Development of A High Temperature Performance Based Binder Specification

Problem-High Temperature Binder Criteria

- Does G*/sinδ reflect rutting performance of modified binders.
  - General anecdotal data says no.
- What are the alternatives?
  - ZSV, LSV, Creep & Recovery testing

High Temperature Binder Criteria

- What is Rutting?
  - Rutting is the plastic deformation of a mix caused by heavy traffic loads.
  - This is a high strain failure in the pavement. It is a non-linear response.
  - Linear criteria of the binder are not likely to correlate with failure.

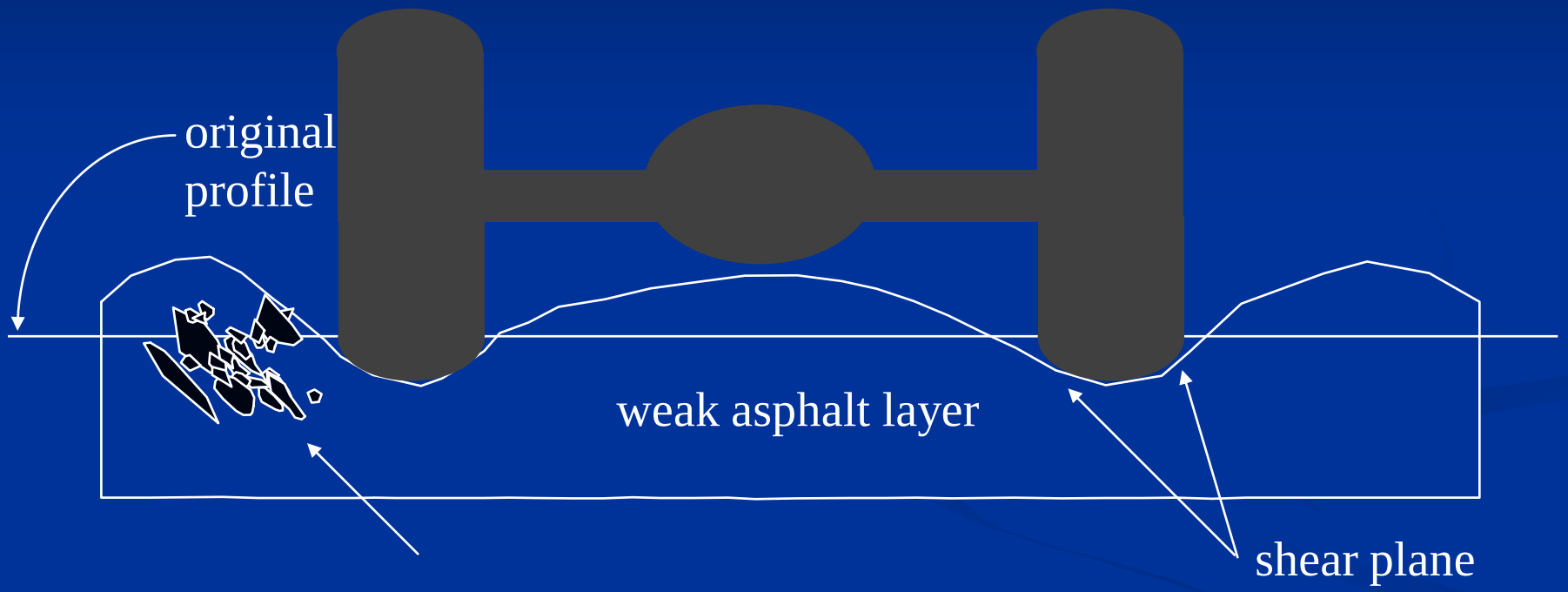
High Temperature Binder Criteria

- Current spec, G* and δ are measured in the linear range.
- For viscous materials flow is linear even under high stress and high strain.
- For polymer networks the binder response is not linear for high stress and high strain.

High Temperature Binder Criteria

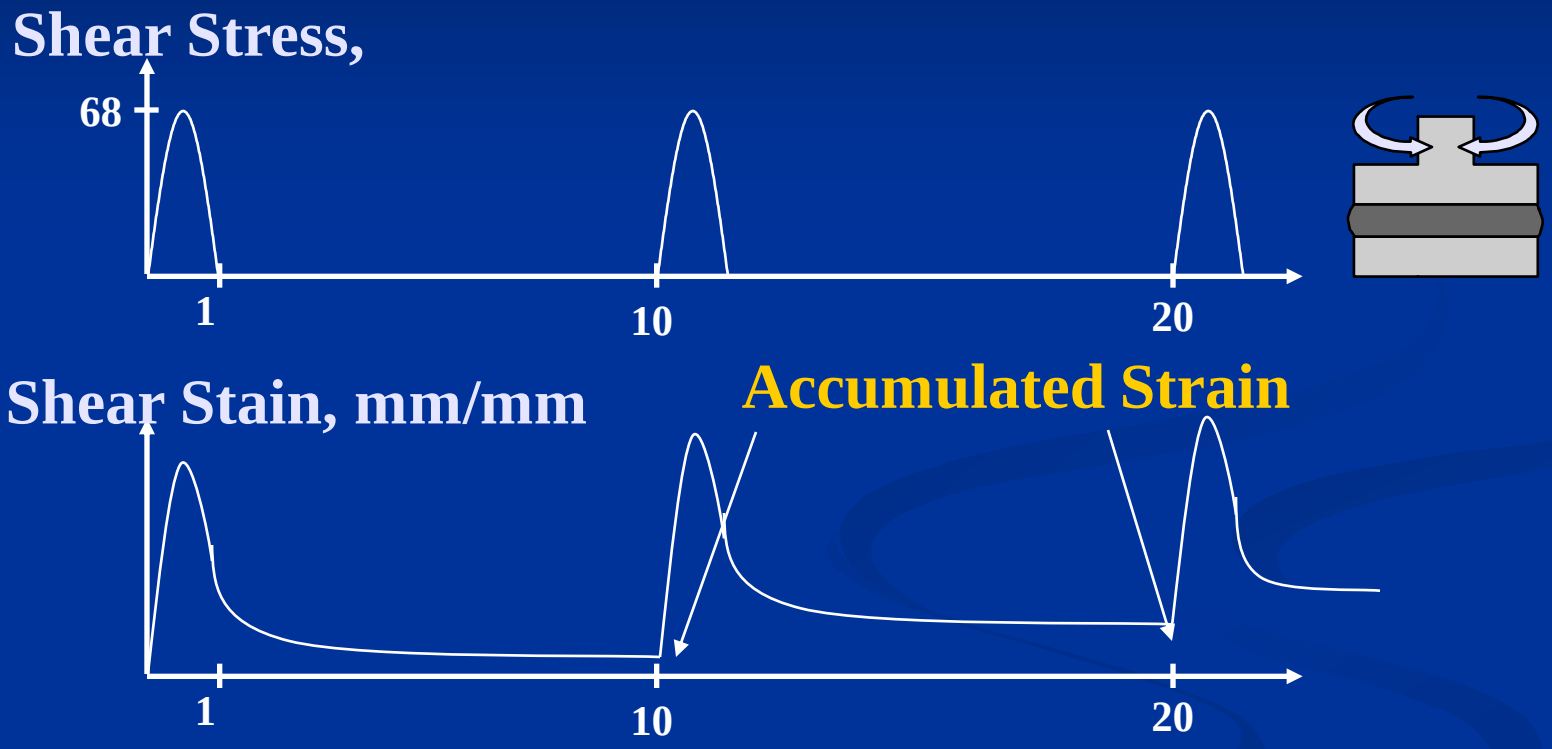
- Study
  - Evaluate several binders in the same mix
  - Evaluate binders in rut testers
  - Hamburg wheel tracker
  - Asphalt Pavement Analyzer

Rutting in Asphalt Layer



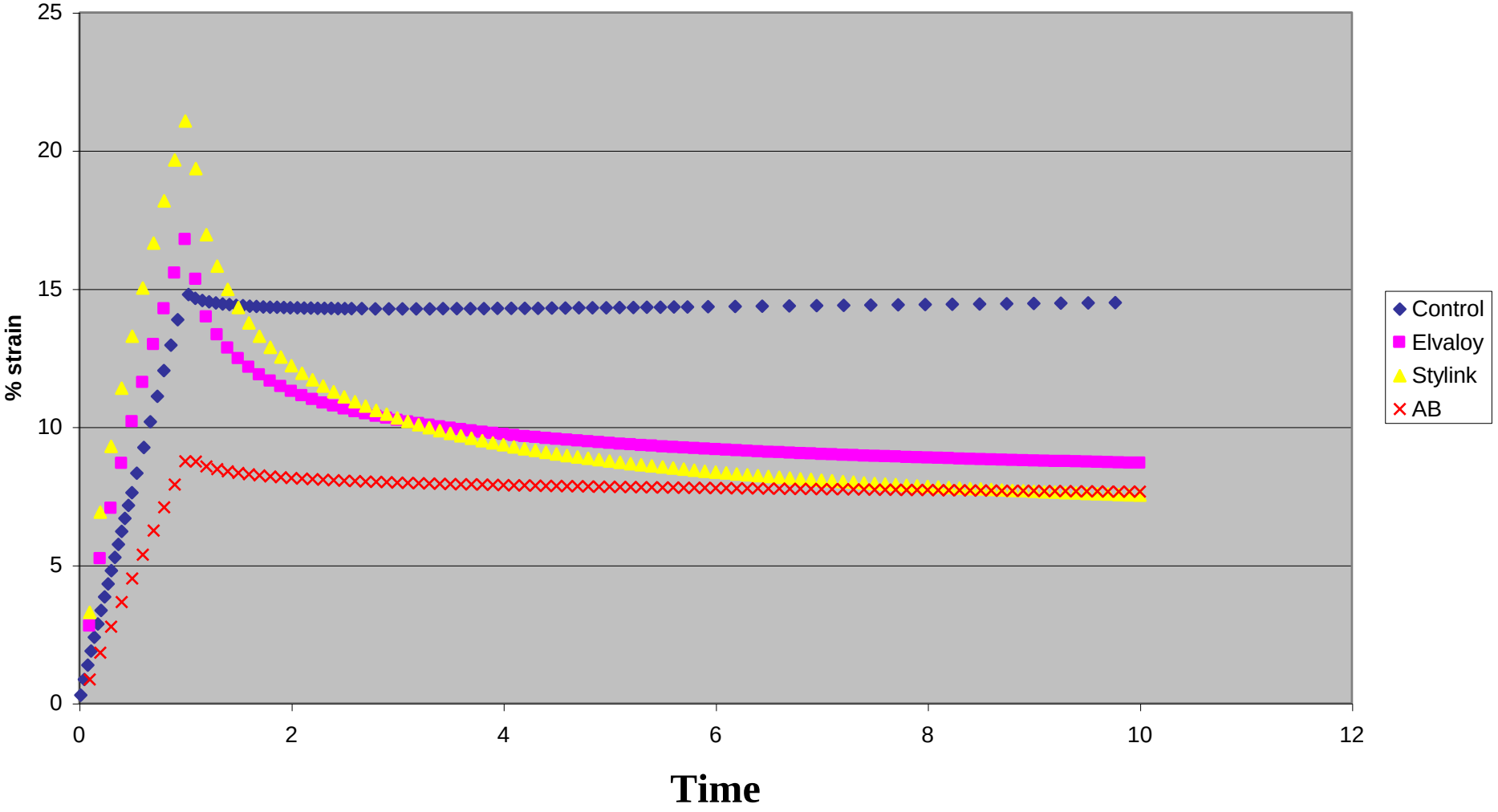
Movement and rotation of aggregate creates very high strain in the binder.

NCHRP 9-10 Rutting Test Repeated Creep Recovery Test

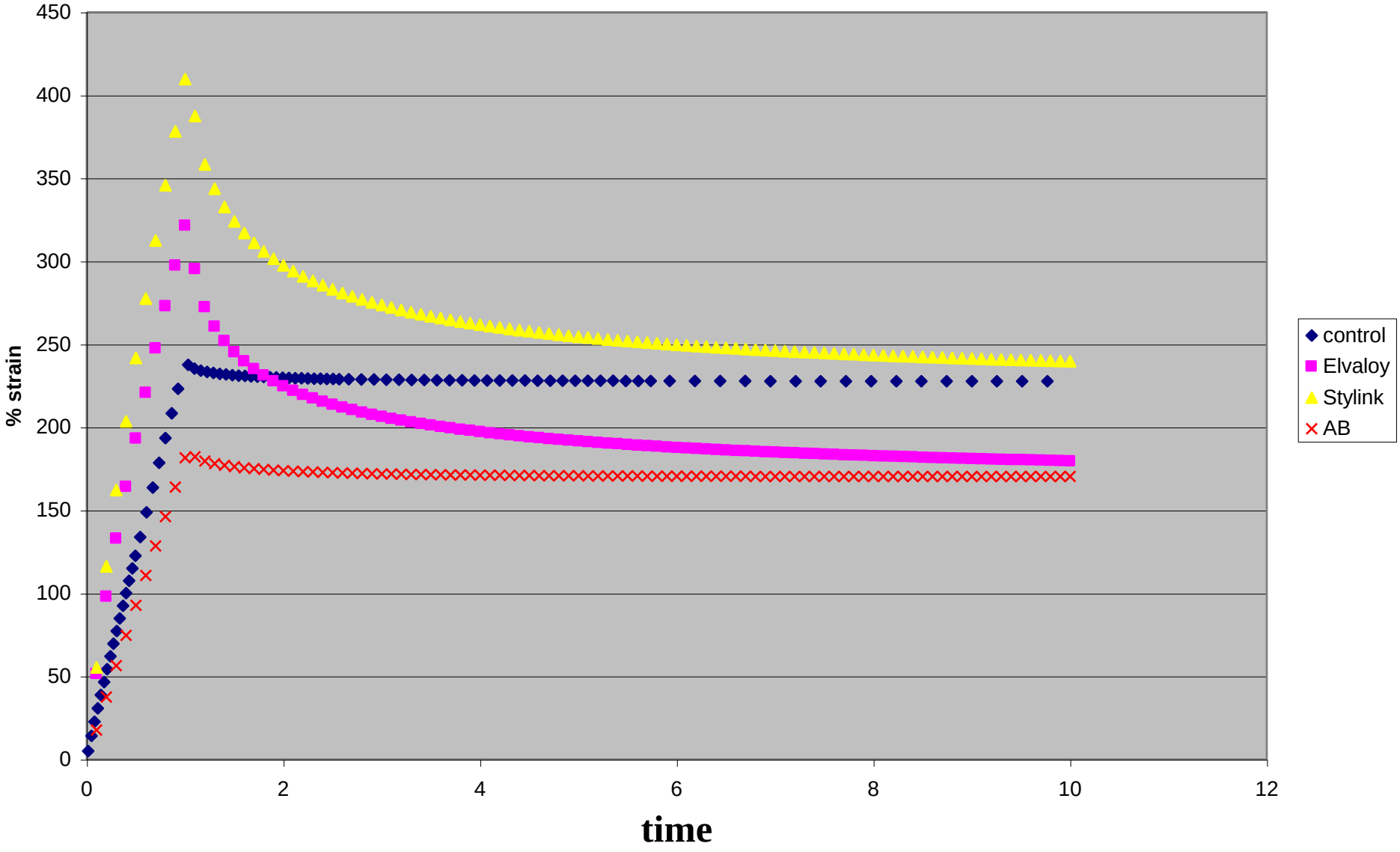


The original 9-10 work included only one stress level. Future work to look at multiple levels.

Creep 1st cycle 70C 50 Pa



Creep 1st cycle 70C 1000 Pa



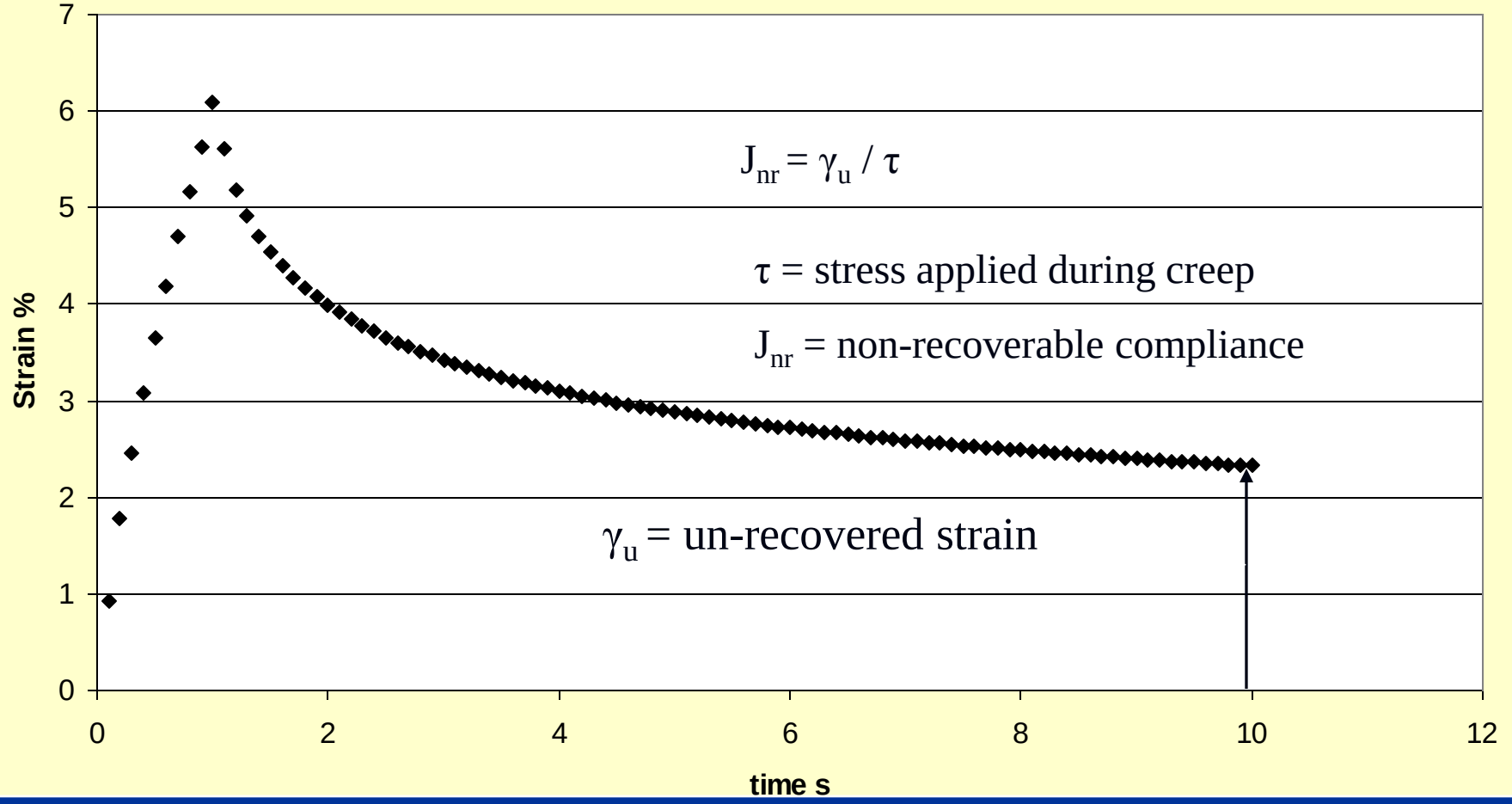
High Temperature Binder Criteria

- APA and Hamburg are failure tests.
- Binder properties measured in the linear range can not correlate with non linear mix tests.
- Polymer chains will slip under high stress and allow high strain
- Pavement response must be determined to relate binder to mix

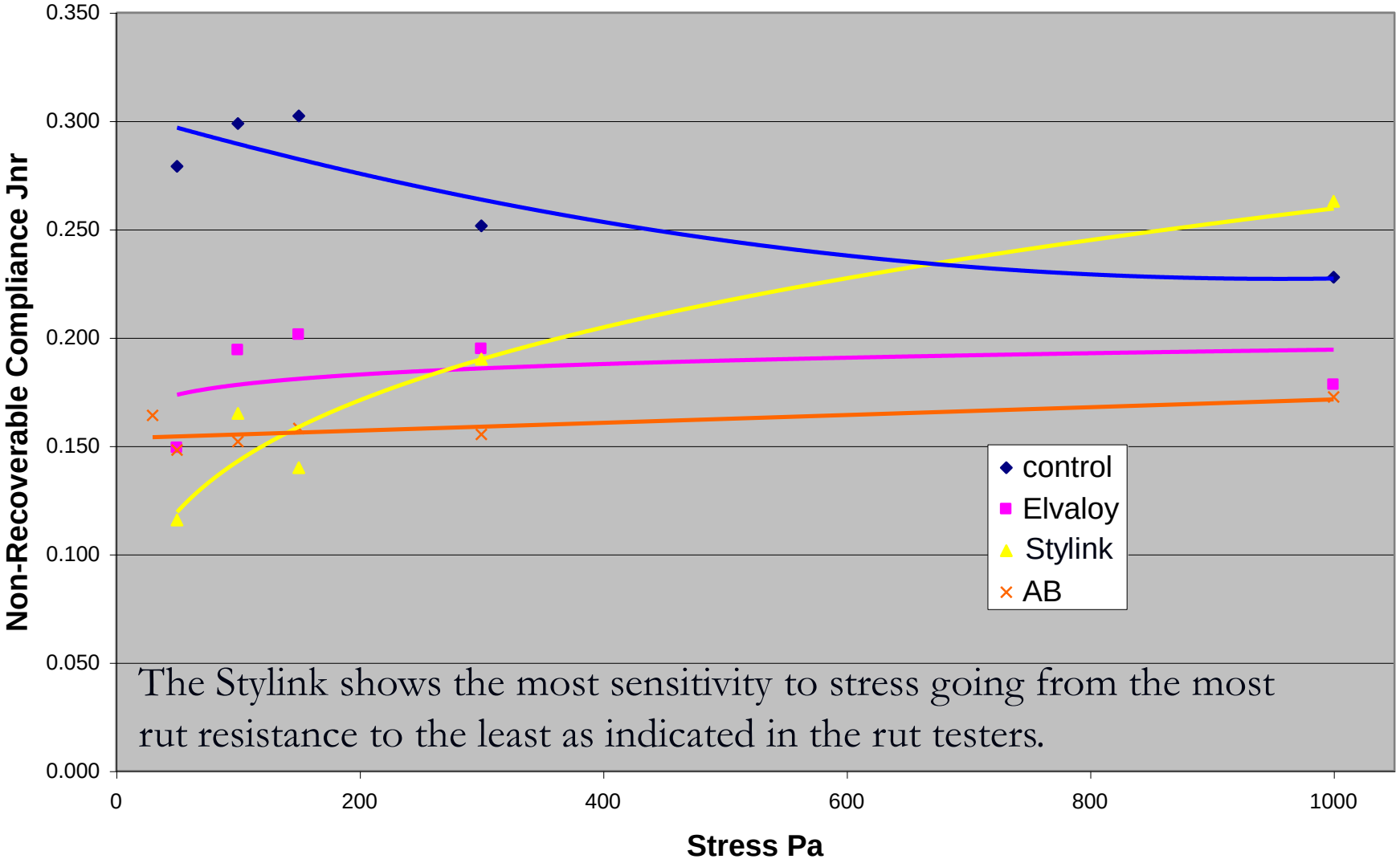
High Temperature Binder Criteria

- New criteria non-recoverable compliance is based on binder creep testing at several stress levels.
- Determine the average non-recovered stain at a specific stress level and then divide the average non-recovered strain by the initial stress = non-recoverable compliance Jnr.

What is Non-recoverable compliance



Jnr of the binder from Rut Tester Study



The Stylink shows the most sensitivity to stress going from the most rut resistance to the least as indicated in the rut testers.

High Temperature Binder Test

- New experimental test criteria:
  - Perform multiple stress levels on the same sample at reduced number of cycles.
  - Stress levels: .025, .05, .1, .2, .4, .8, 1.6, 3.2, 6.4, 12.8, 25.6 kPa.
  - Run 10 cycles at each stress level no rest periods
  - Total cycles per test 110.

High Temperature Binder Criteria

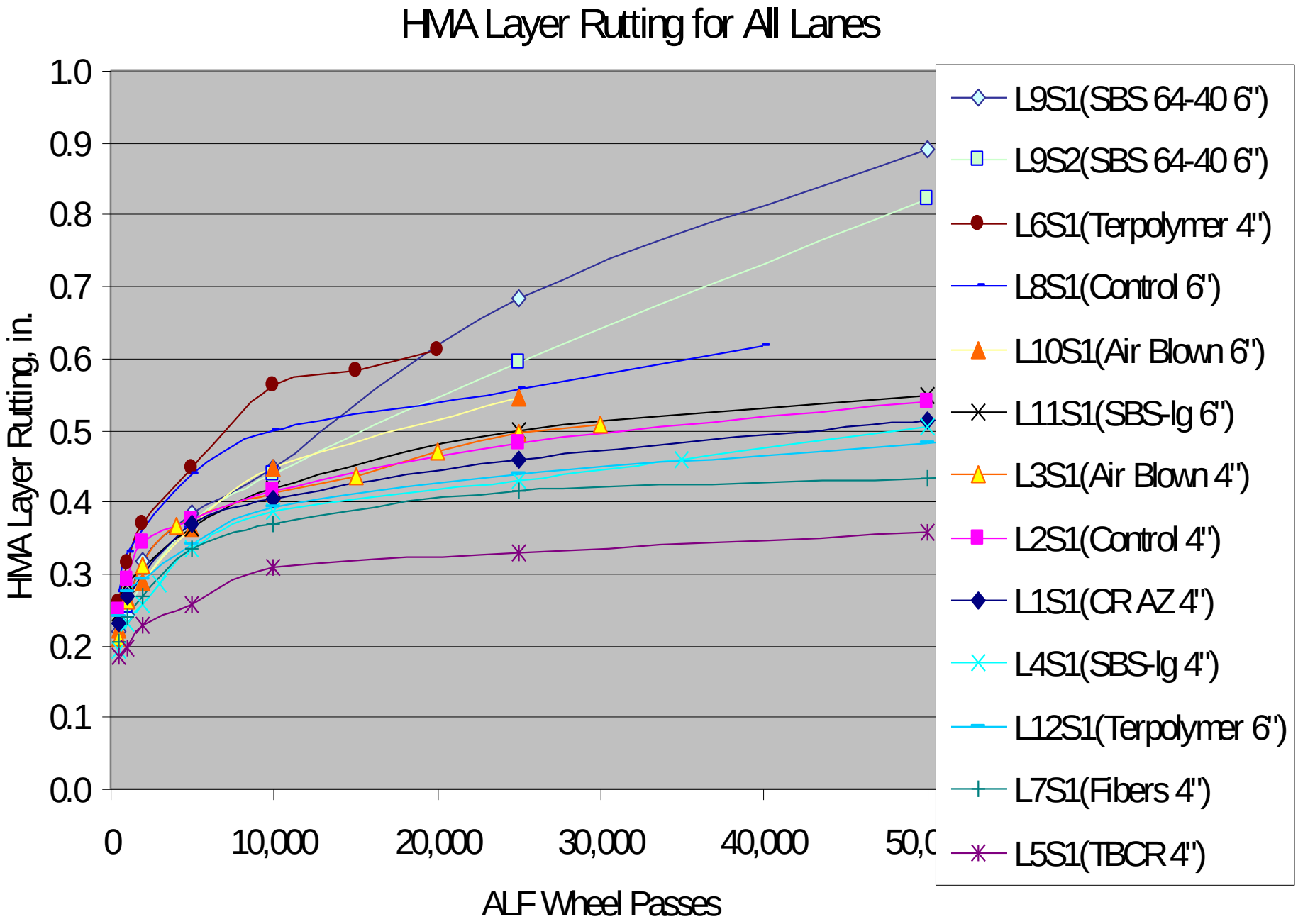
- New test criteria:
  - Does the strain of the multi-step compare to the individual test?
  - Does the reduced number of cycles per stress level compare to the individual test at greater number of cycles?

Polymer Binder response to stress

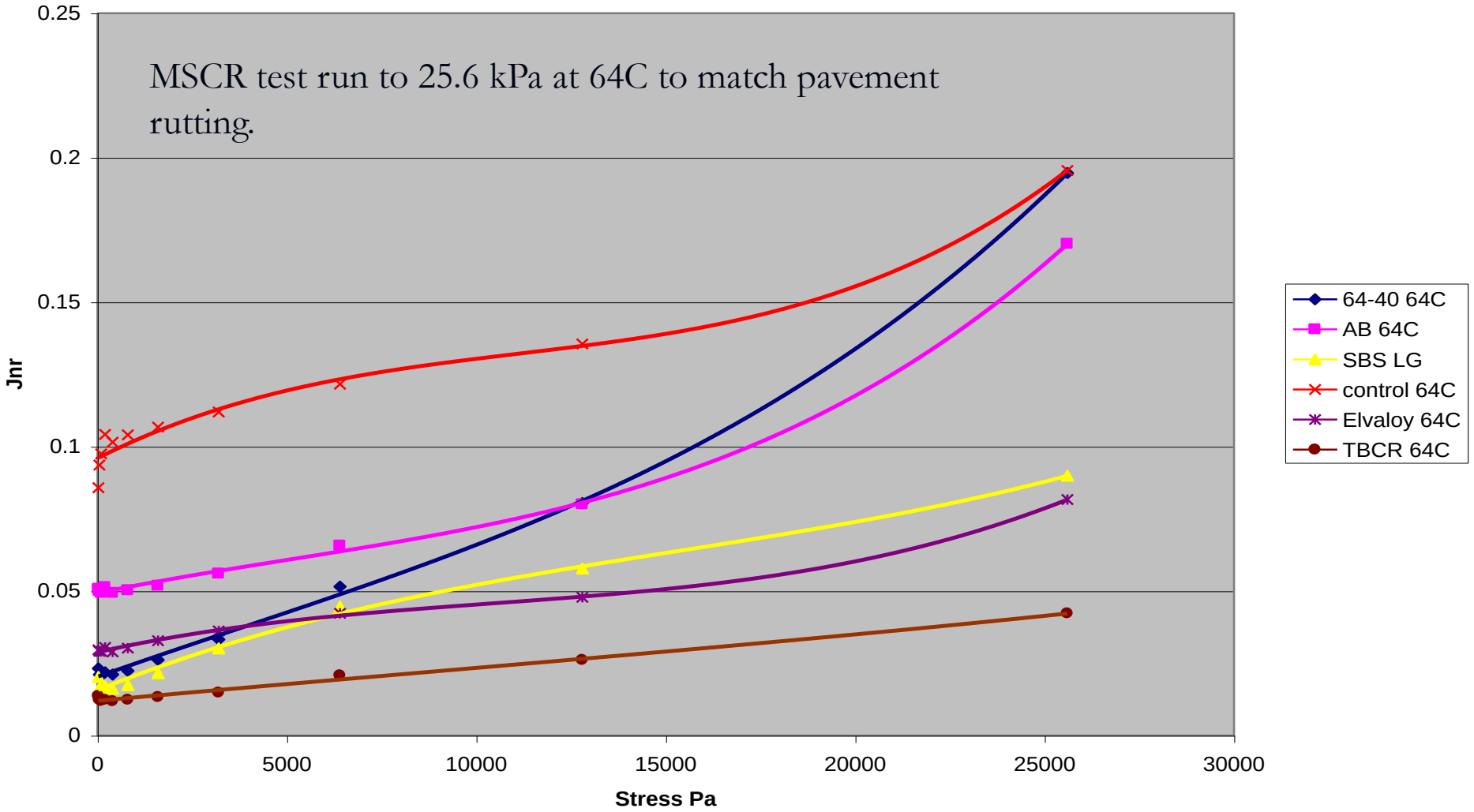
- Polymer binders are basically a two phase system made up of polymer dispersion in a viscoelastic solution typically a neat asphalt binder.
- How this combination responds to loading is greatly affected by the base binder, the entanglement of the polymer chains and any cross linking in the polymer network.

7 Asphalt Binders

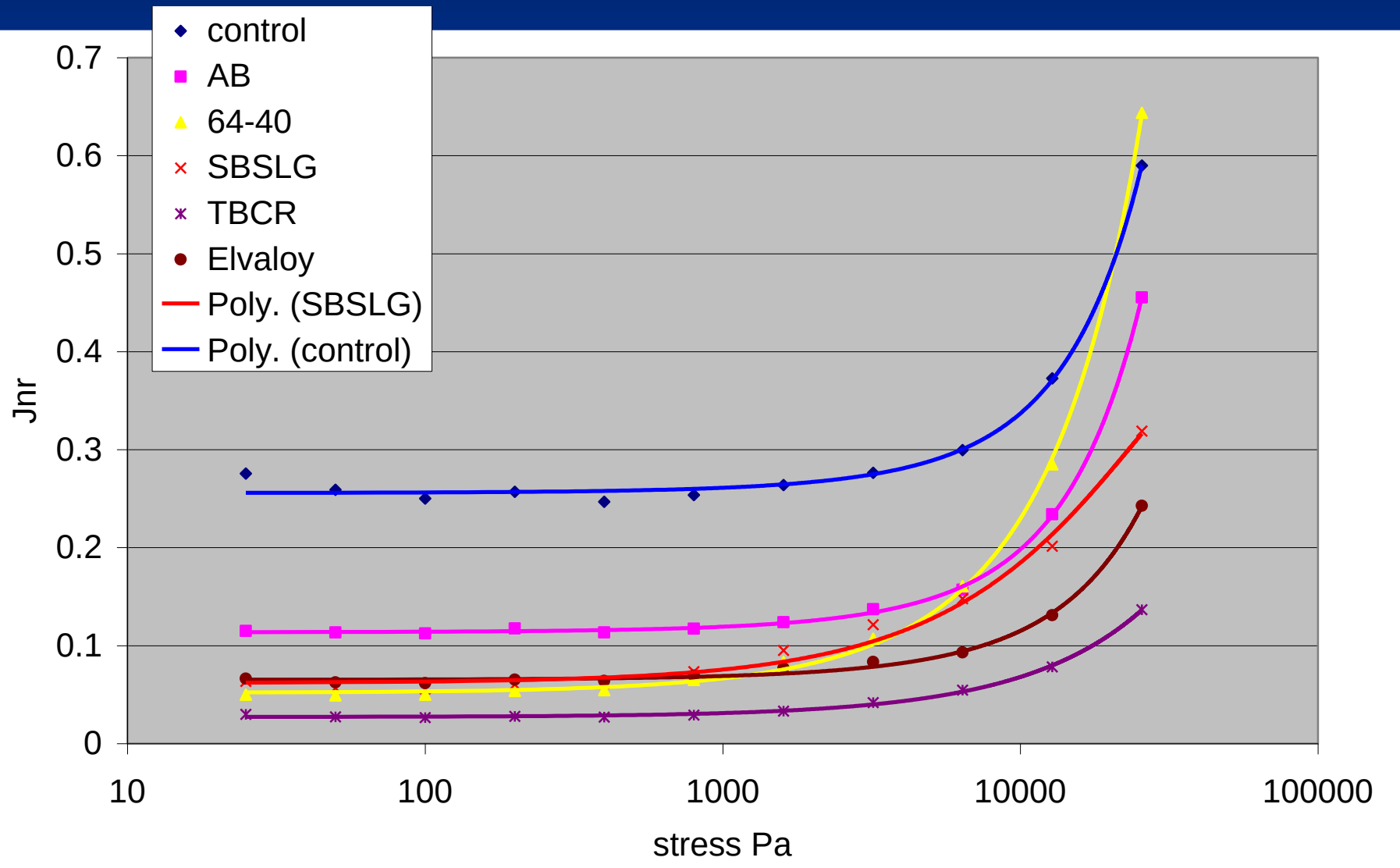
AZ CRM ---- 70-22	PG 70-22 Control	Air Blown	SBS	TX TBCR	TP	PG 70-22 + Fibers	PG 70-22	SBS 64-40	Air Blown	SBS	TP
1	2	3	4	5	6	7	8	9	10	11	12


HMA Layer Rutting for All Lanes
HMA Layer Rutting, in.
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10,000
20,000
30,000
40,000
50,0
ALF Wheel Passes
L9S1(SBS 64-40 6")
L9S2(SBS 64-40 6")
L6S1(Terpolymer 4")
L8S1(Control 6")
L10S1(Air Blown 6")
L11S1(SBS-lg 6")
L3S1(Air Blown 4")
L2S1(Control 4")
L1S1(CR AZ 4")
L4S1(SBS-lg 4")
L12S1(Terpolymer 6")
L7S1(Fibers 4")
L5S1(TBCR 4")

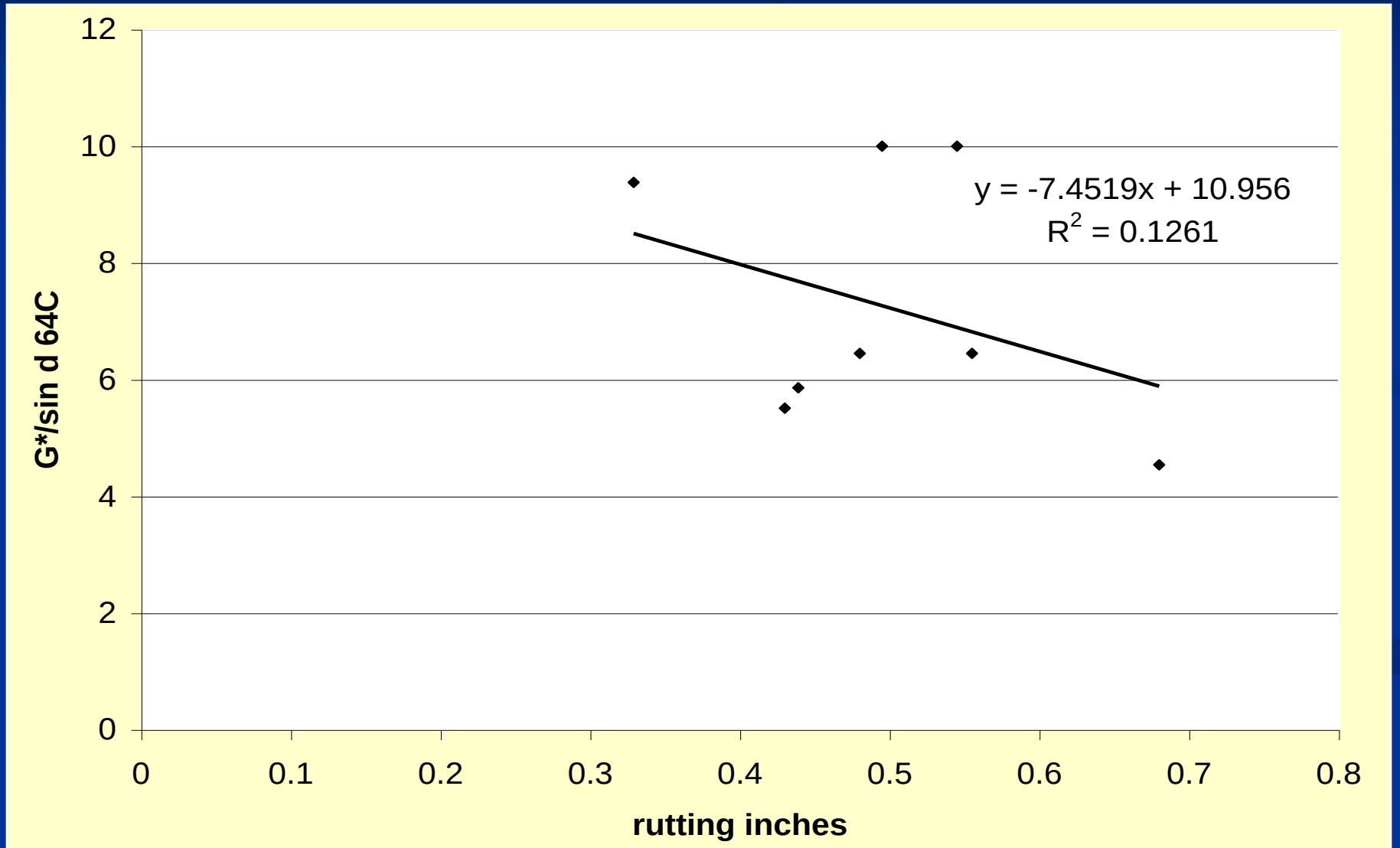
Non-Recoverable compliance on the polymer binders tested in the ALF sections



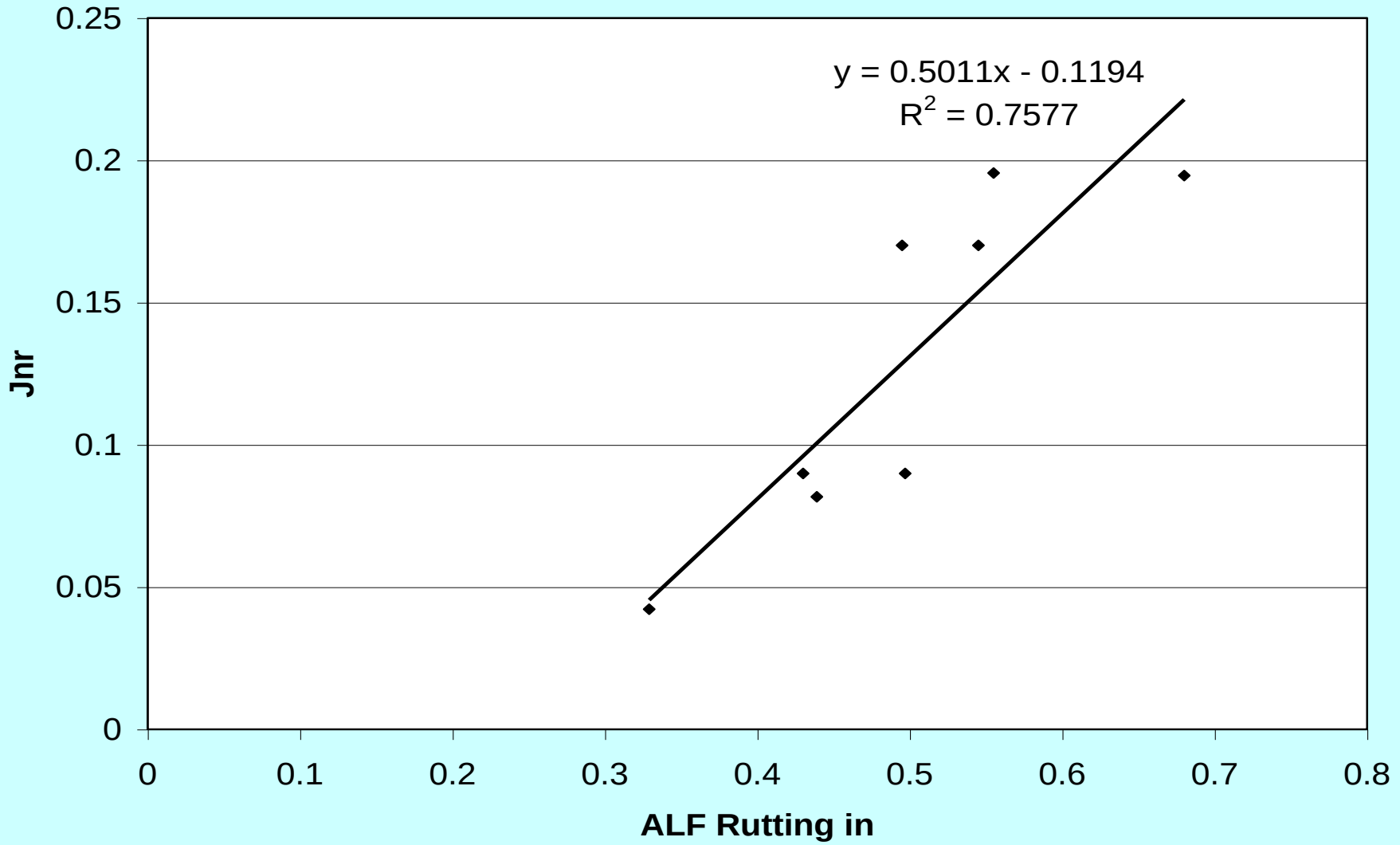
ALF binder @ 70C



Relationship between G*/ sinδ and ALF rutting



Relationship between Jnr and ALF rutting



High Temperature Binder Criteria

- Conclusion
  - Linear binder tests will not correlate with high temperature mix failure test unless the binder is a viscous fluid at those temps.
  - To accurately address mix failure non-linear binder properties have to be evaluated.
  - Creep & Recovery testing of the binder at different stress levels is needed to describe binder properties in the non-linear range.

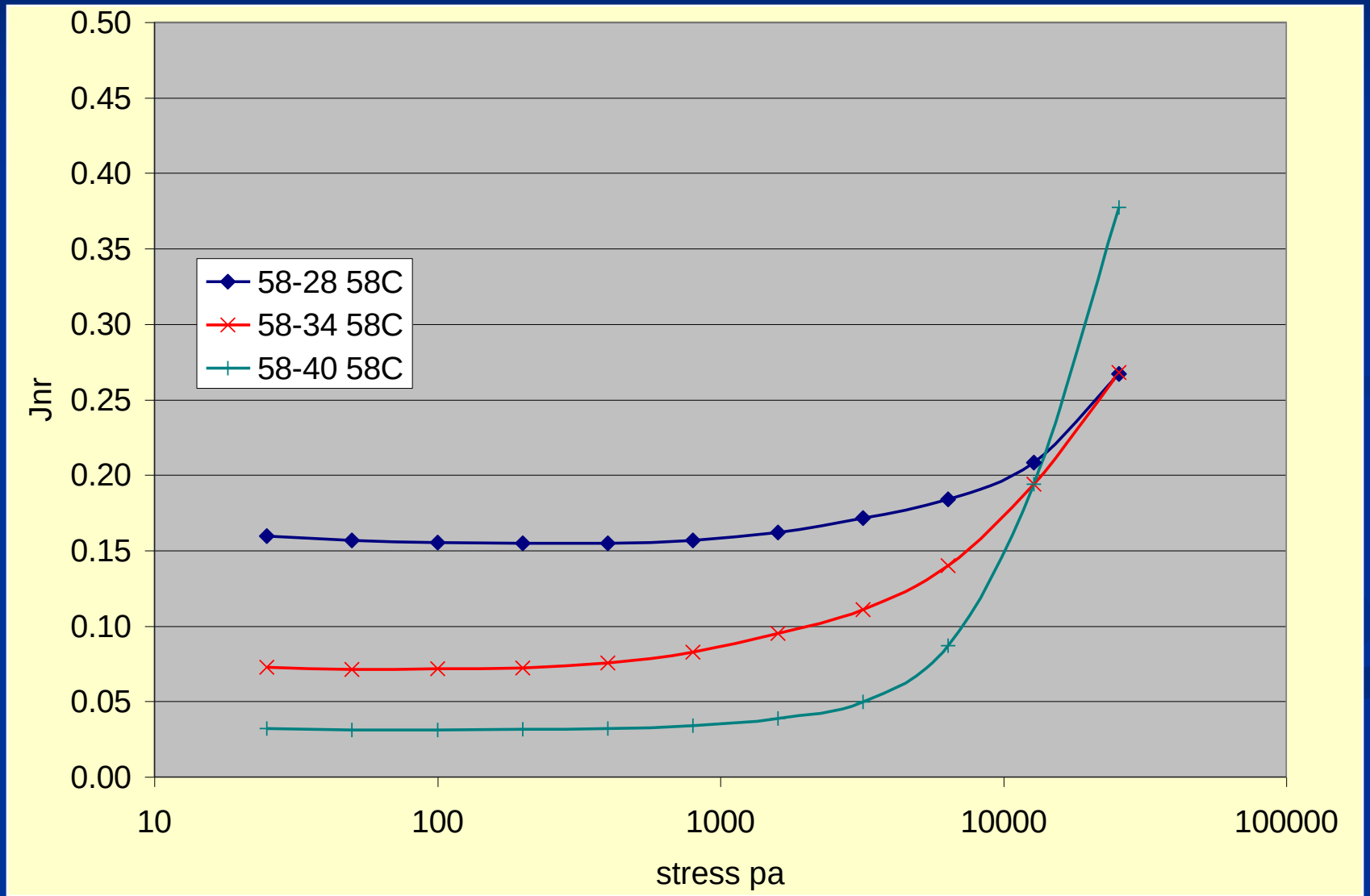
High Temperature Binder Criteria

- Conclusion
  - Non-recoverable compliance of the binder describes the stress dependency of the binder.
  - Creep and recovery run at multiple stress levels on one sample can be run to describe the stress dependency of the binder.
  - Creep and recovery non-recoverable compliance can be correlated to mix testing done at different stress conditions.

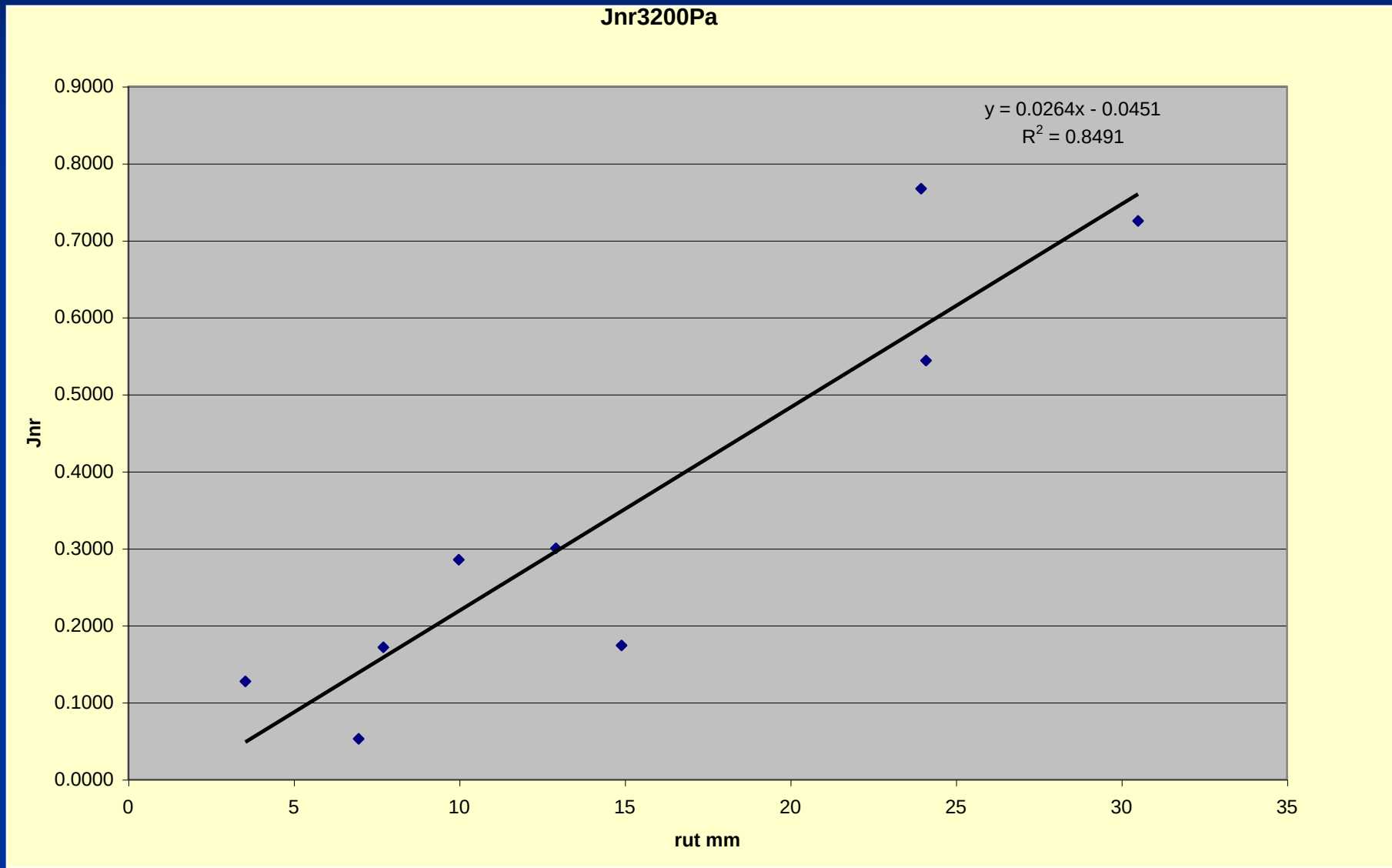
High Temperature Binder Criteria

- Recommendation
  - Test more binders with various modification systems to finalize test procedure.
  - Evaluate binder results against mix testing to determine the relationship of rate of change of compliance to mix performance.

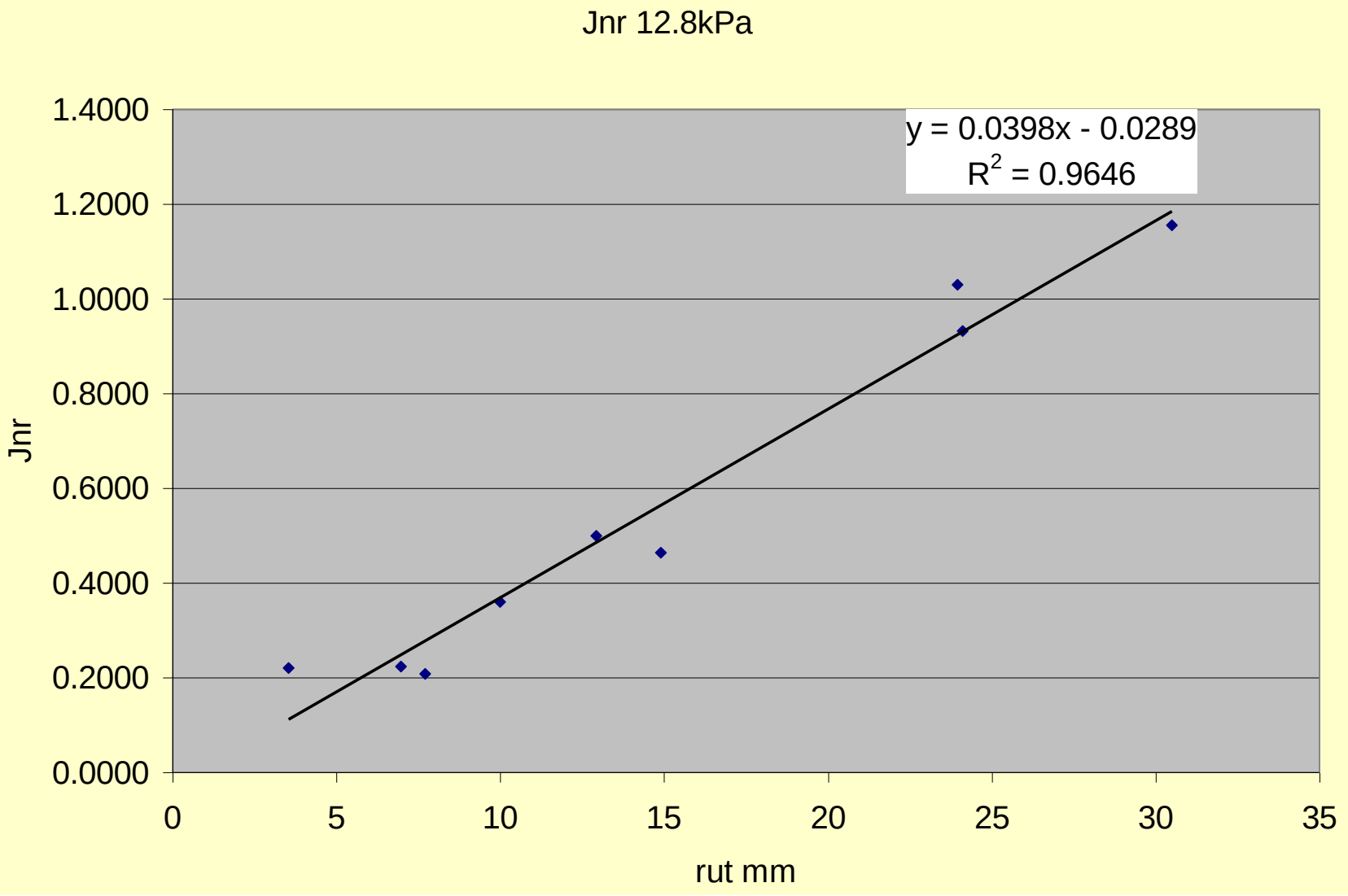
MinnRoad Binders



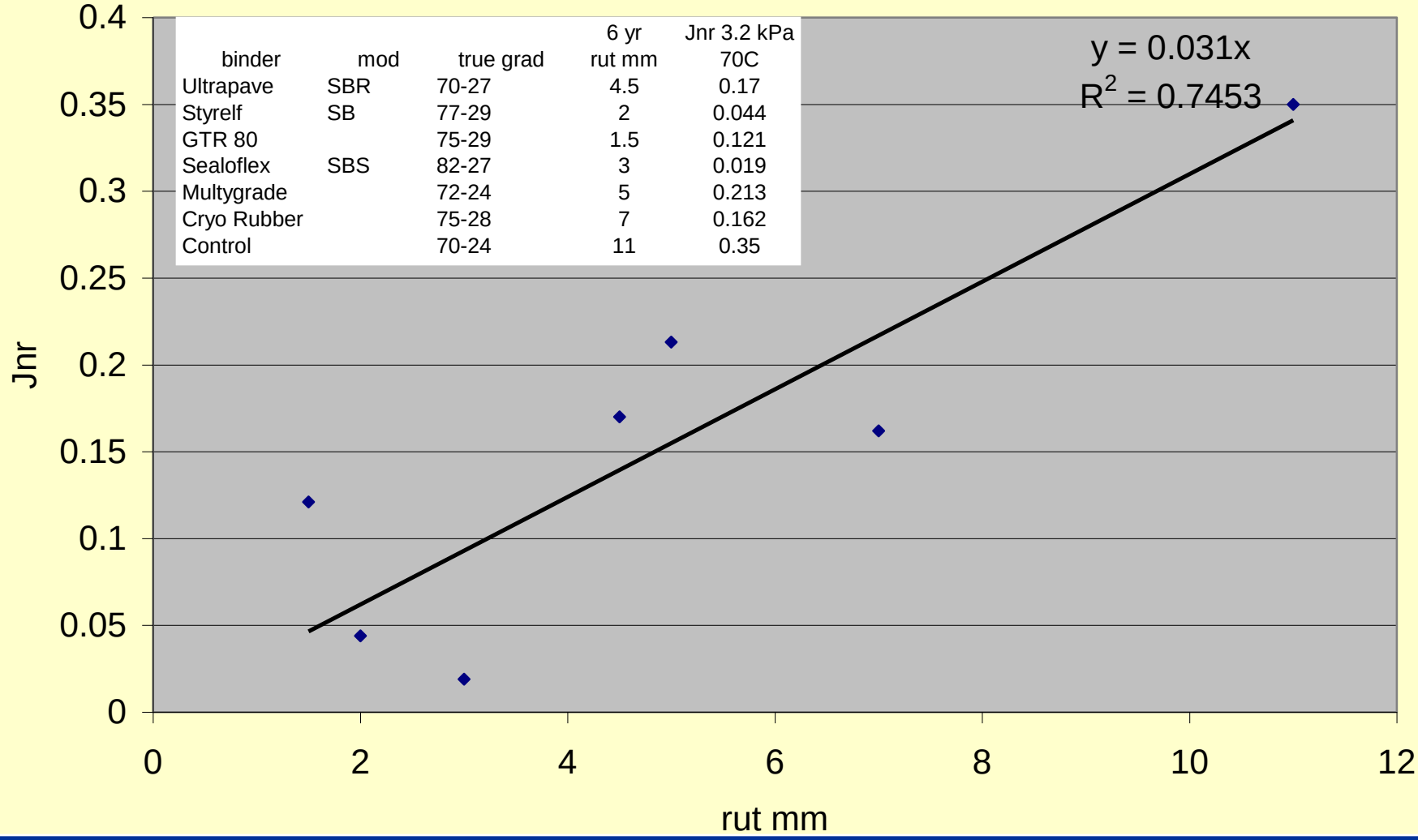
Hamburg Rut testing MINN Road mixes



Hamburg Rut testing MINN Road mixes



Miss I55 6yr rut Jnr 3.2 kPa



binder	mod	true grad	6 yr rut mm	Jnr 3.2 kPa 70C
Ultrapave	SBR	70-27	4.5	0.17
Styrelf	SB	77-29	2	0.044
GTR 80		75-29	1.5	0.121
Sealoflex	SBS	82-27	3	0.019
Multygrade		72-24	5	0.213
Cryo Rubber		75-28	7	0.162
Control		70-24	11	0.35

Affect of Jnr on Rutting

- Reducing Jnr by half typically reduced rutting by half.
- This affect is seen on ALF sections, Hamburg Rut Testing
- But most importantly this is seen on the Mississippi I 55 sections.

Neat Binder Response

- Neat binders linear over a wide range of stresses and strains.
- Most neat binders remain linear up to 3.2 kPa stress.

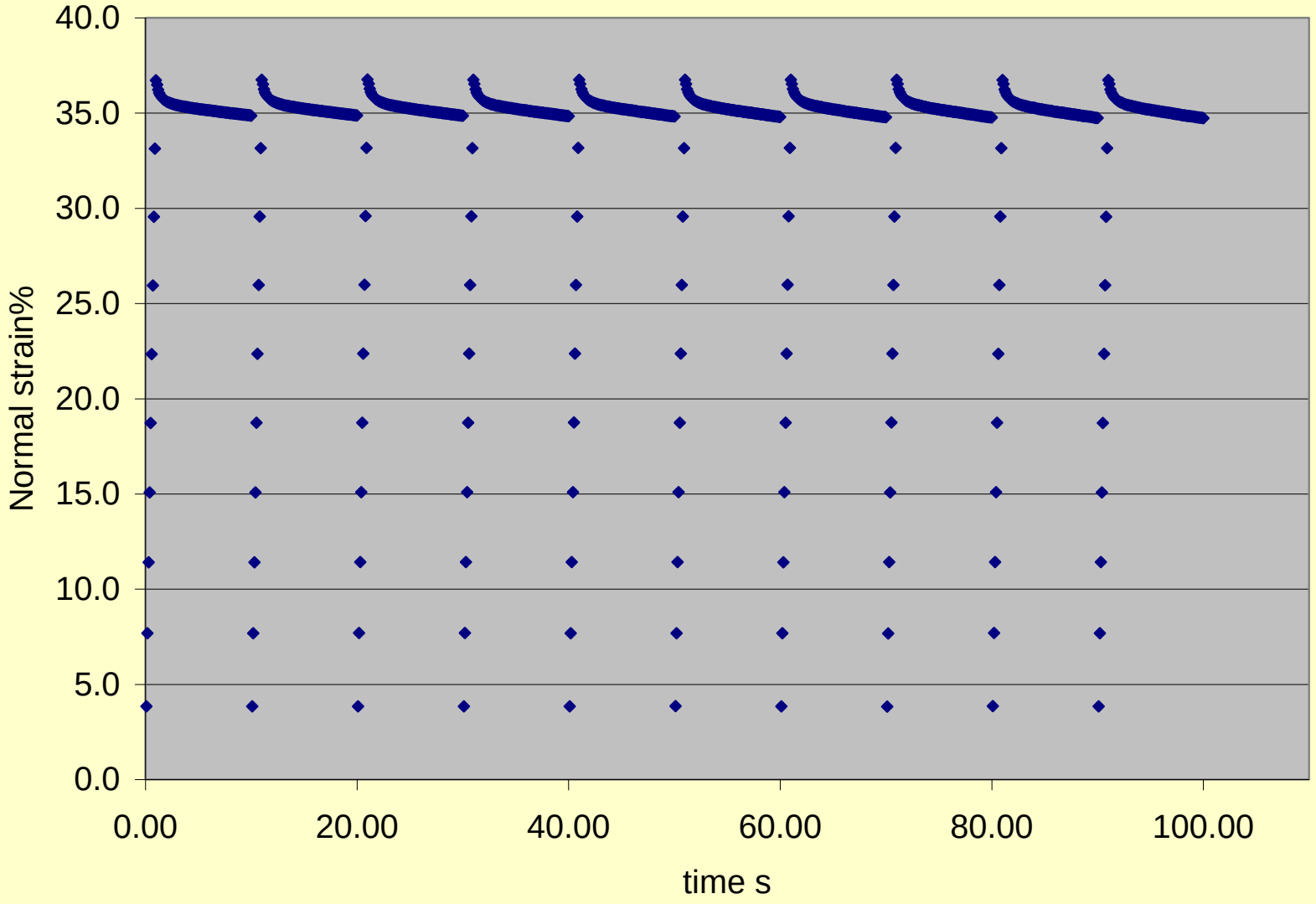
Determination of a Specification criteria.

- The existing binder specification works very well for neat binders.
- The grading for neat binders should not change.
- Establish new Jnr criteria based on response of neat binders at their continuous grade temp.
- Evaluate the binders near the end of their linear range.

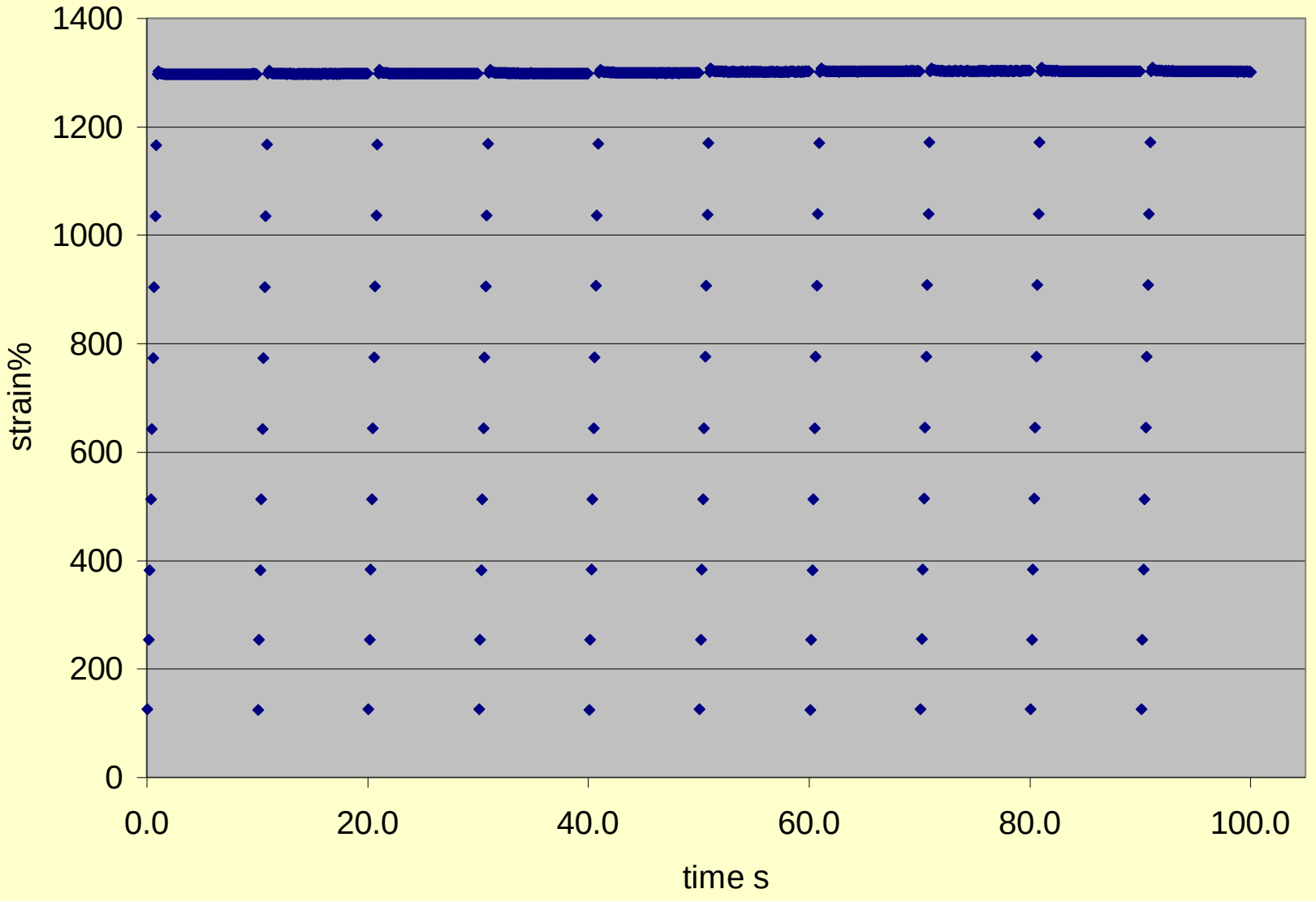
Evaluation of Straight run binders

Sample ID	Name	Grade	true grade	Temp	Jnr 3200Pa
ALF 6727	Control	70-22	72.7-74.2	72.7	0.439122
BBRS3	straight	64-22	66.1-27.3	66.1	0.418449
MN county rd 112	neat Valero	58-28	60.8-33.4	60.8	0.368445
MN county rd 112	neat Citgo	58-28	59.5-29.8	59.5	0.529647
MN county rd 112	AshlandM	58-28	60.7-31.4	60.7	0.430165
Minn Road	straight	58-28	61.8-30.8	61.8	0.302951
Miss I-55	CSL	67-22	68.3-25.1	68.3	0.266912
Shandong	straight	64-22	64.4-23.5	64.4	0.444057
BBRS3	straight	70-22	71.4-24.8	71.4	0.480855
BBRS3	straight	58-28	61.3-30	61.3	0.400345
MD project	straight	64-28	64.8-29.6	64.8	0.459335
average					0.412753

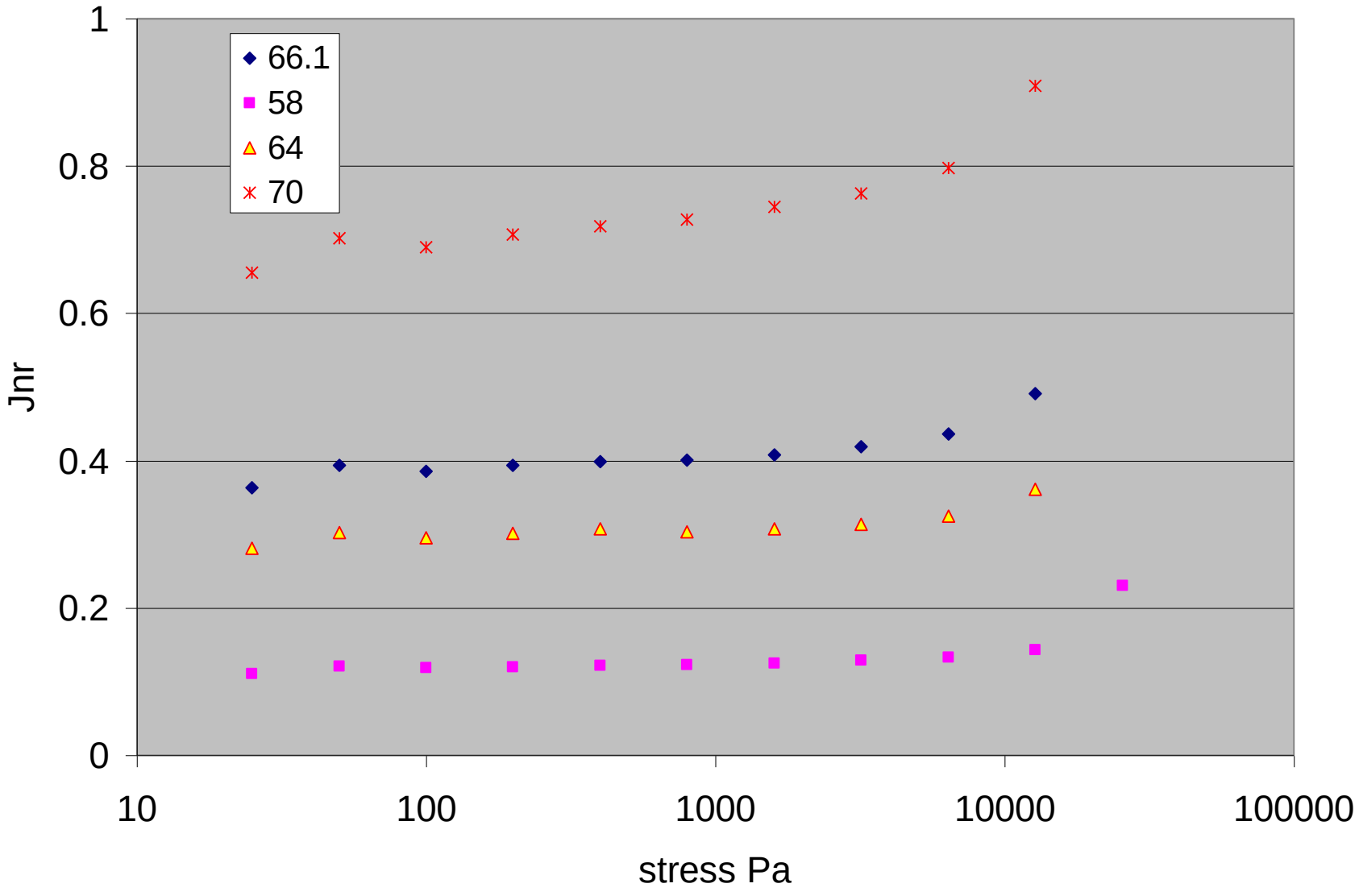
Neat PG 70-22 @ 70C 0.1 kPa



Neat PG 70-22 @ 70C 3.2 kPa



BBRS3 PG 64-22



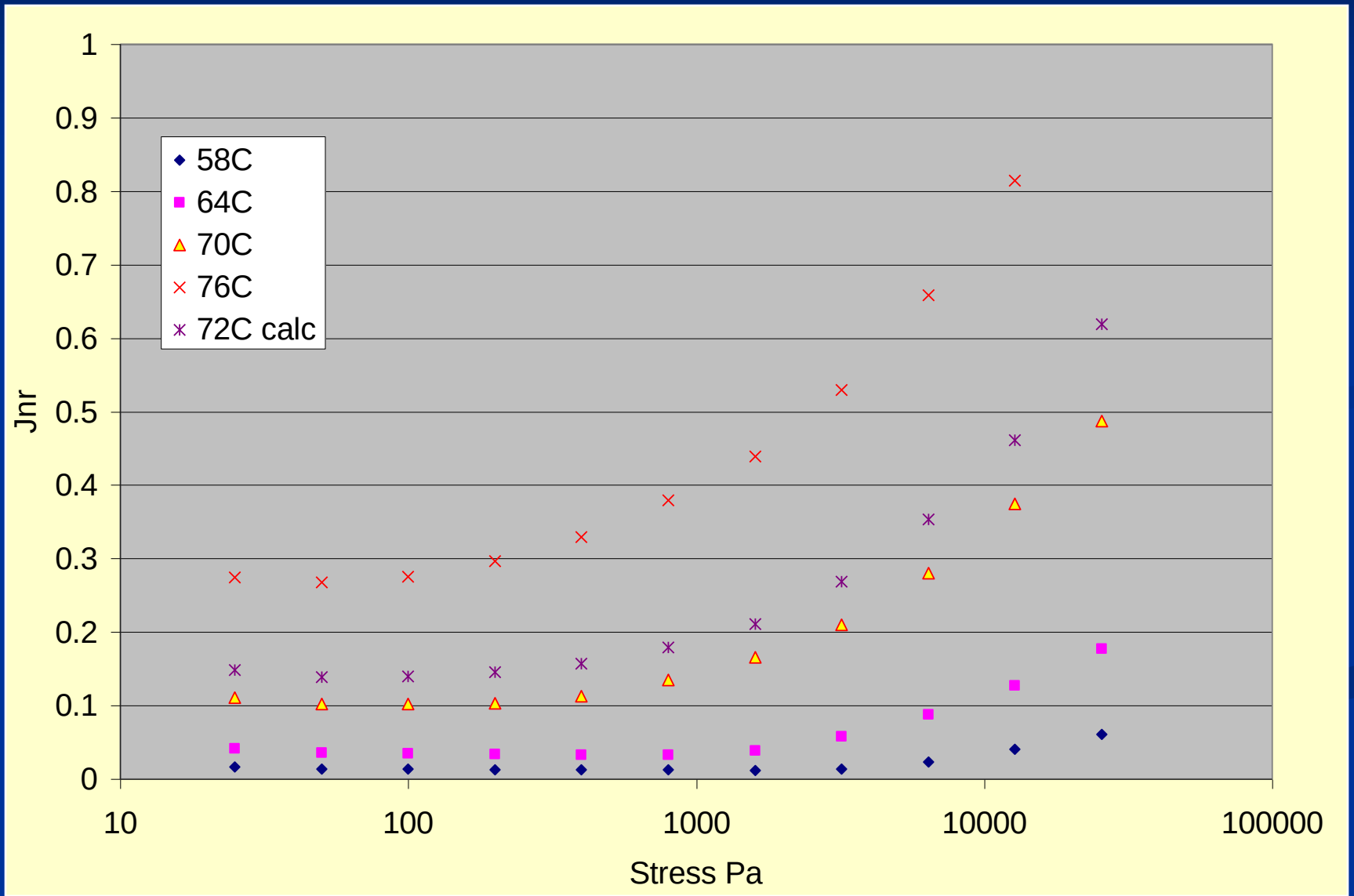
Determination of a Specification criteria.

- The average Jnr of many neat binders at their continuous grade temperature is 0.4
- Use Jnr of 0.4 at 3.2 kPa as the specification criteria.

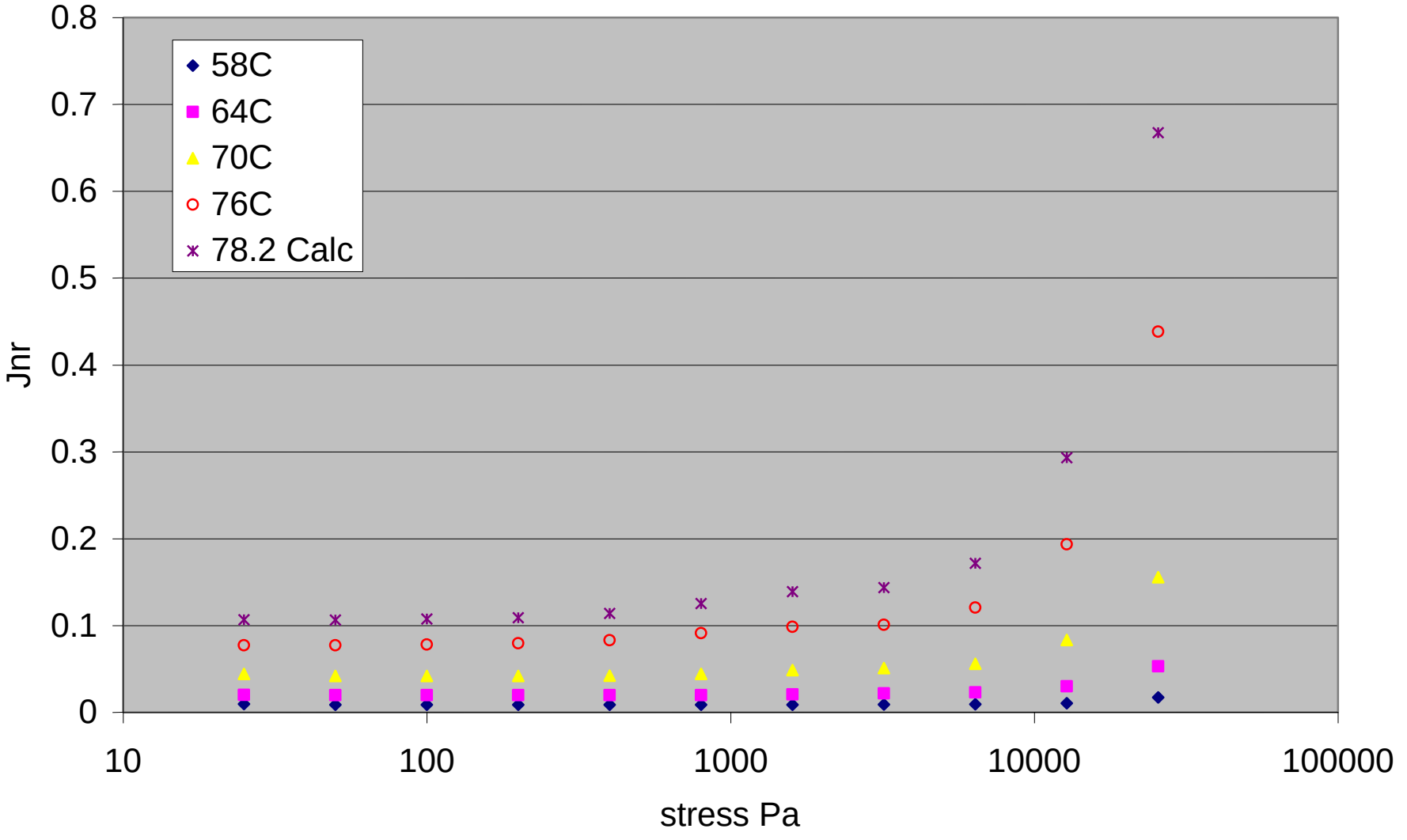
Grade Bumping and how it would work

- The existing system uses temperature to adjust for increased traffic or slower traffic speeds.
- Should the new criteria use the same system or is there a better way?
- The first step is to see how the existing polymer systems have worked

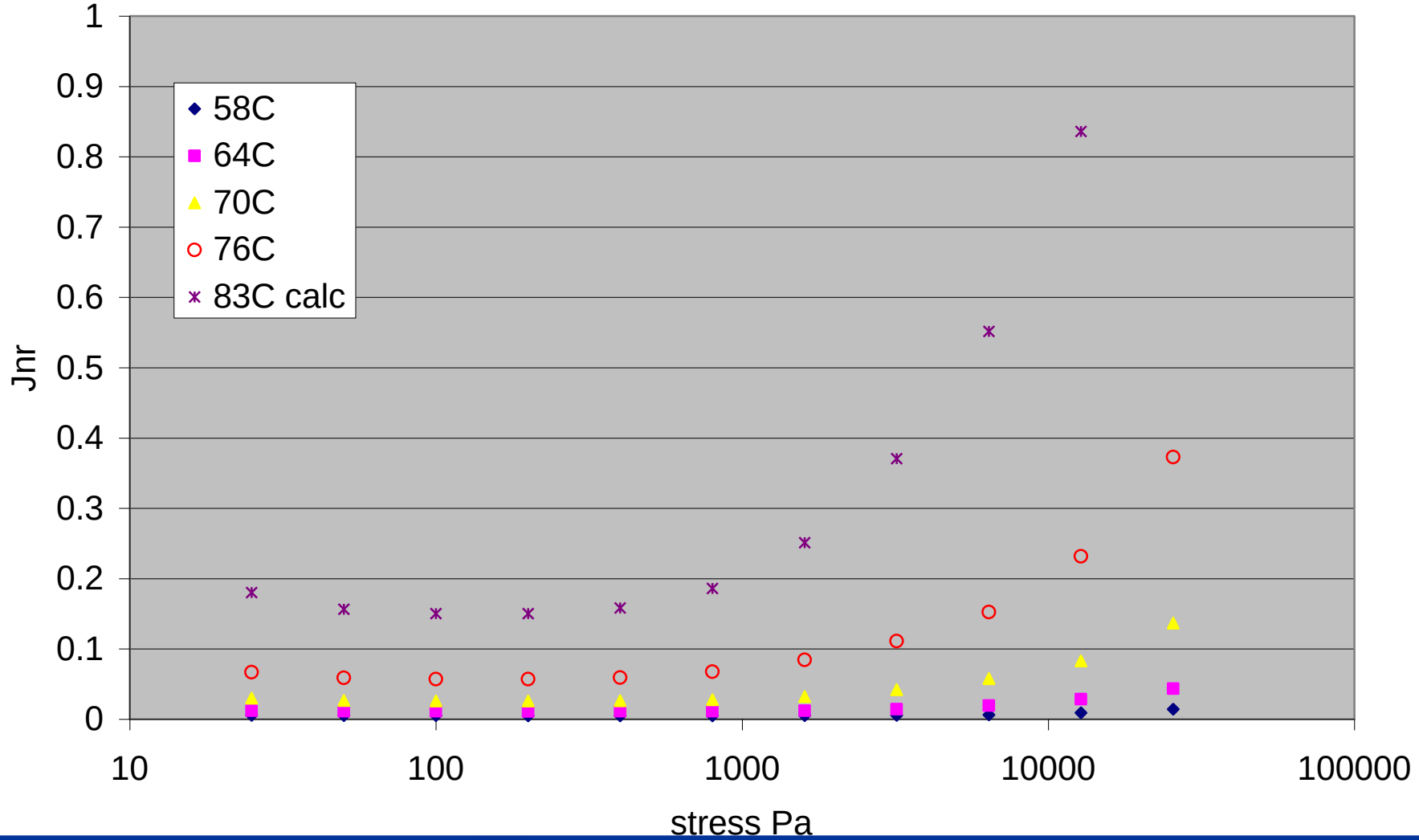
SBS PG 70-28


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jnr
58C
64C
70C
76C
72C calc
10
100
1000
10000
100000
Stress Pa

Elvaloy PG 76-28



Ergon PG 82-22



Affect of Temp and Stress on Jnr

- In neat binders a grade bump by temp will more than double the Jnr value.
- Some neat binders will maintain their compliance value well beyond the 3.2 kPa stress.
- Grade bumping by increases in PG grade temp have forced suppliers to use very soft base binders and high degree of polymer modification to meet wide temperature ranges.
- This has made some polymers very stress sensitive.

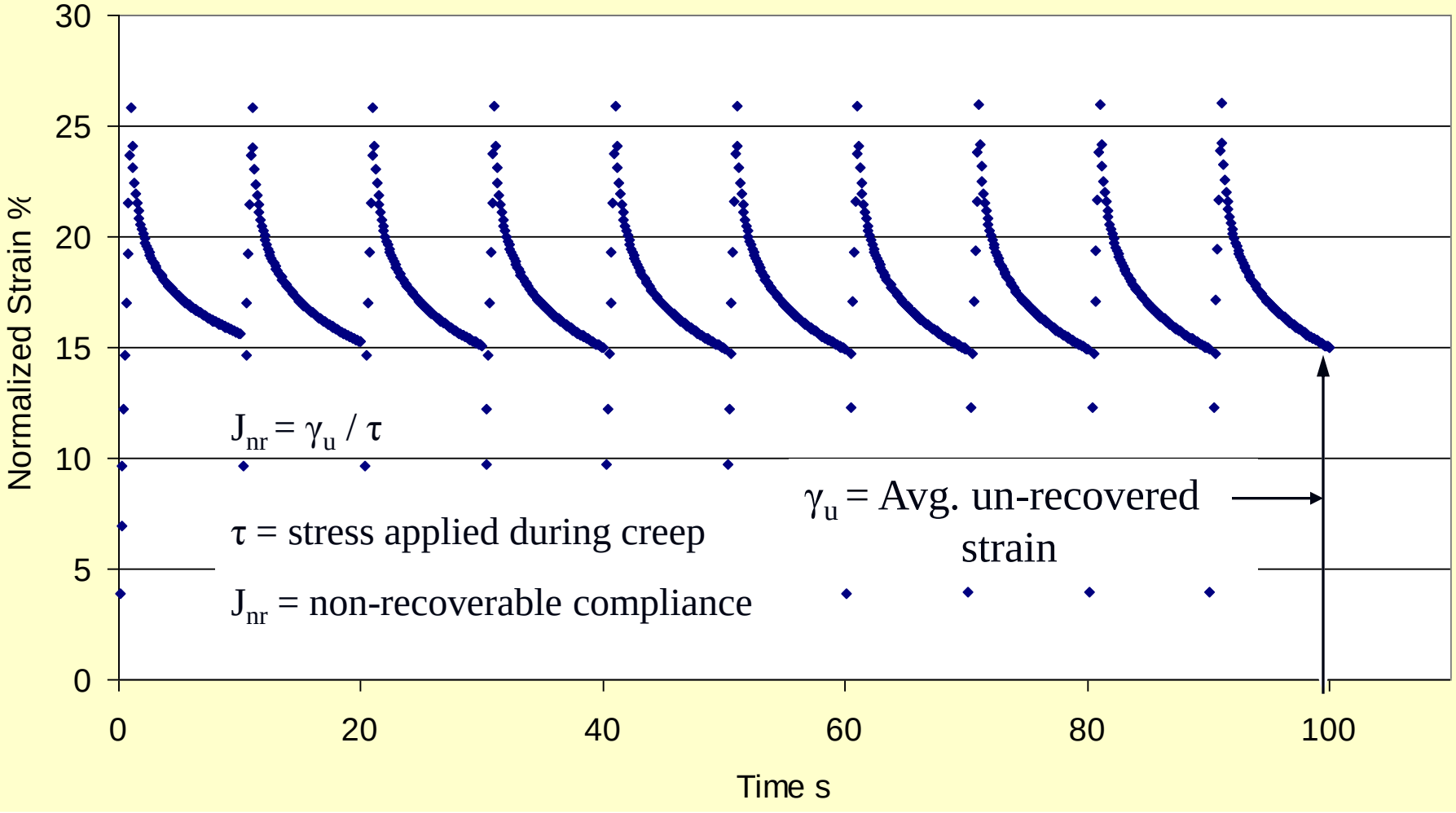
Grade bumping recommendation

- All testing should be done at the environmental grade temp.
- The standard grade should be based on the Jnr value of existing neat binders.
- For high traffic the Jnr value should be reduced by half at the grade temp.
- For standing traffic the Jnr value should be reduced by half again.

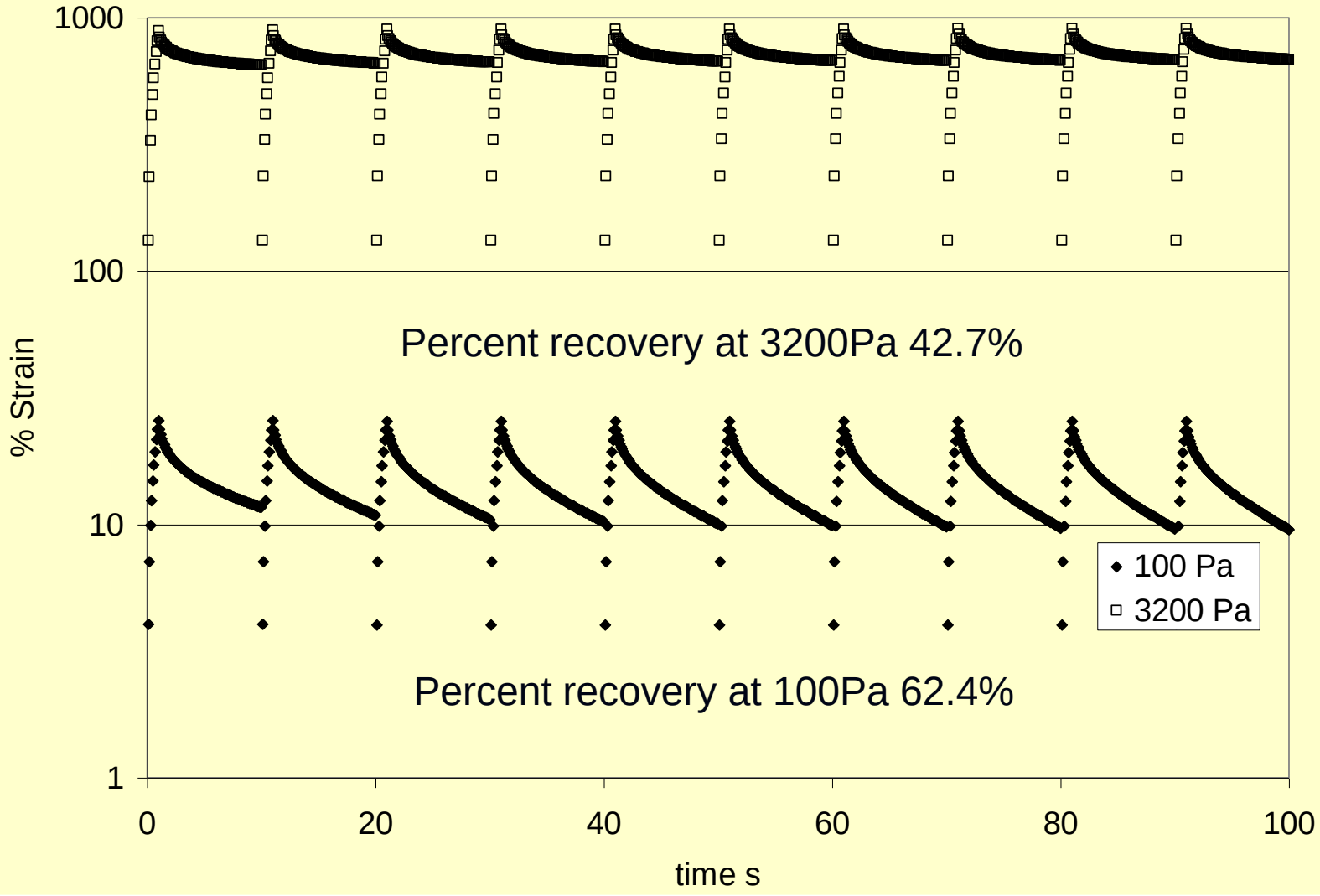
New High Temperature Binder spec

- The new specification should be based on the non-recoverable compliance on the binder.
- All testing should be done at the pavement environmental grade temp
- The test should be run at two stress levels 0.1 and 3.2 kPa ten cycles at each level. A comparison would be made to check how stress sensitive the binder is.
- Grade bumping should be done by halving the Jnr value.

Determination of Jnr



New High Temp Spec Verifies Polymer Use



Thank You