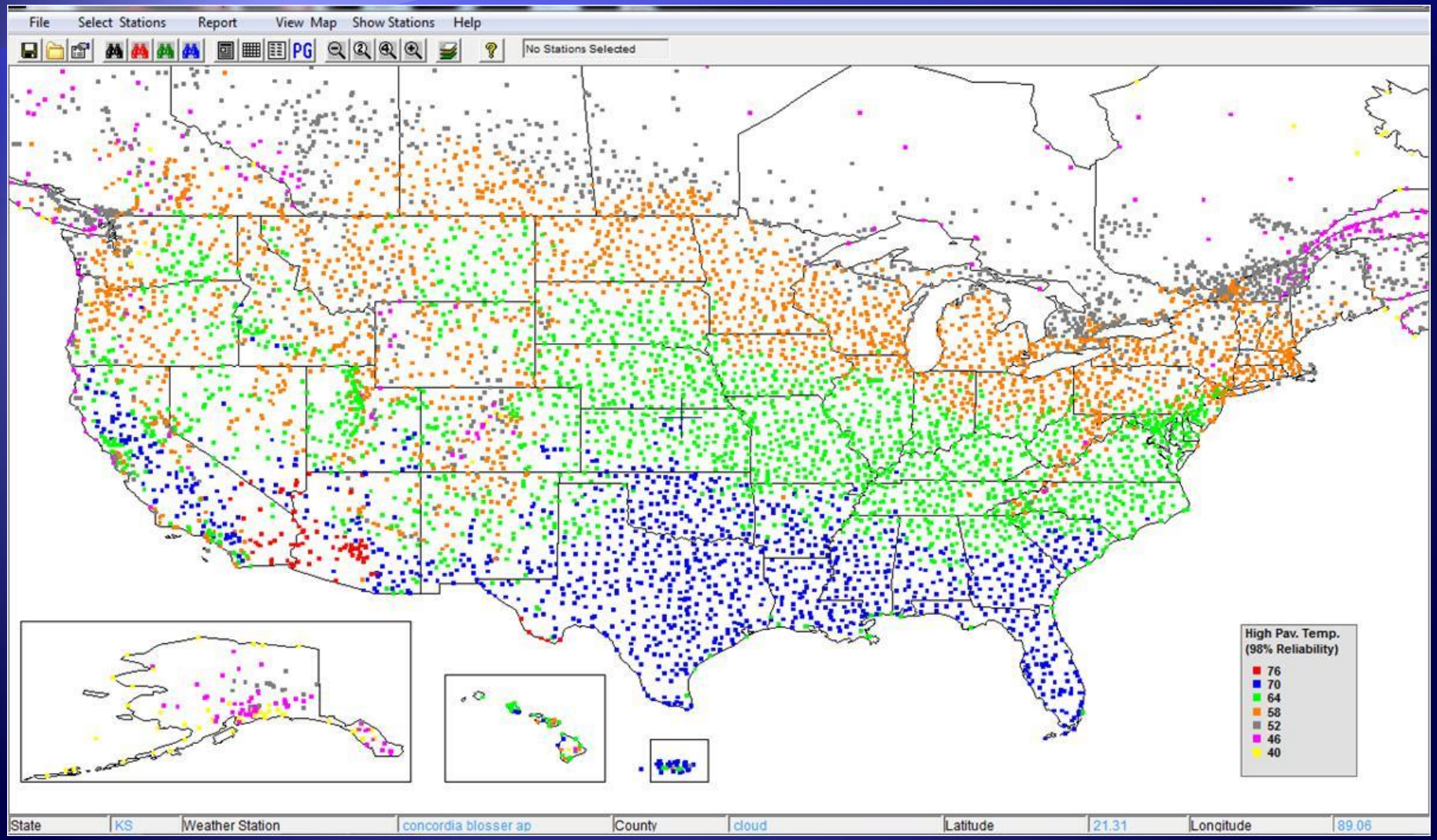
Acknowledgements

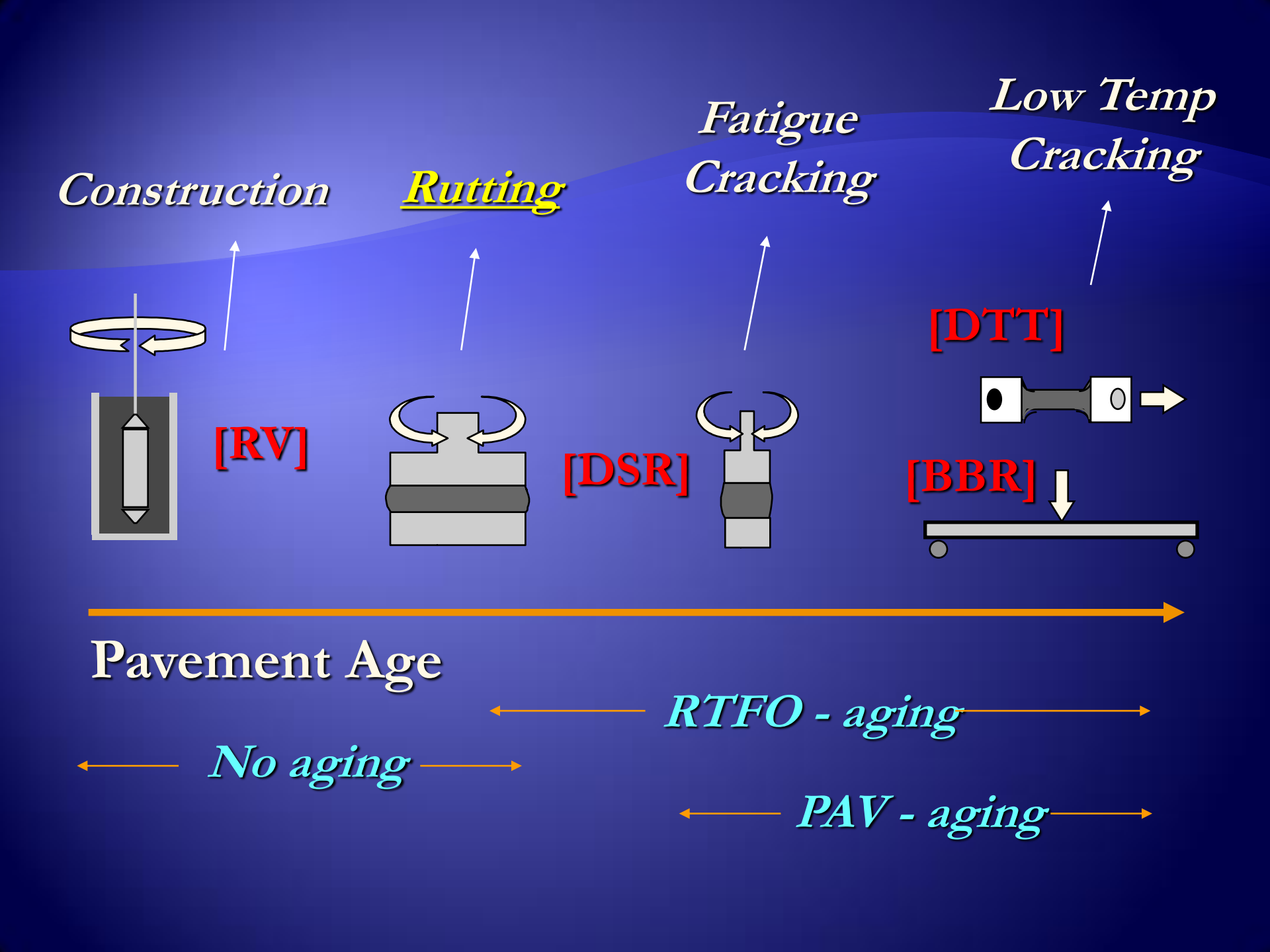
- John D'Angelo, Ph.D. P.E. – D'Angelo Consulting LLC
- R. Michael Anderson, P.E. – Asphalt Institute

How Do We Measure Rut Resistance of Asphalt Binders?

- PG test system uses Dynamic Shear Rheometer to measure stiffness
- Testing performed at high pavement temperature for pavement location

LTPPBind v3 98% Reliability High Temperature Grades




Construction
Rutting
Fatigue Cracking
Low Temp Cracking
[RV]
[DSR]
[DTT]
[BBR]
Pavement Age
No aging
RTFO - aging
PAV - aging

Dynamic Shear Rheometer (DSR)

- Place asphalt sample between two steel plates
- Apply a oscillating shear stress
- Measure strain

- Calculate a materials modulus
  - Modulus = Stress / Strain
  - A measure of material stiffness

DSR provides G^* and δ

- G^*, Complex Shear Modulus
- δ , Phase Angle

- $G^* / \sin \delta$
  - Correlates to rutting resistance
  - A measure of stiffness

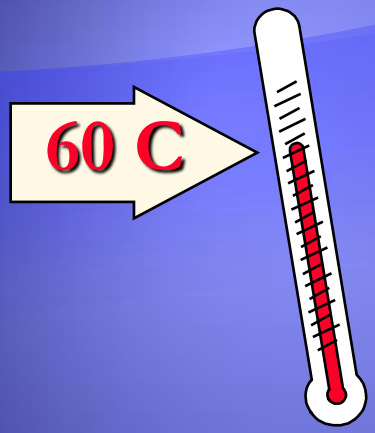
Rutting Specification - Minimum Stiffness @ $T_{(high)}$

- $G^* / \sin \delta > 1.00$ kPa on unaged binder
- $G^* / \sin \delta > 2.20$ kPa on RTFO aged binder

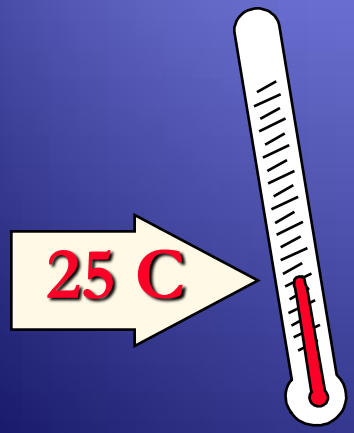
Why Do We Bump Binder Grades?

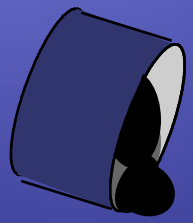
- Traffic conditions
  - Weights
  - Speed

Time vs. Temperature



1 hour



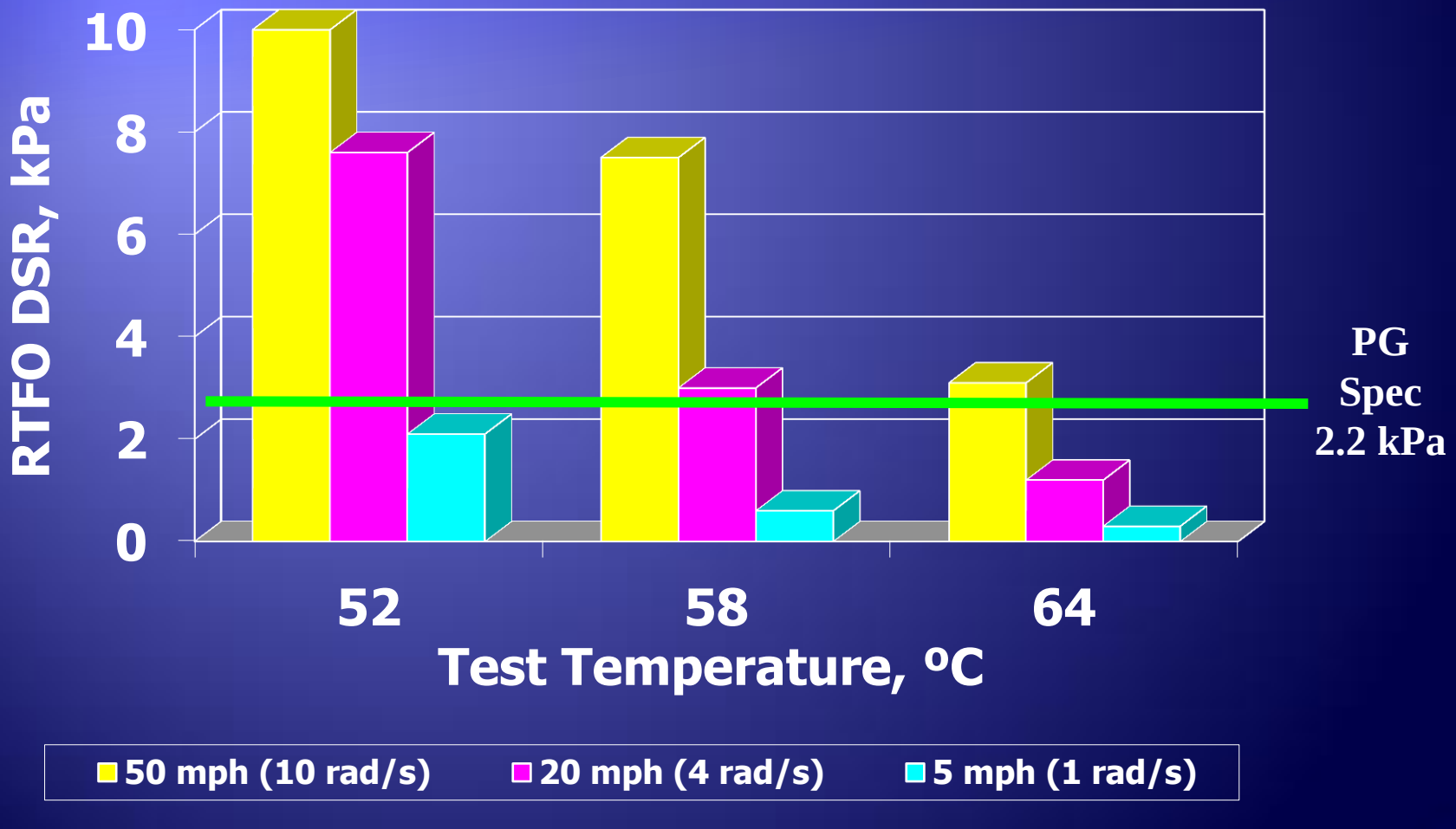


1 hour

10 hours

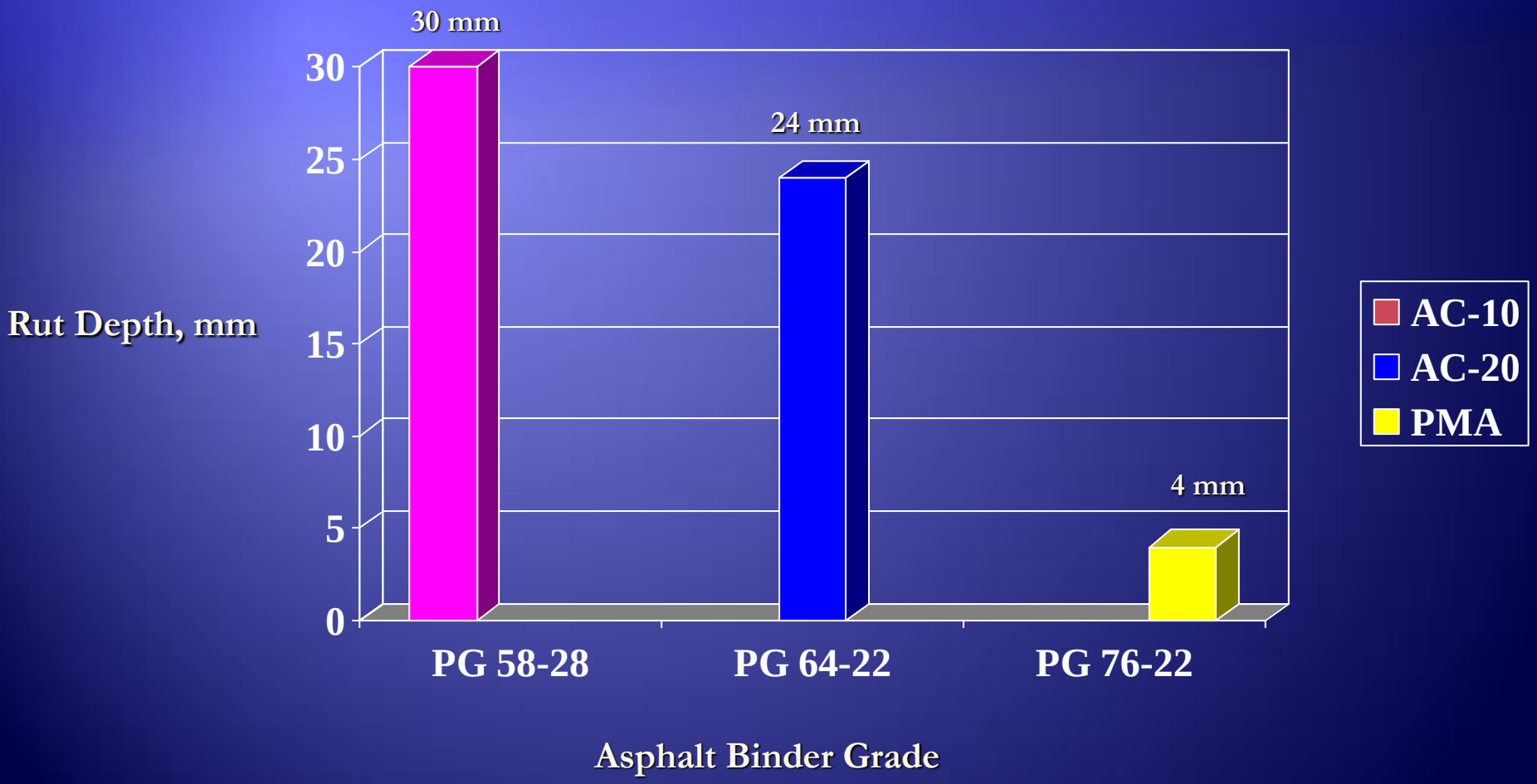
Effect of Traffic Speed on Binder Stiffness

PG 64-22



FHWA ALF Binder Study

Rut Depth @ 5000 passes of ALF
11 mph @ 58ºC



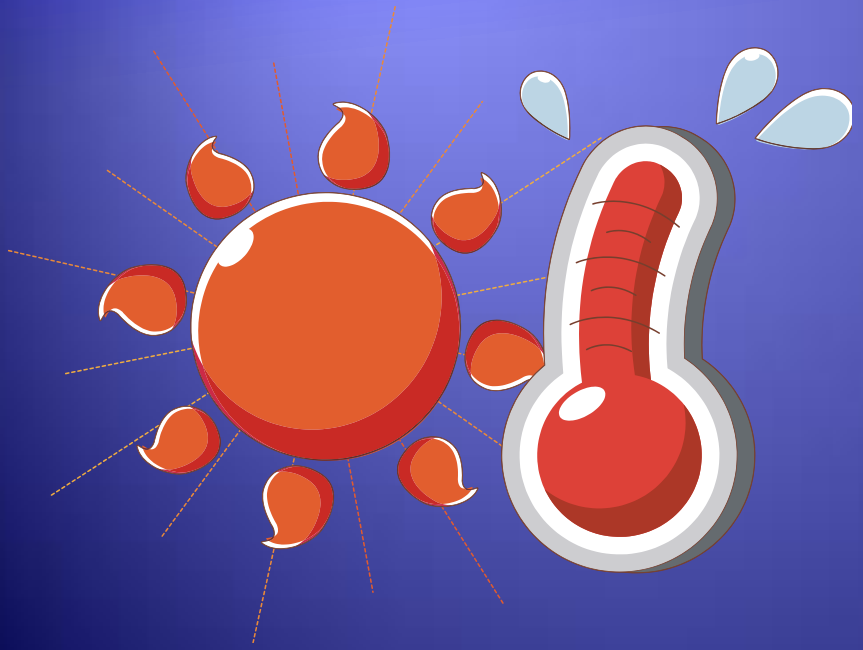
Modified Binders Affect Performance

- Same mix - different binders

PG 63-22 modified no rutting

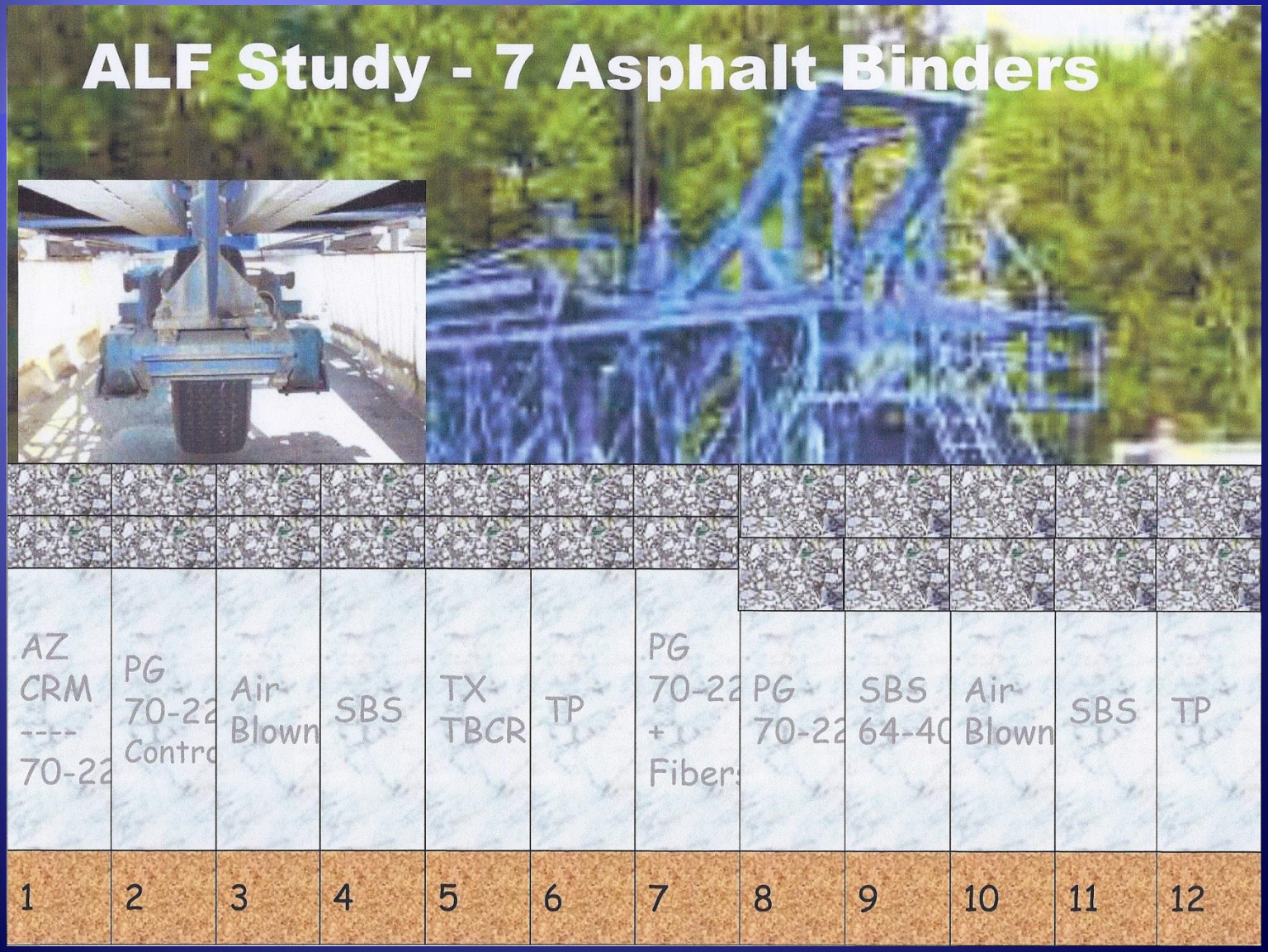
PG 67-22 unmodified 15mm rutting

What's Wrong With the Current High Temperature PG Test?

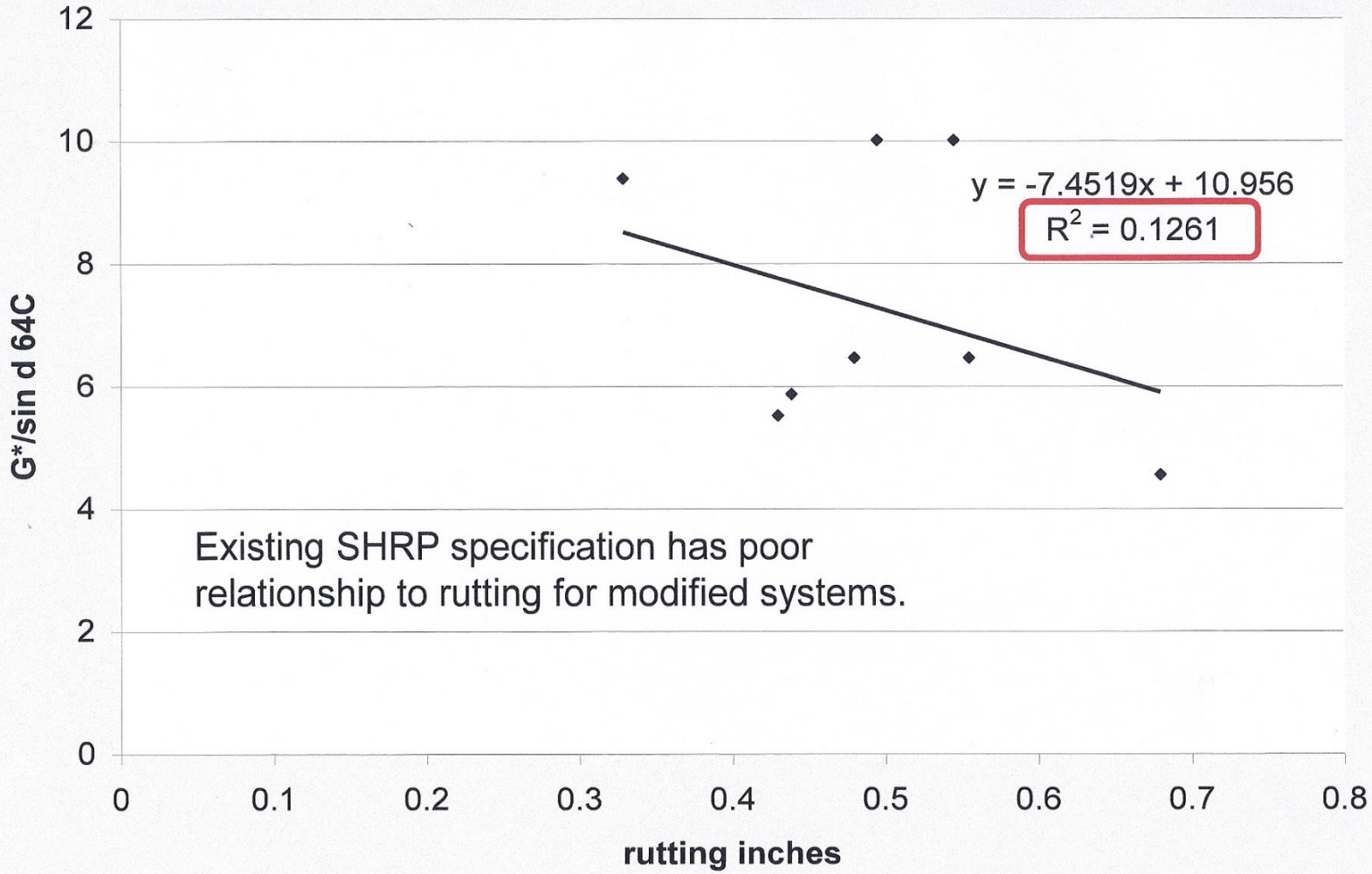


- We currently test a PG 76-22 at 76°C ≈ 170°F
- Pavements and asphalt binders do not reach 170°F
- Testing binders at artificially high temperatures which may distort performance
- PG test high temperature grading does not correlate with field rutting performance

FHWA Accelerated Loading Facility (ALF)



Correlation of G*/Sinδ To ALF



What's Wrong With the Current High Temperature PG Test?

- SHRP research used only unmodified asphalts and current test does not measure benefits of elastomeric polymers
- Most modified asphalts contain an elastomeric polymer
- Elastomeric material bounces back after load is removed – "recovers"

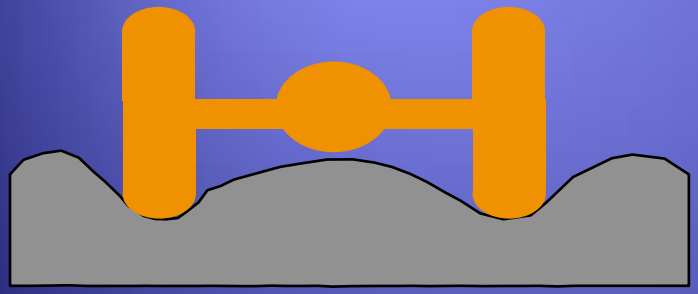
Multiple Stress Creep Recovery (MSCR) Test

- Any new specification must be blind to modification.
- A new specification must identify the rutting potential of all binder types under multiple conditions.
- Incorporate a rest period after loading the sample to measure recovery

MSCR Test

- Research looked for a material property other than Stiffness Modulus (G*) that would correlate with pavement rutting
- Discovered rutting correlation with non-recoverable compliance (J_{nr})
- J_{nr} is inverse of stiffness

Multiple Stress Creep and Recovery

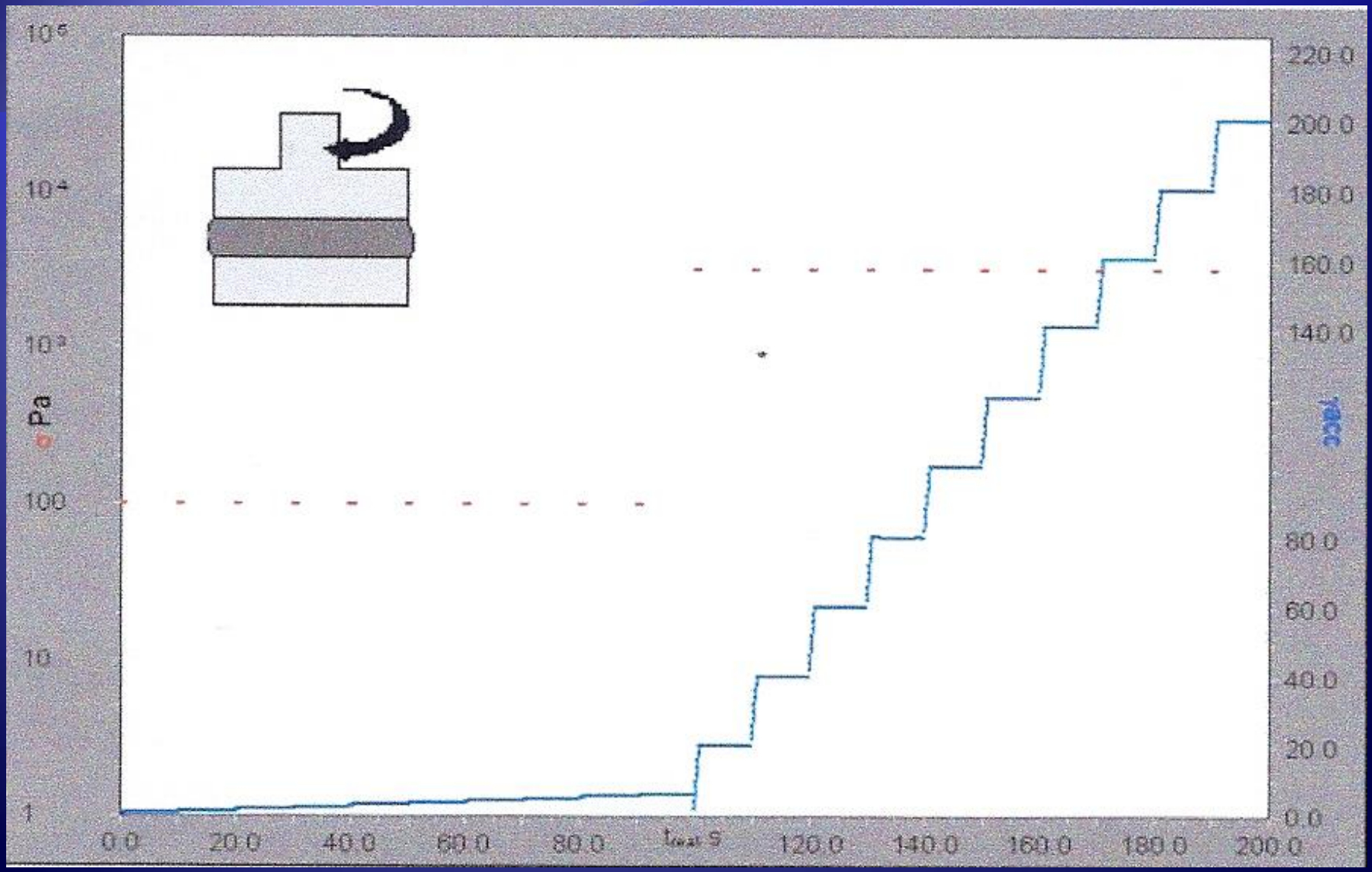


- Non-recoverable compliance (J_{nr}) describes stress dependency of the binder
- For neat asphalts, flow is linear and not sensitive to stress level
- For polymer-modified asphalts, response is not linear and is sensitive to stress level of the test
- Perform MSCR testing at two stress levels (100 Pa and 3200Pa) to check how sensitive the asphalt binder response is to stress level

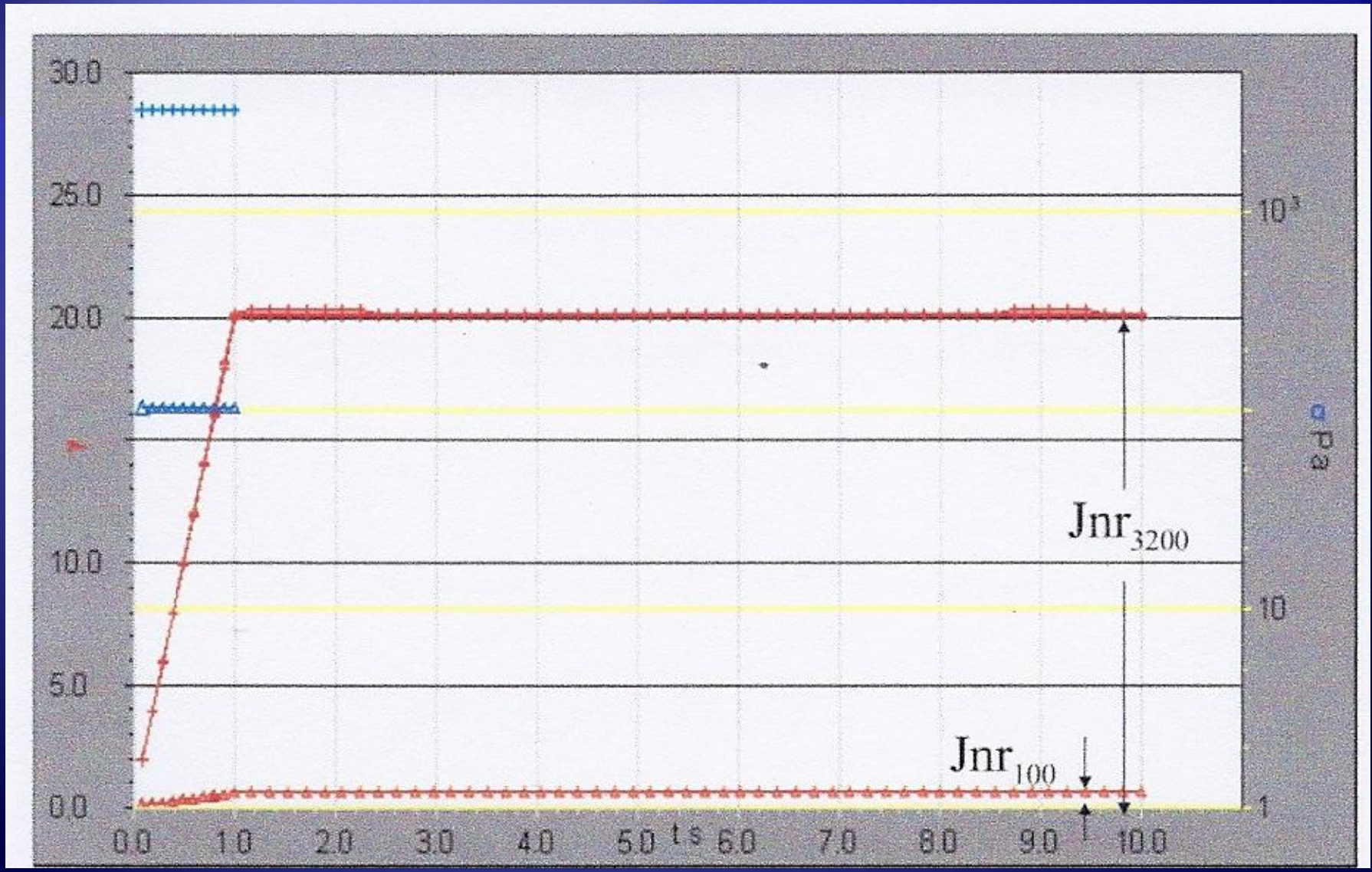
Multiple Stress Creep and Recovery

- Test Procedure
  - Apply 100 Pa Stress for a 1 second Creep period
  - Remove the Stress for a 9 second Recovery period
  - Repeat for 10 cycles
  - Apply 3200Pa Stress for a 1 second Creep period
  - Remove the Stress for a 9 second Recovery period
  - Repeat for 10 cycles

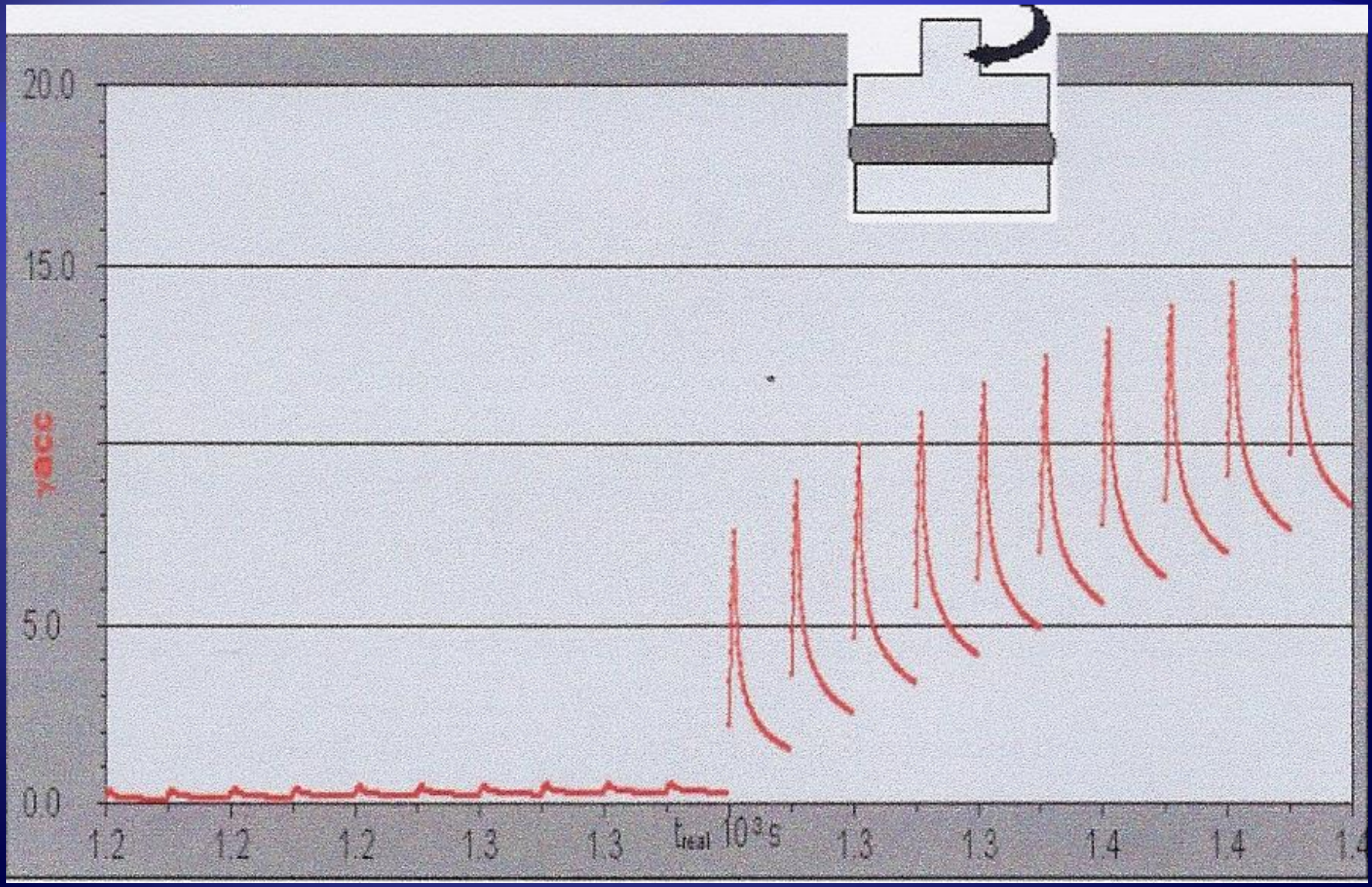
MSCR Plot for Neat Asphalt



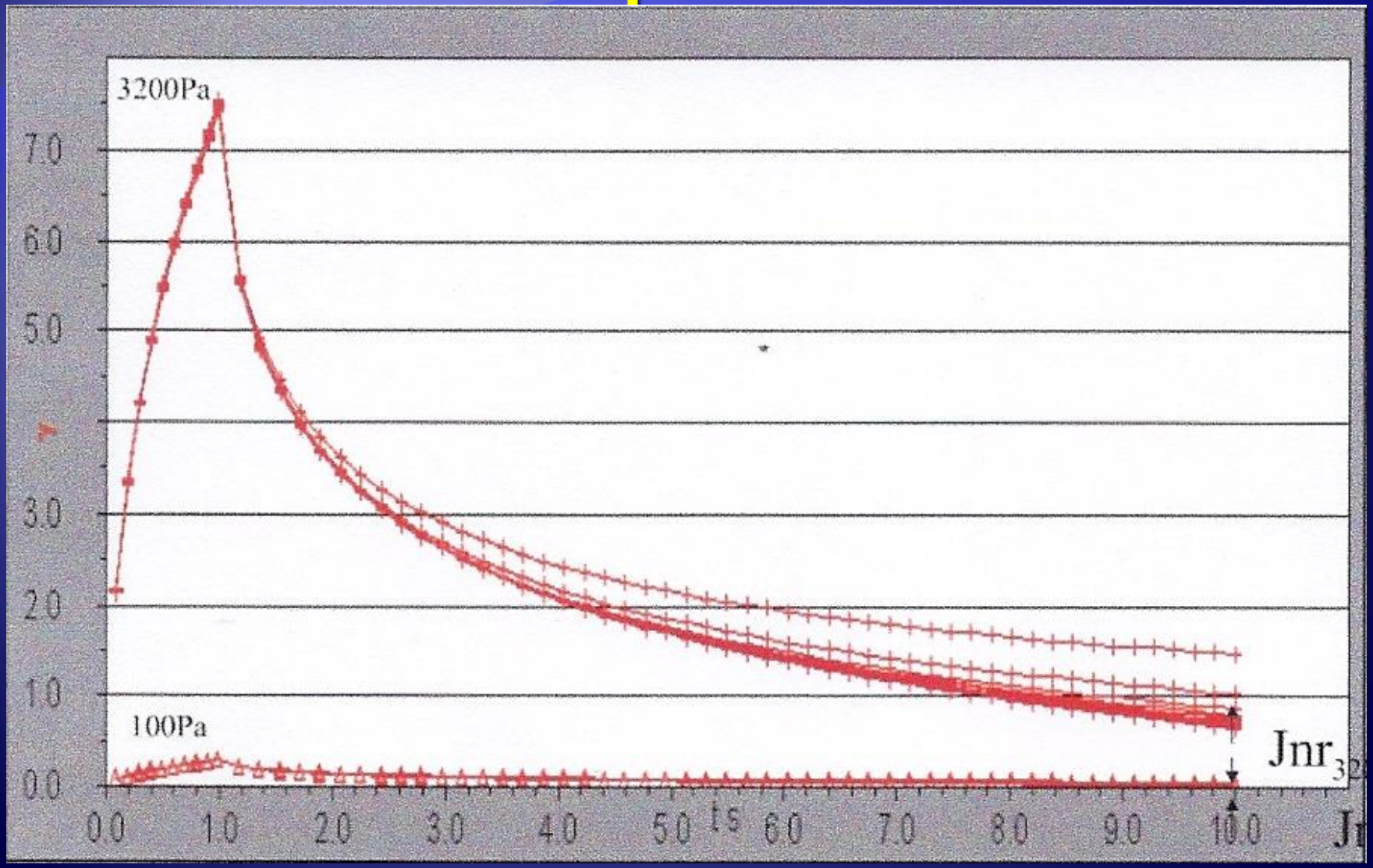
MSCR Single Cycle for Neat Asphalt



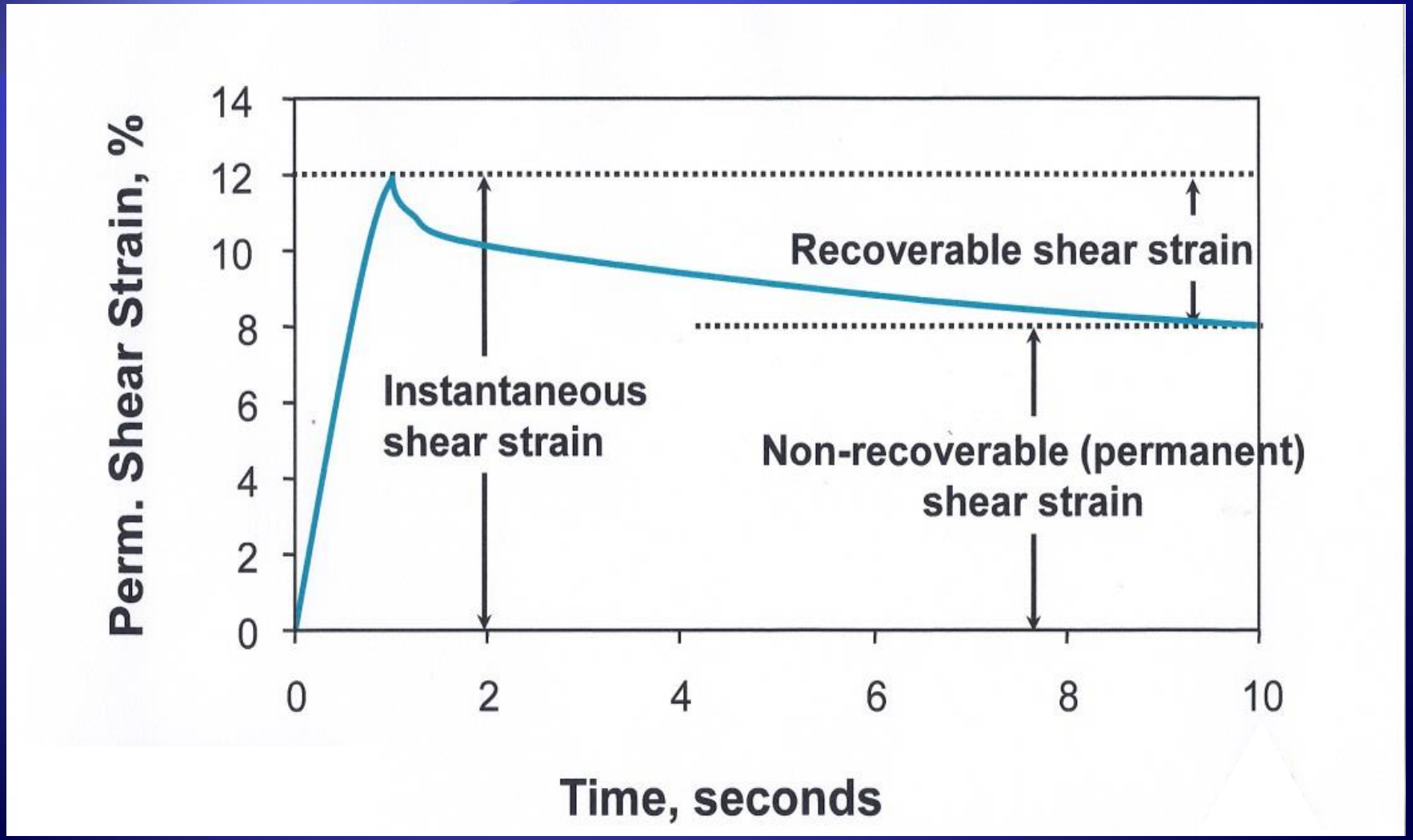
MSCR Plot for Modified Asphalt



MSCR Single Cycle for Modified Asphalt



MSCR Measurements



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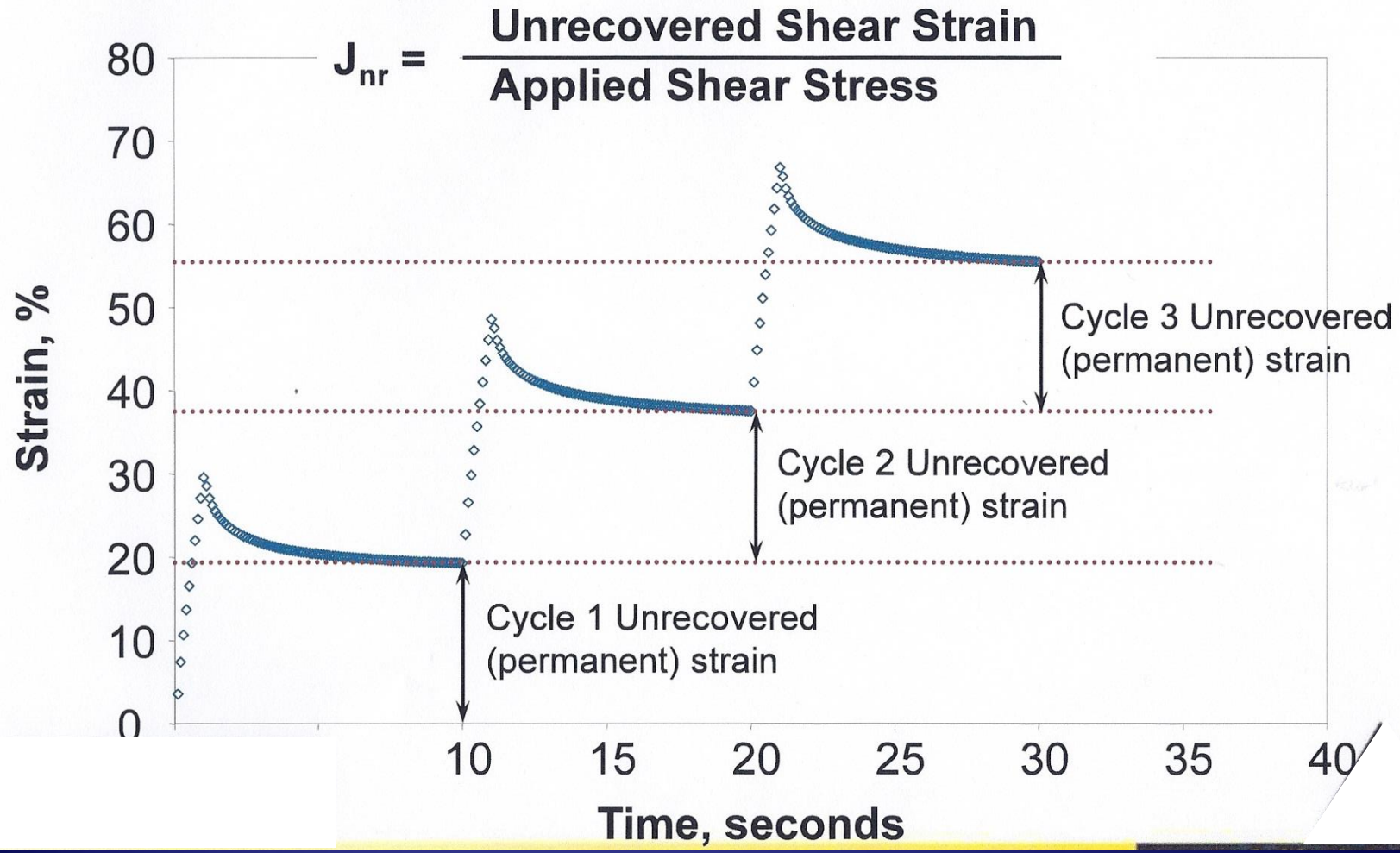
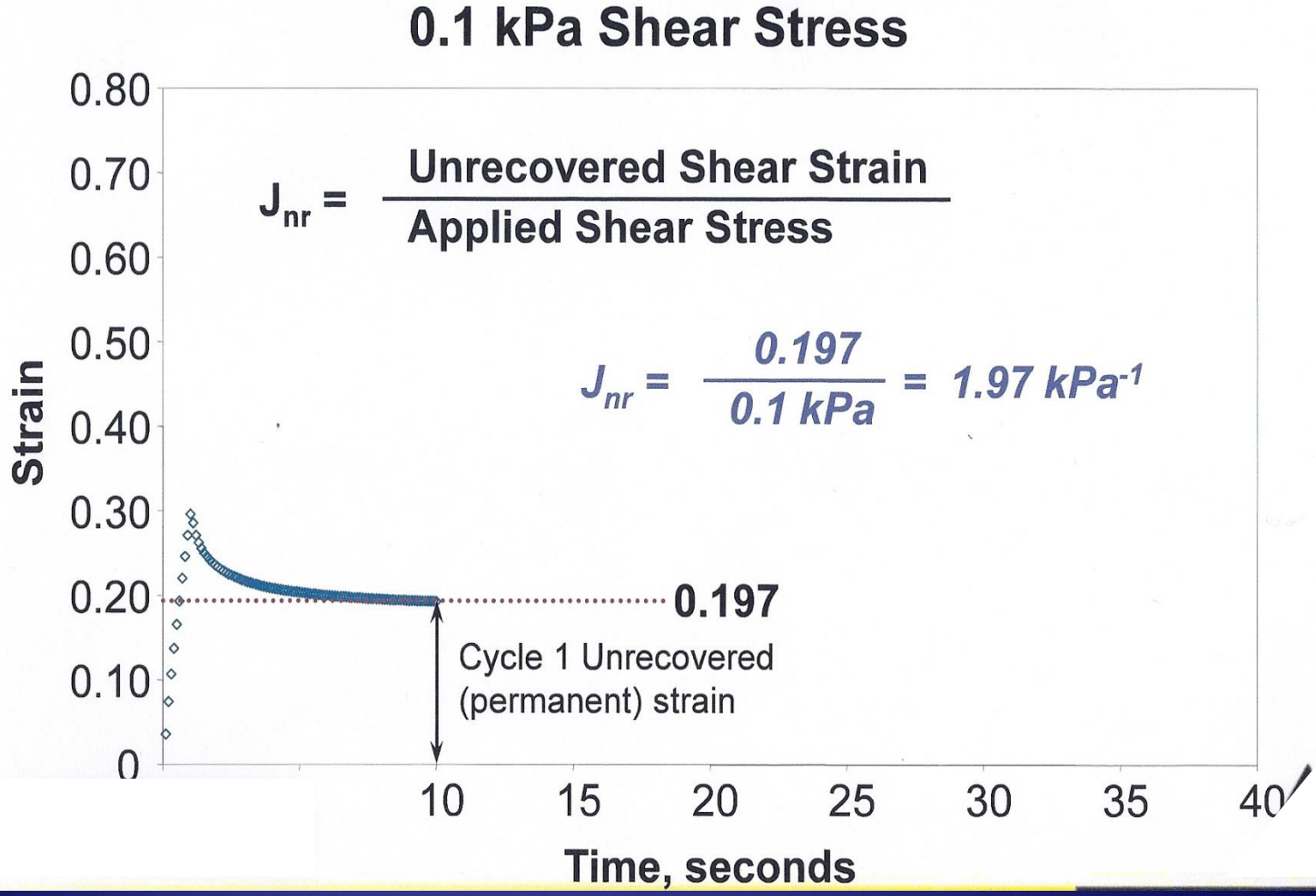


J_{nr} Calculations



Relationship Between G and J_{nr}

- Stiffness Modulus
  - G = Stress/ Strain
- Compliance
  - J = Strain/Stress
- J_{nr} and G are inverse values $1/J_{nr} \approx G^*/\sin\delta$
  - $G^*/\sin\delta$ = 2.2 for RTFO material
  - 1 / 2.2 ≈ .4
- $J_{nr} \geq 0.4$ established from research correlating J_{nr} values to mix testing and field performance
- Research and field data showed cutting J_{nr} in half cut rutting in half

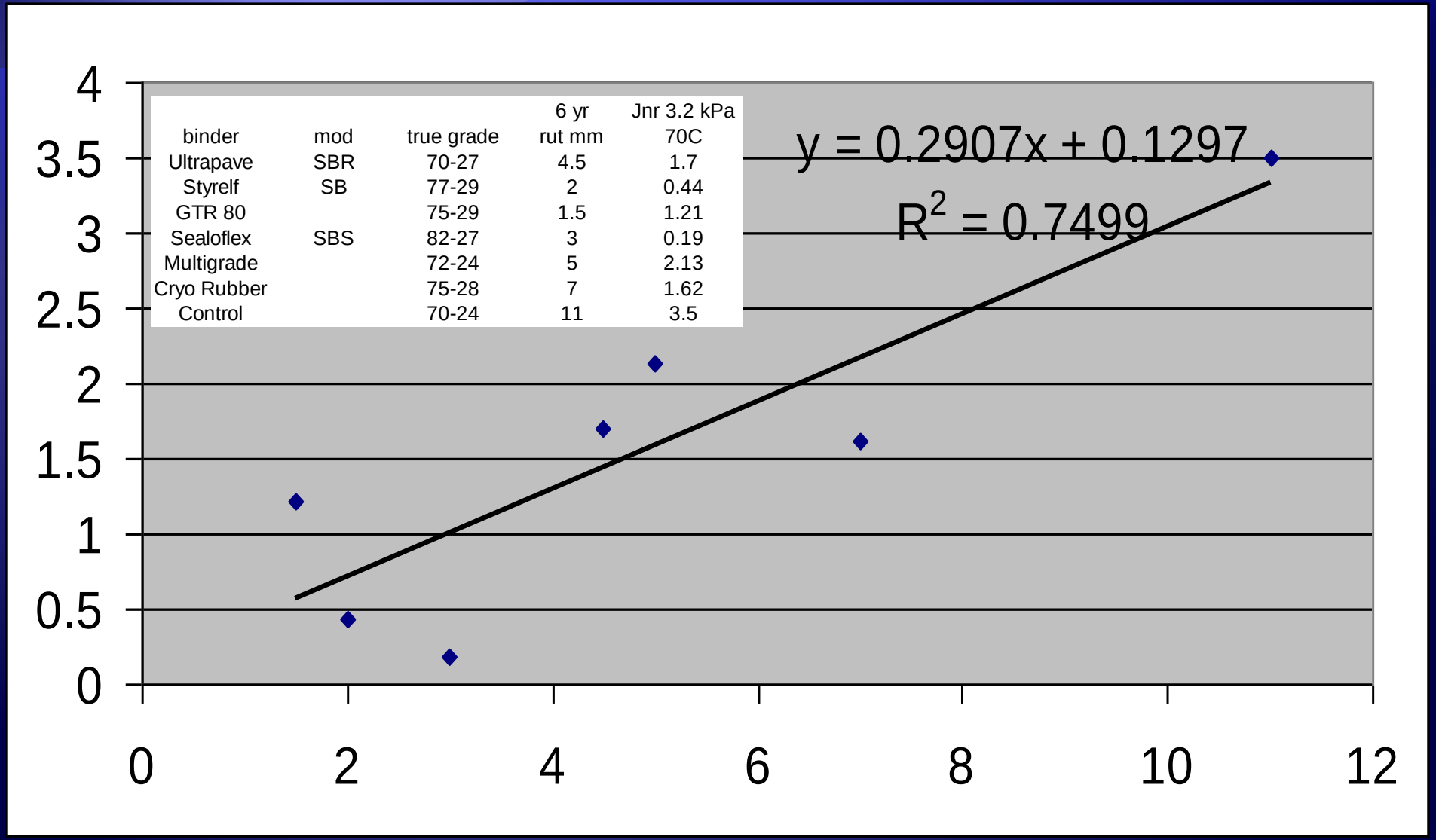
New PG Grading System (MSCR)

- Environmental grade plus traffic level designation
- Four Traffic Levels
  - S = Standard < 10 million ESALs and standard traffic loading
  - H = Heavy 10-30 million ESALs or slow moving traffic
  - V = Very Heavy > 30 million ESALs or standing traffic
  - E = Extreme > 30 million ESALs and standing traffic

New PG Grading System (MSCR)

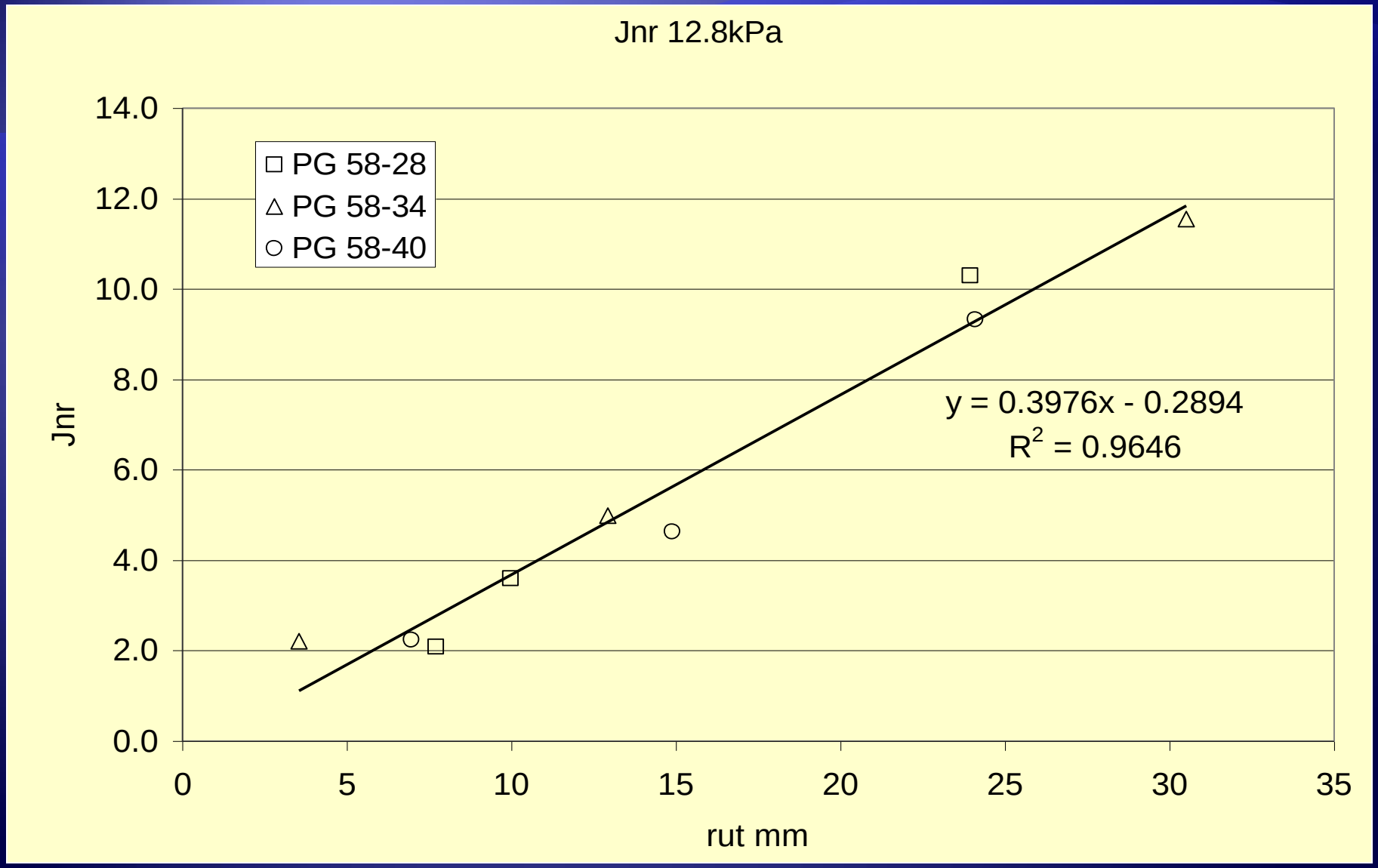
- PG 64-22 has 4 grades based on traffic (Standard, Heavy, Very Heavy, Extreme)
  - PG 64-22 becomes PG 64-22S $J_{nr} \leq 4.0$
  - PG 70-22 becomes PG 64-22H $J_{nr} \leq 2.0$
  - PG 76-22 becomes PG 64-22V $J_{nr} \leq 1.0$
  - PG 82-22 becomes PG 64-22E $J_{nr} \leq 0.5$
- Test temperature is 64°C for all grades and J_{nr} changes for each grade
- Old PG system the stiffness requirement remains the same, but test temperature changes

Mississippi I-55 6yr Rutting vs. Jnr @ 3.2 kPa



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

Hamburg Rut Testing MINN Road Mixes



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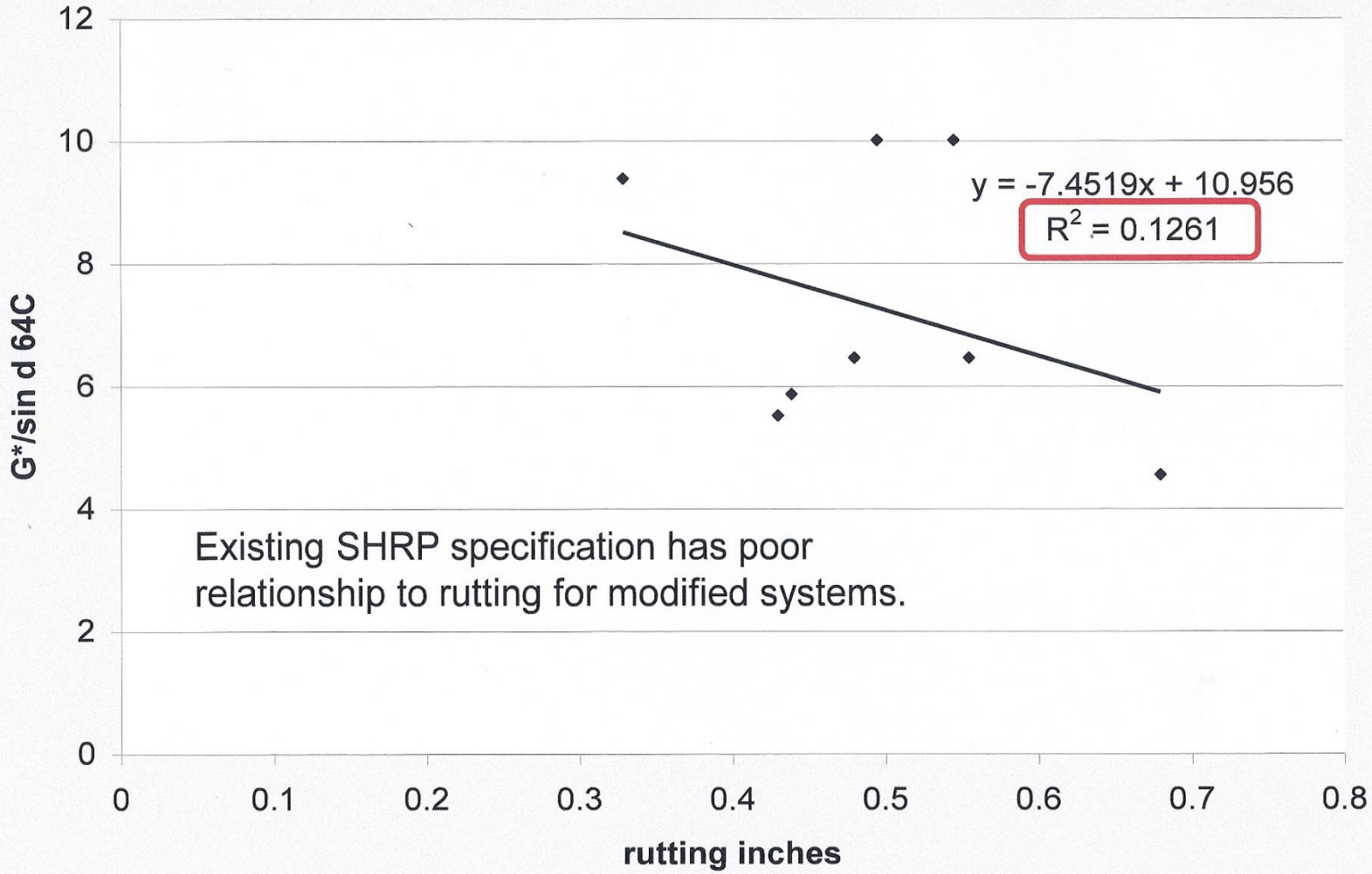
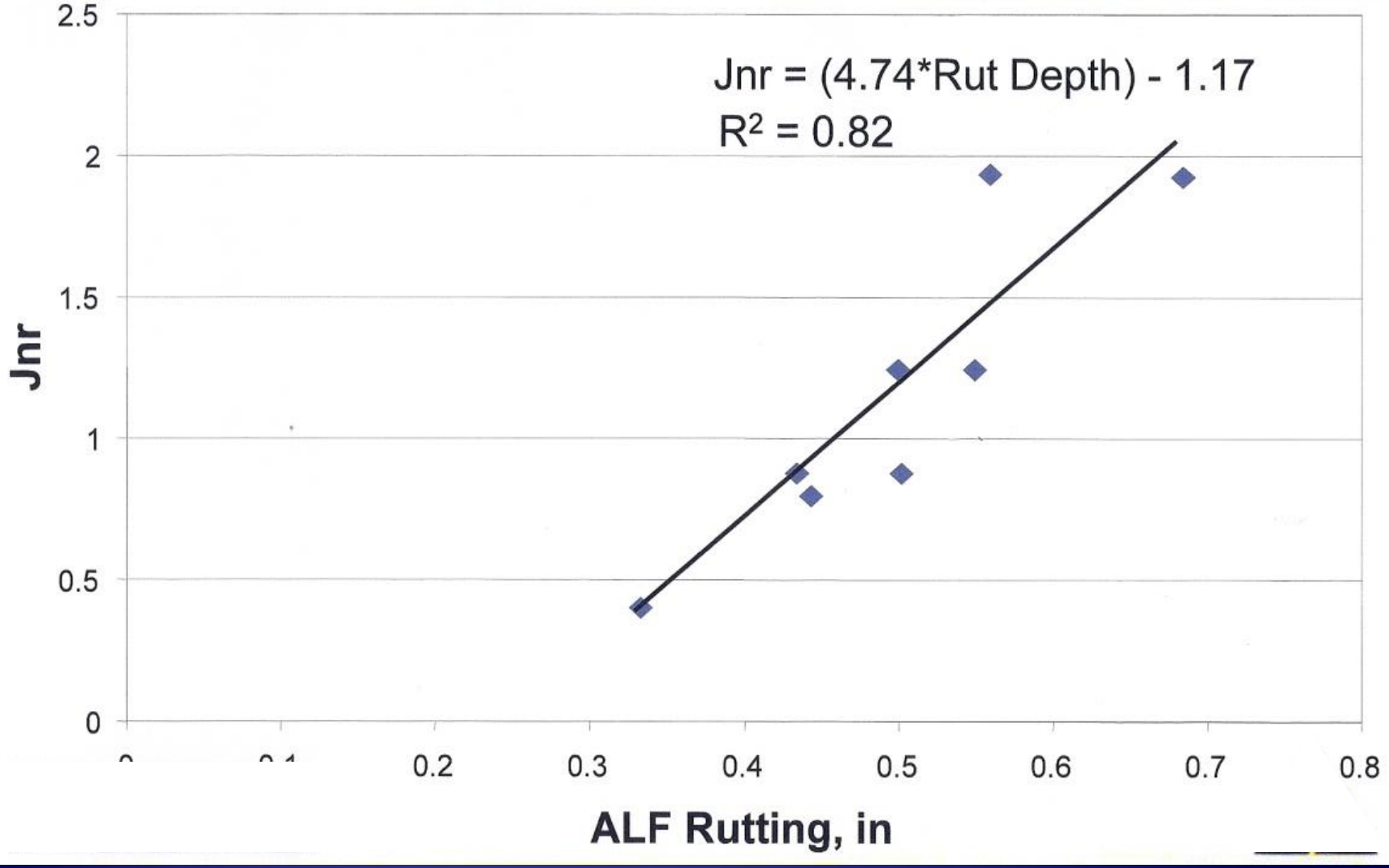


Correlation of J_{nr} to ALF



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 rutting, cracking and durability
- Most agencies using polymer-modified asphalt use a test in addition to the PG testing to ensure polymer modification
- PG+ tests are empirical methods to determine the presence of an elastic material
  - Stretch tests
  - Recovery tests

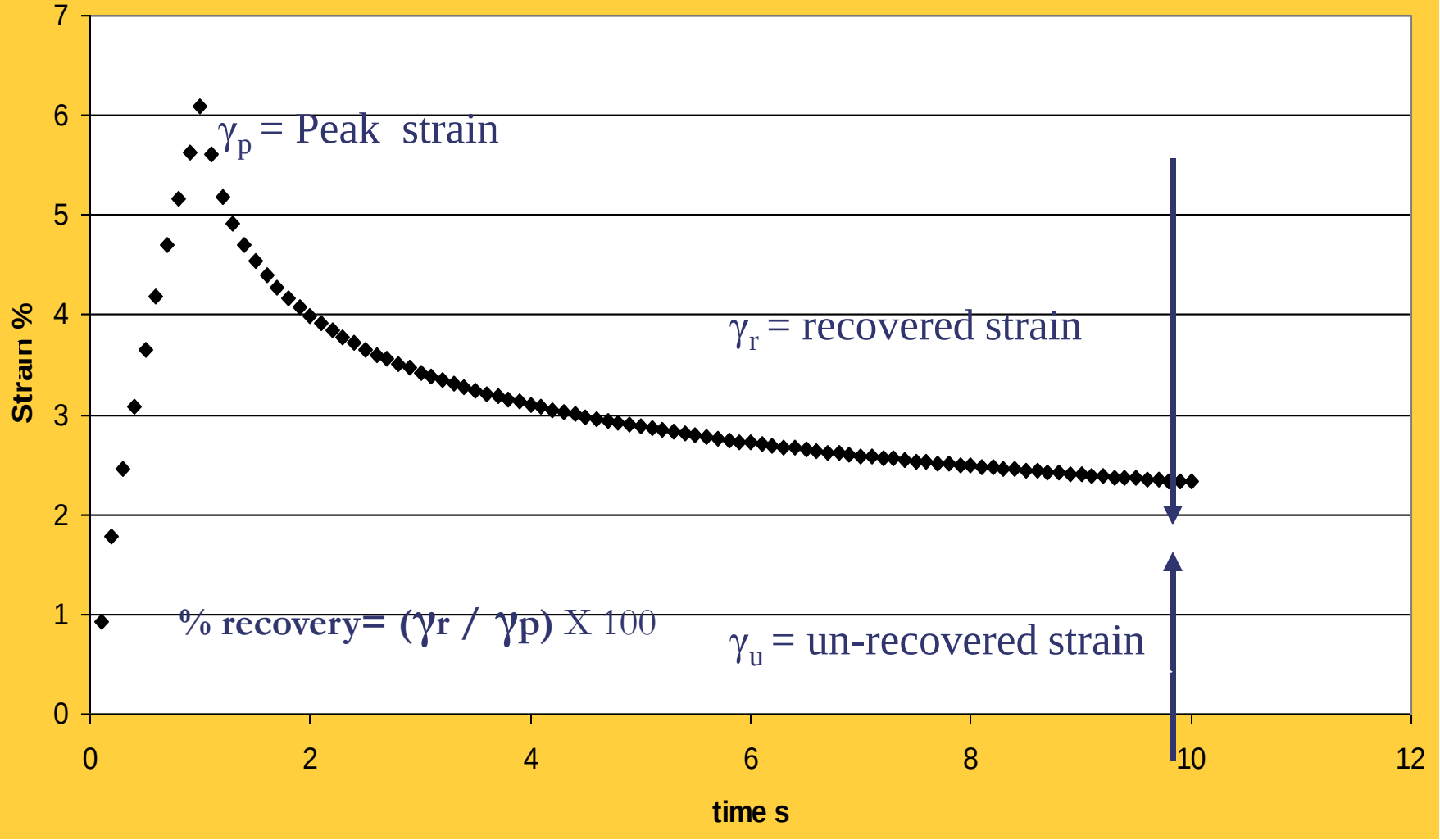
MSCR: What is % Recovery?

- PG+ tests in use
  - Phase Angle
  - Elastic Recovery
  - Forced Ductility
  - Toughness and Tenacity
- PG+ test procedures may vary widely from one agency to another
  - Mold shape
  - Amount of stretch
  - Hold time
  - Test temperature
- Multiple tests and procedures are burden for suppliers selling to multiple states

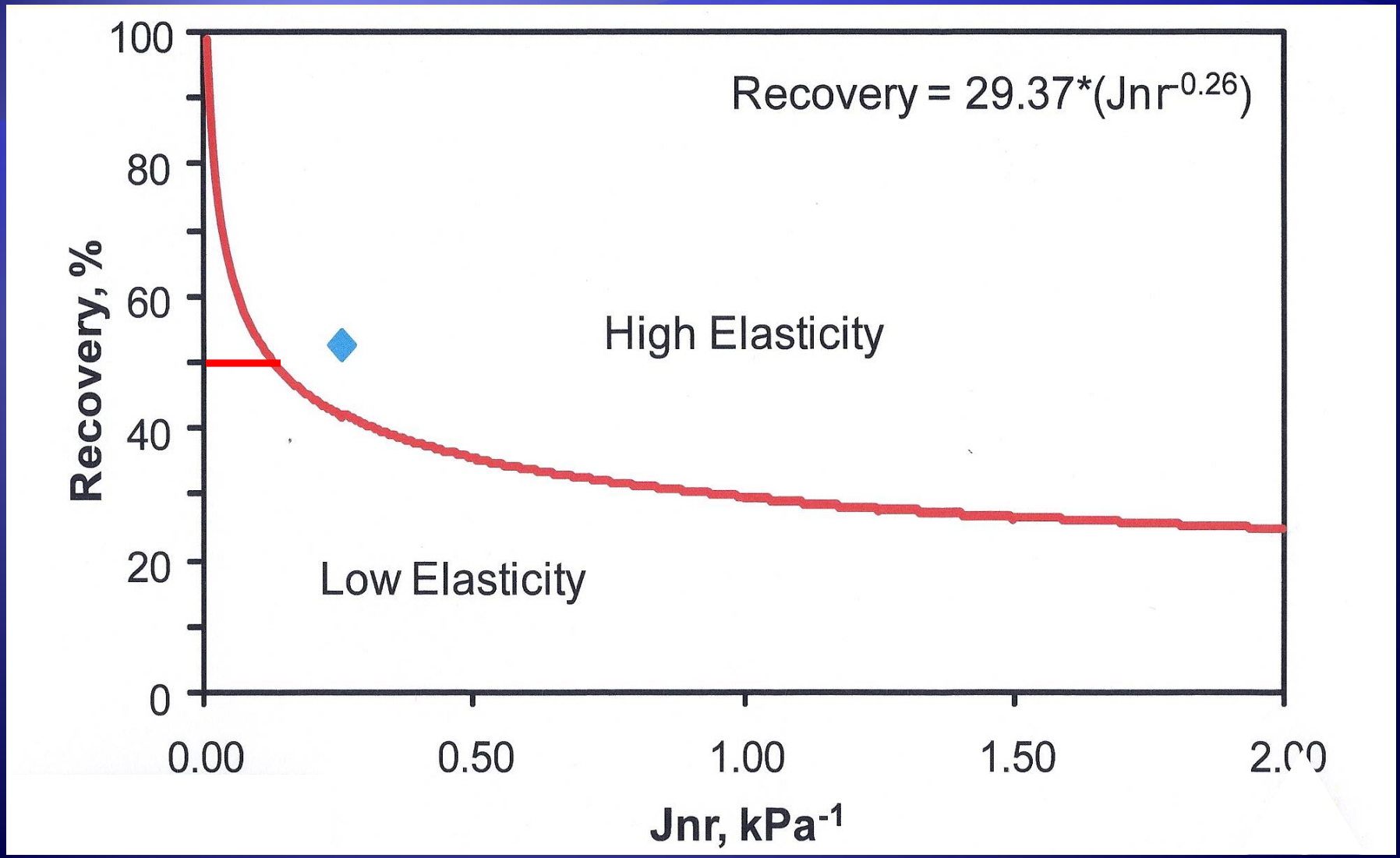
MSCR: What is % Recovery?

- PG+ tests may determine presence of elastomeric polymer, but not how effectively it is blended with the polymer
- MSCR % Recovery can identify presence of elastomeric polymer and its effectiveness

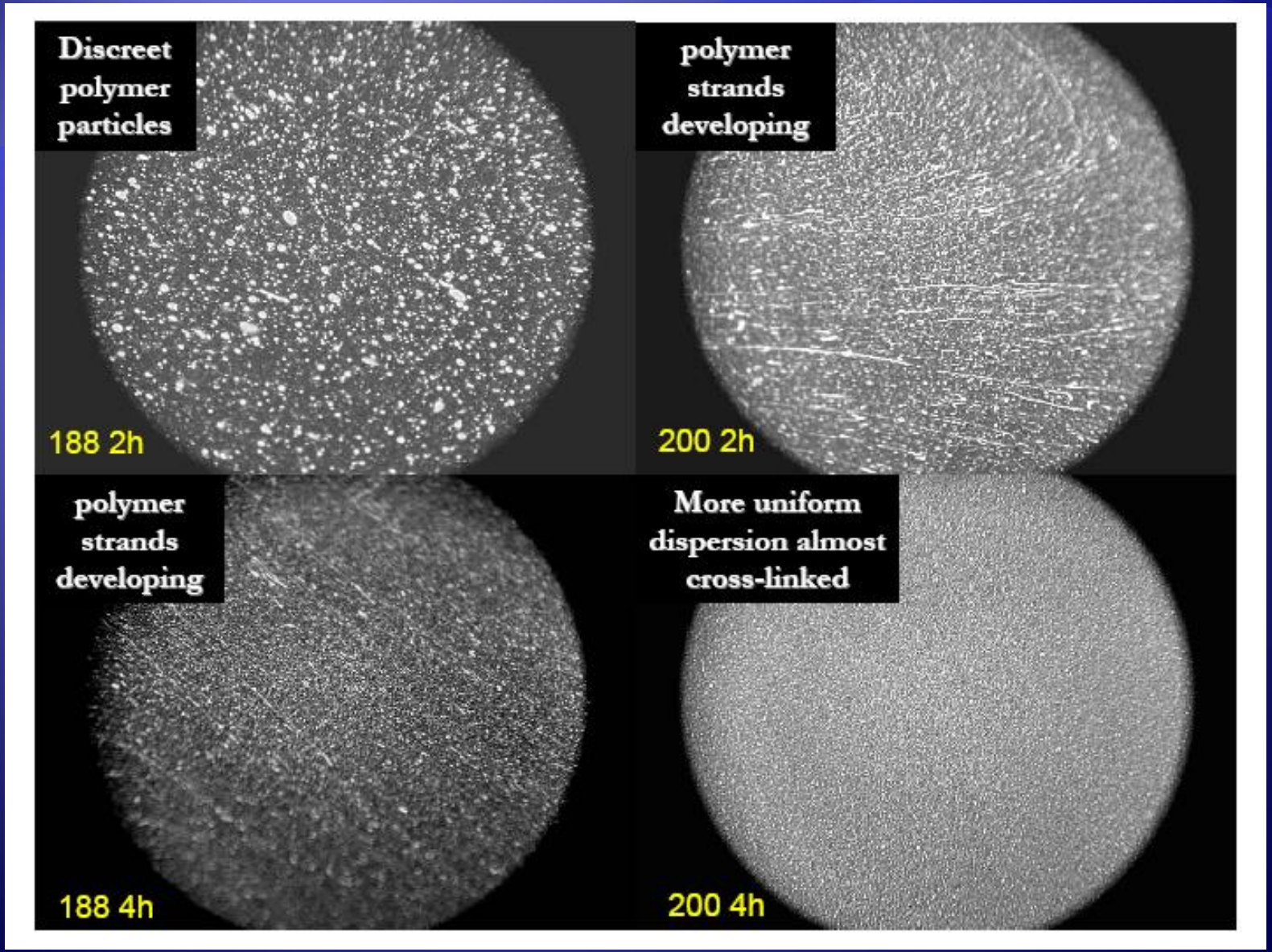
MSCR: What is % Recovery?



MSCR Recovery Requirements



Fluorescence Micro-graphs of PMA



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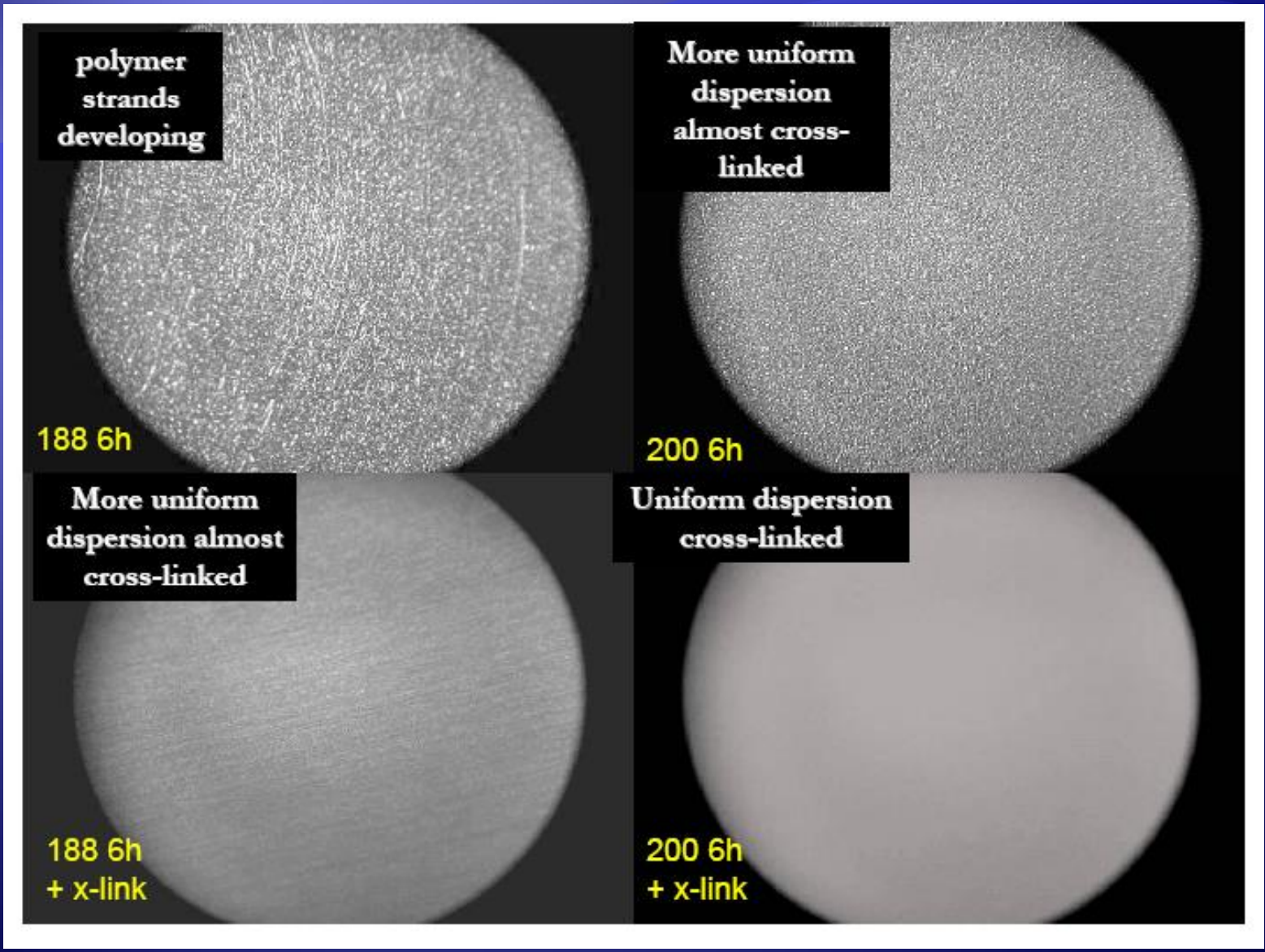
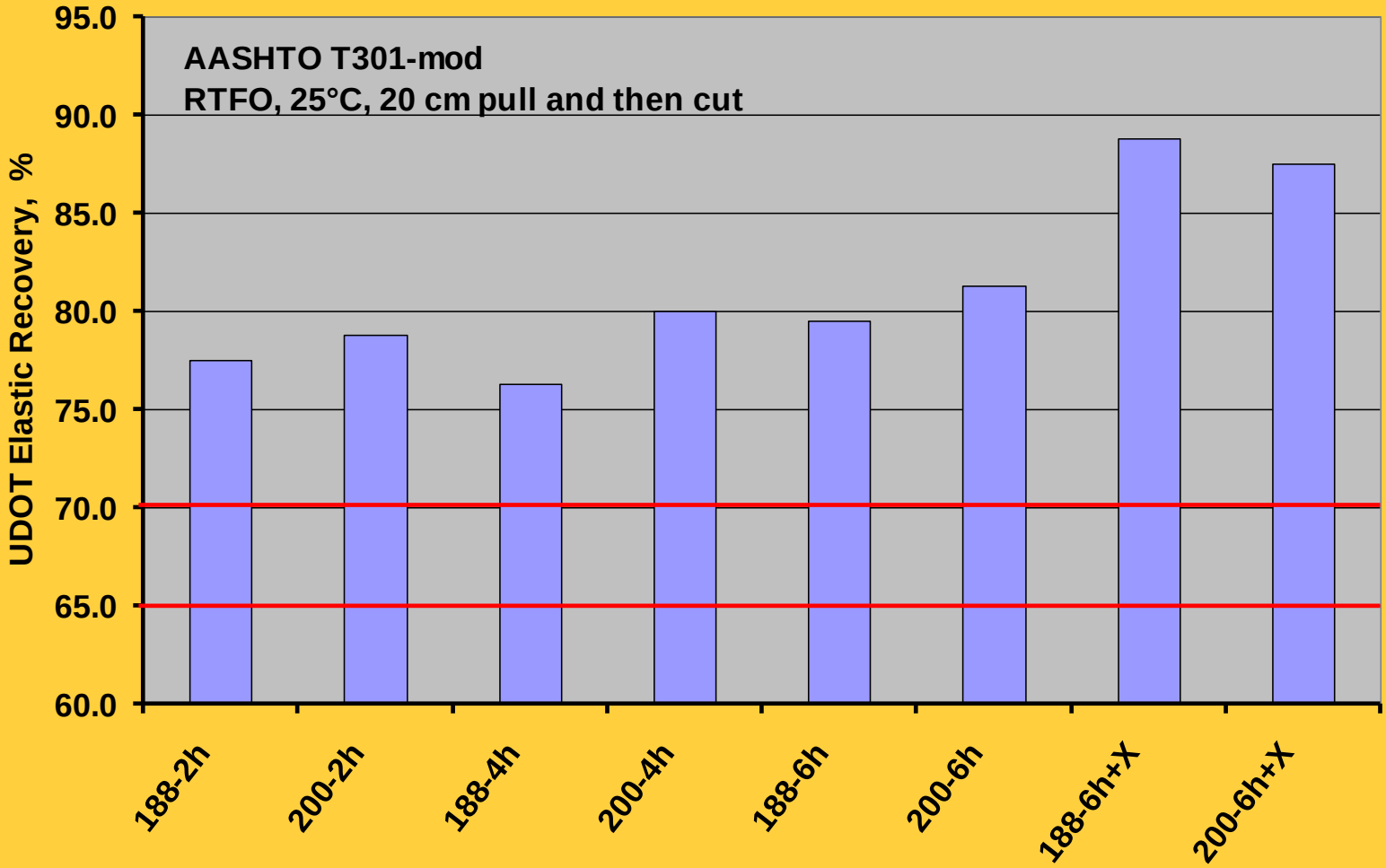
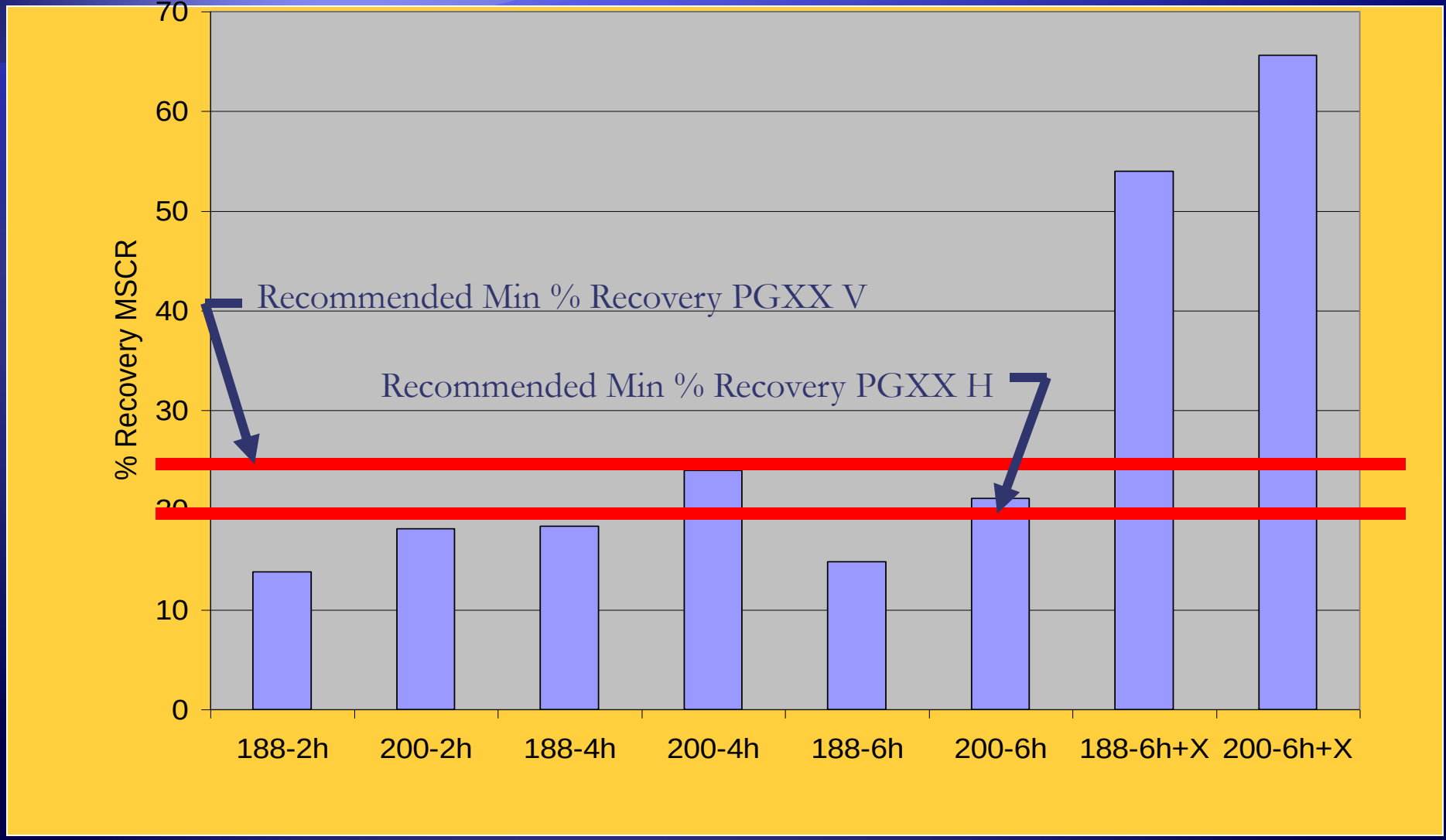


Changes in UDOT Elastic Recovery with Processing



Changes in % Recovery MSCR test with Processing



MSCR % Recovery Conclusions

- Mixing Temperature and cross-linking affect the properties of polymer modified binders.
- The Elastic Recovery showed little difference between the different processing methods.
- The MSCR J_{nr} and MSCR % Recovery indicated larger differences than the current PG and ER tests.
- The Larger differences were verified by the Florescence Microscopy.
- MSCR can replace the ER
  - Single protocol
  - Quick and easy
  - Fundamental property

Current Products Tested With J_{nr} Specification

PG Grade	PG Grade (J_{nr})	J_{nr} Spec	J_{nr} Value	% Recovery Spec	% Recovery Value	Hamburg Rut Depth (10,000 passes)
PG 64-22	PG 64E-22	≤4.0	3.40	NA	NA	7.1 mm
PG 70-22	PG 64H-22	≤2.0	1.35	NA	NA	3.57 mm
PG 76-22	PG 64V-22	≤1.0	0.24	>50%	55.8%	1.68 mm
PG 82-22	PG 64E-22	≤0.5	0.082	>66%	78.5%	1.55 mm

- Current Axeon SP Asphalt Binders
- PG 64-22 and PG 70-22 are neat asphalts
- PG 76-22 and PG 82-22 are polymer modified

Implementation of MSCR Specification

- NEAUPG states agreed to implement MSCR grading on polymer-modified grades in 2014
- NJDOT specifies PG 76-22
- Testing on current PG 76-22 binders indicates they are PG 64E-22
- NJDOT and other NEAUPG states will specify PG 64E-22 in place of PG 76-22
- For first year Axeon SP will label as follows:
  - PG 76-22 (PG 64E-22)

Implementation of MSCR Specification

- MSCR research indicates J_{nr} is a major improvement in high temperature PG asphalt testing
  - Much better correlation with rutting in the roadway
- MSCR % Recovery does a much better job of measuring the presence of polymer and the effectiveness of the polymer in the asphalt than current PG+ tests

THANK YOU

Questions?