Multi-Stress Creep and Recovery Test Method New Specification

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Problem-High Temperature Binder Criteria

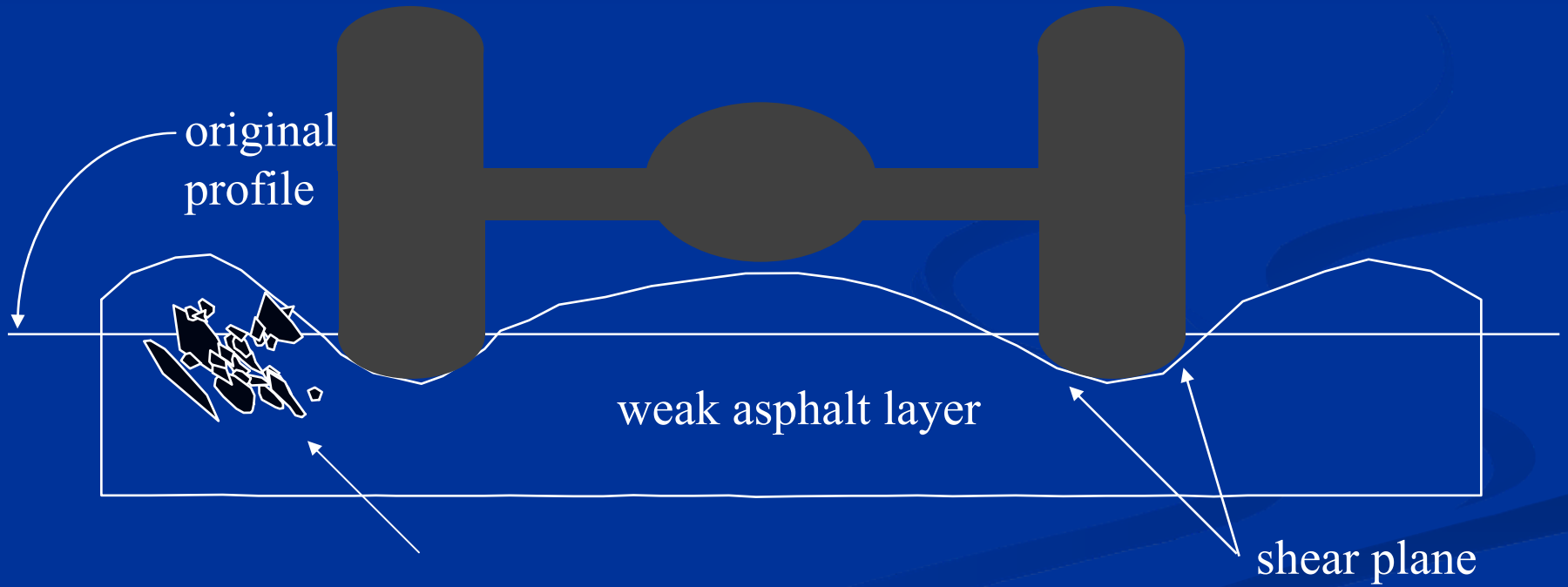
- Does G*/sinδ reflect rutting performance of modified binders.
  - General anecdotal data says no.

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.

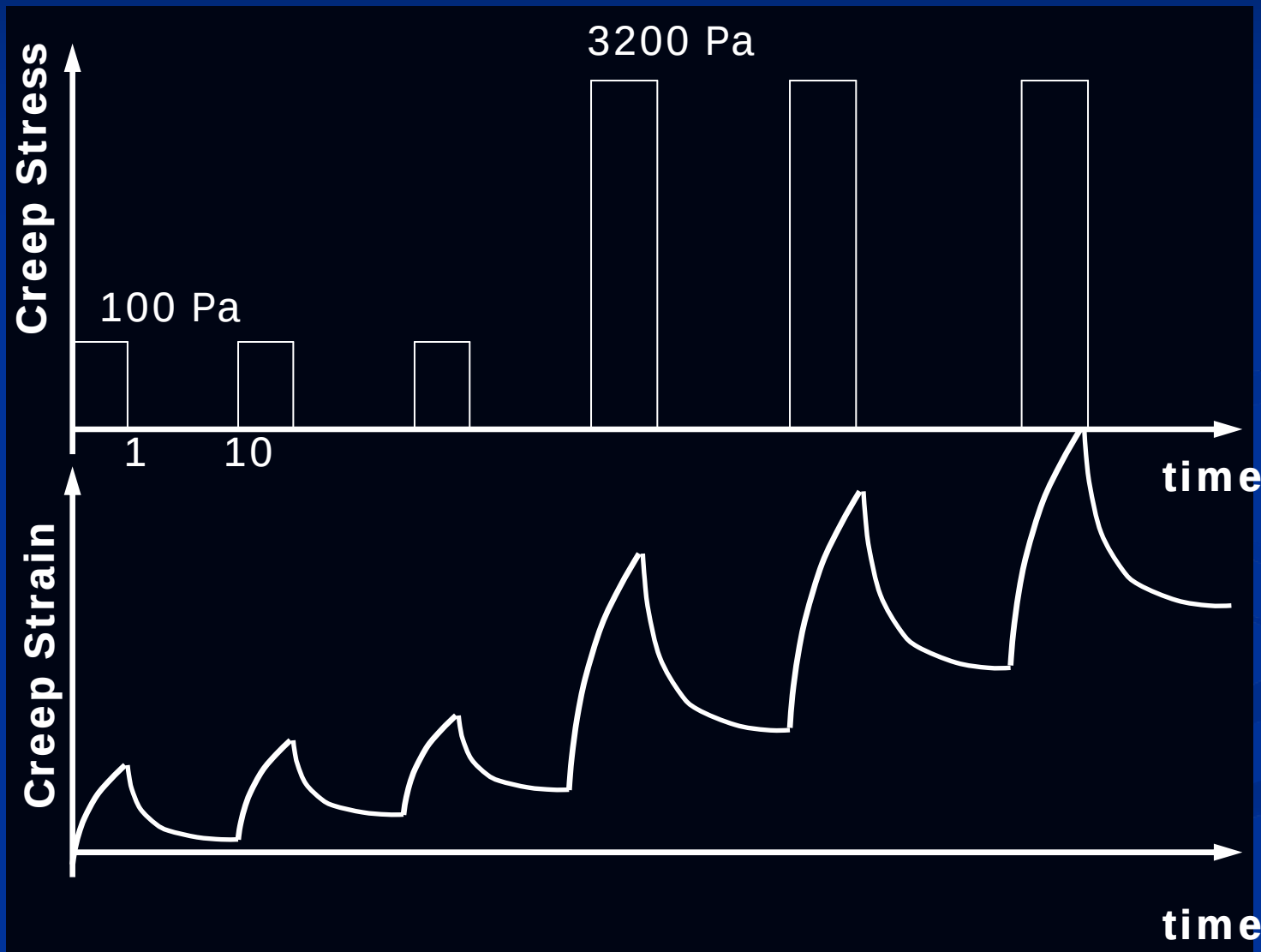
Review of the Multi-Step Creep and Recovery Work

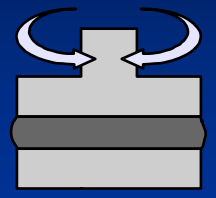
Rutting in Asphalt Layer



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

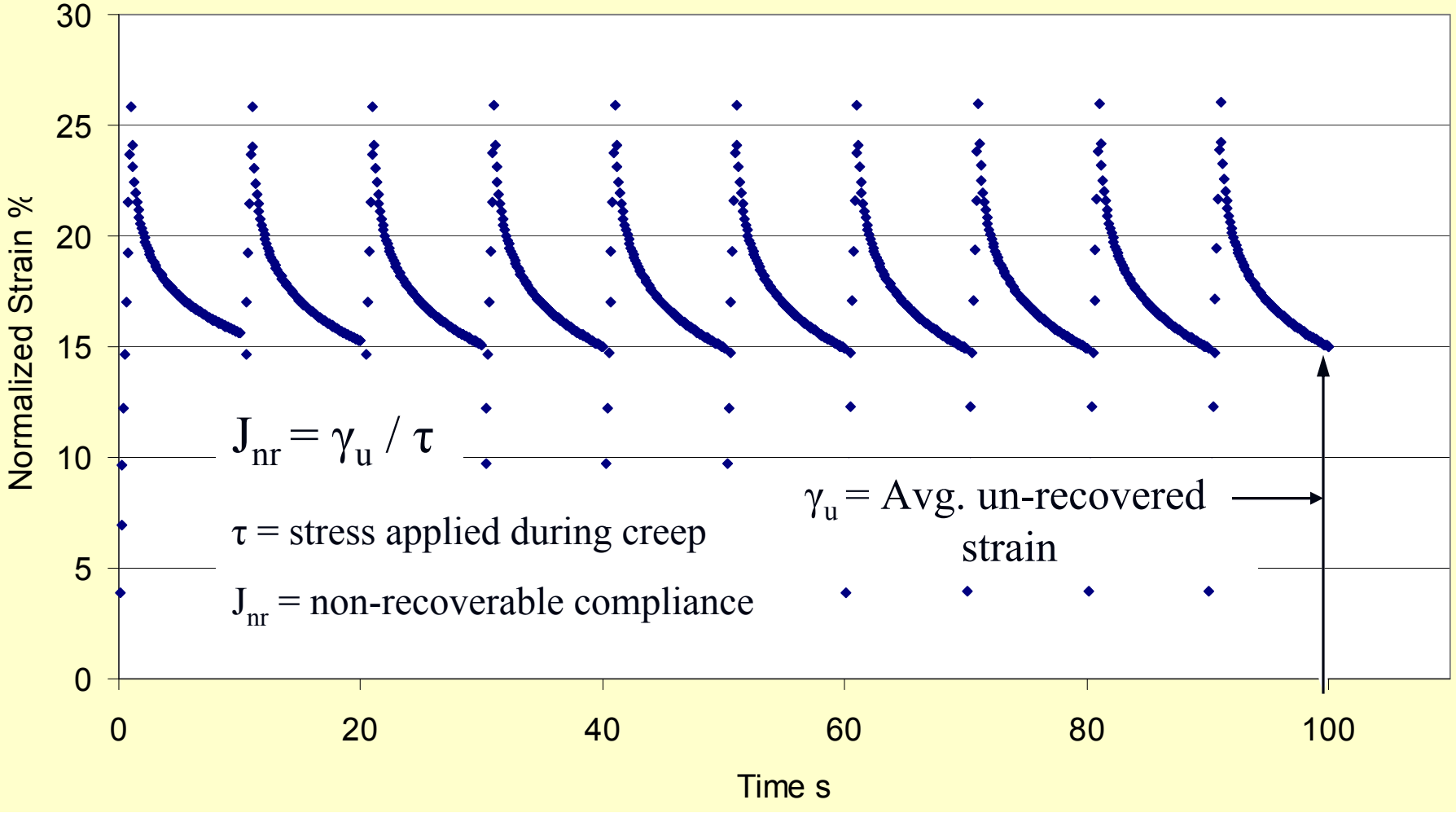
Multi Step Creep and Recovery



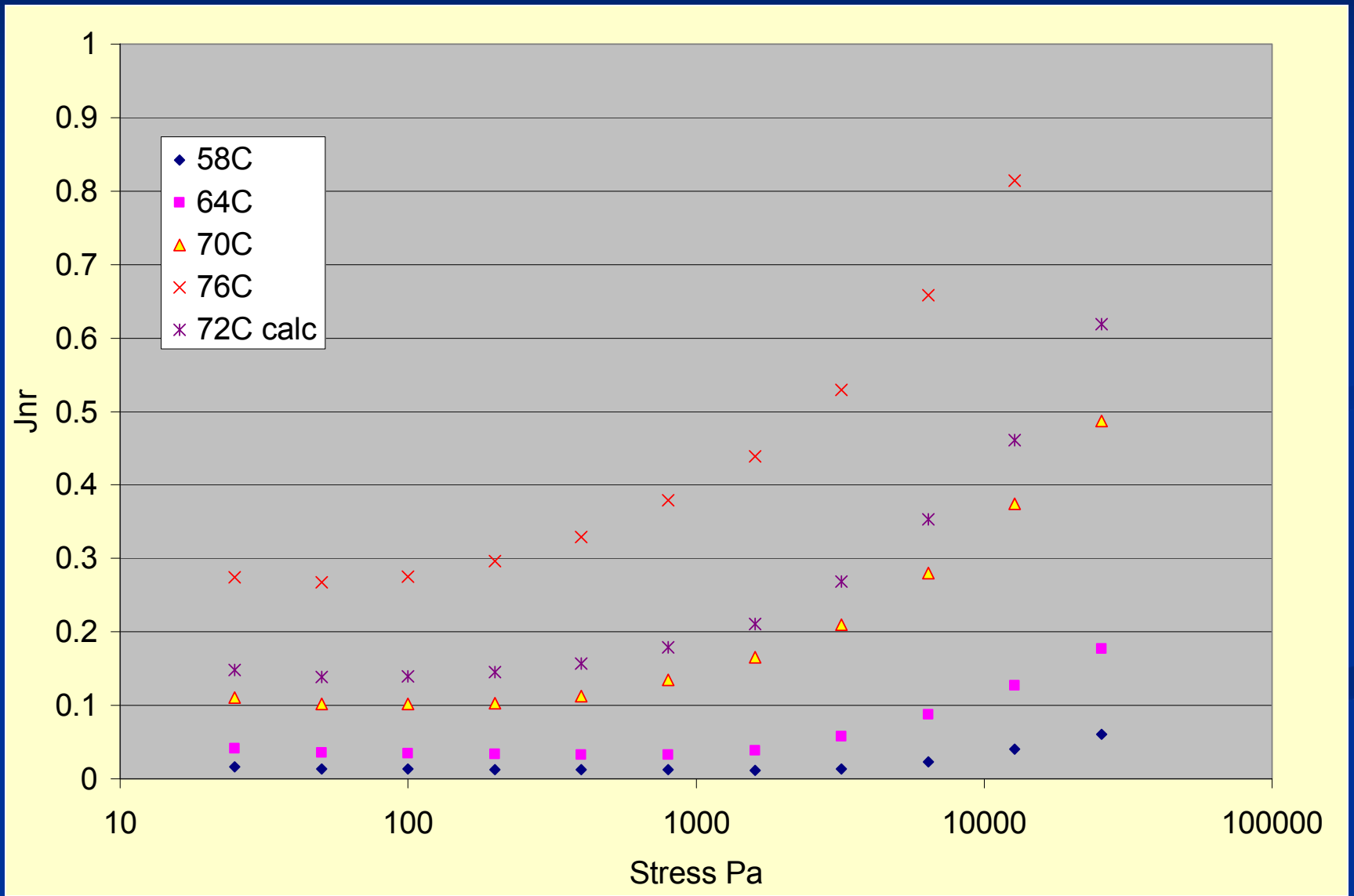


Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.

Determination of Jnr



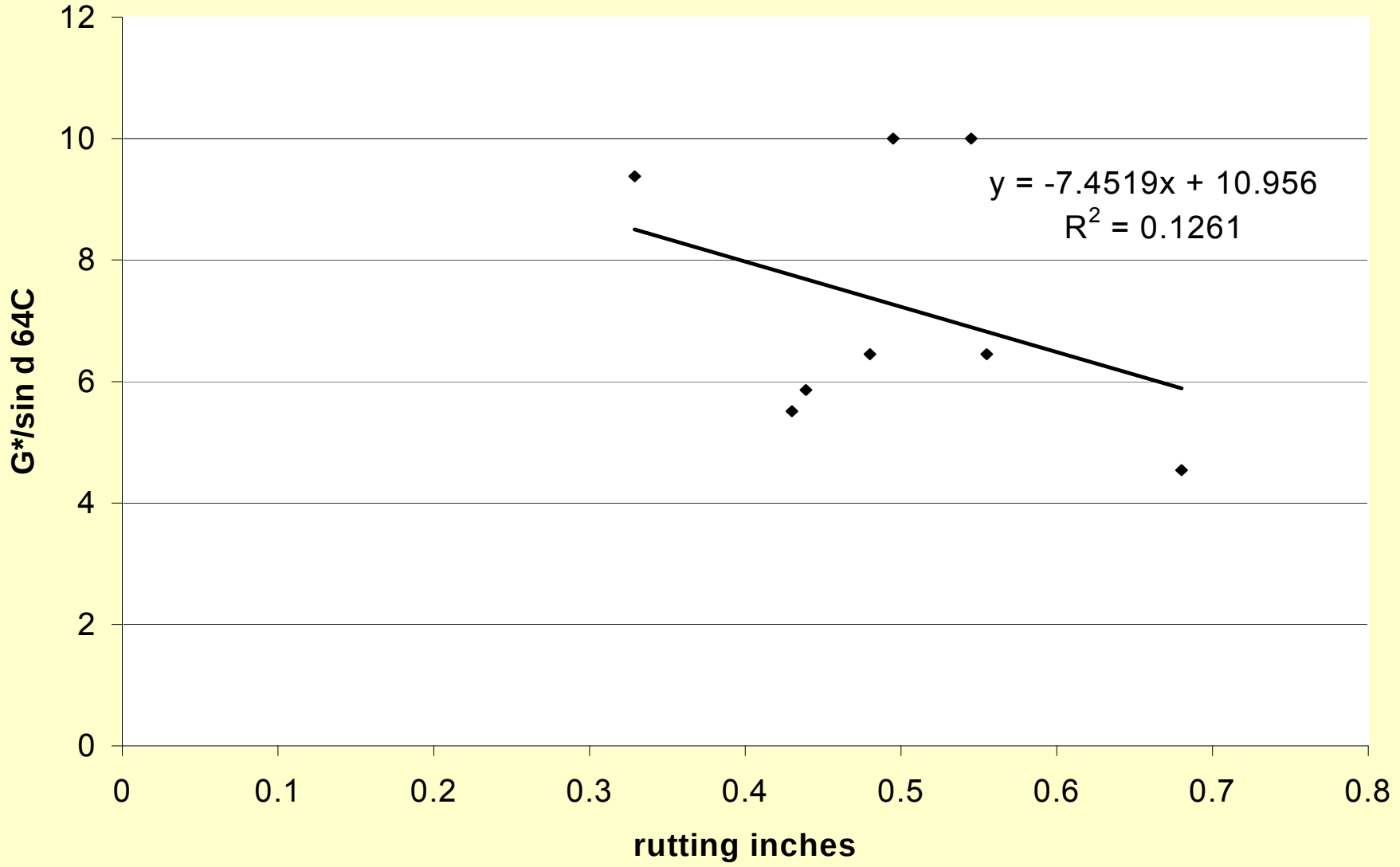
SBS PG 70-28


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

7 Asphalt Binders

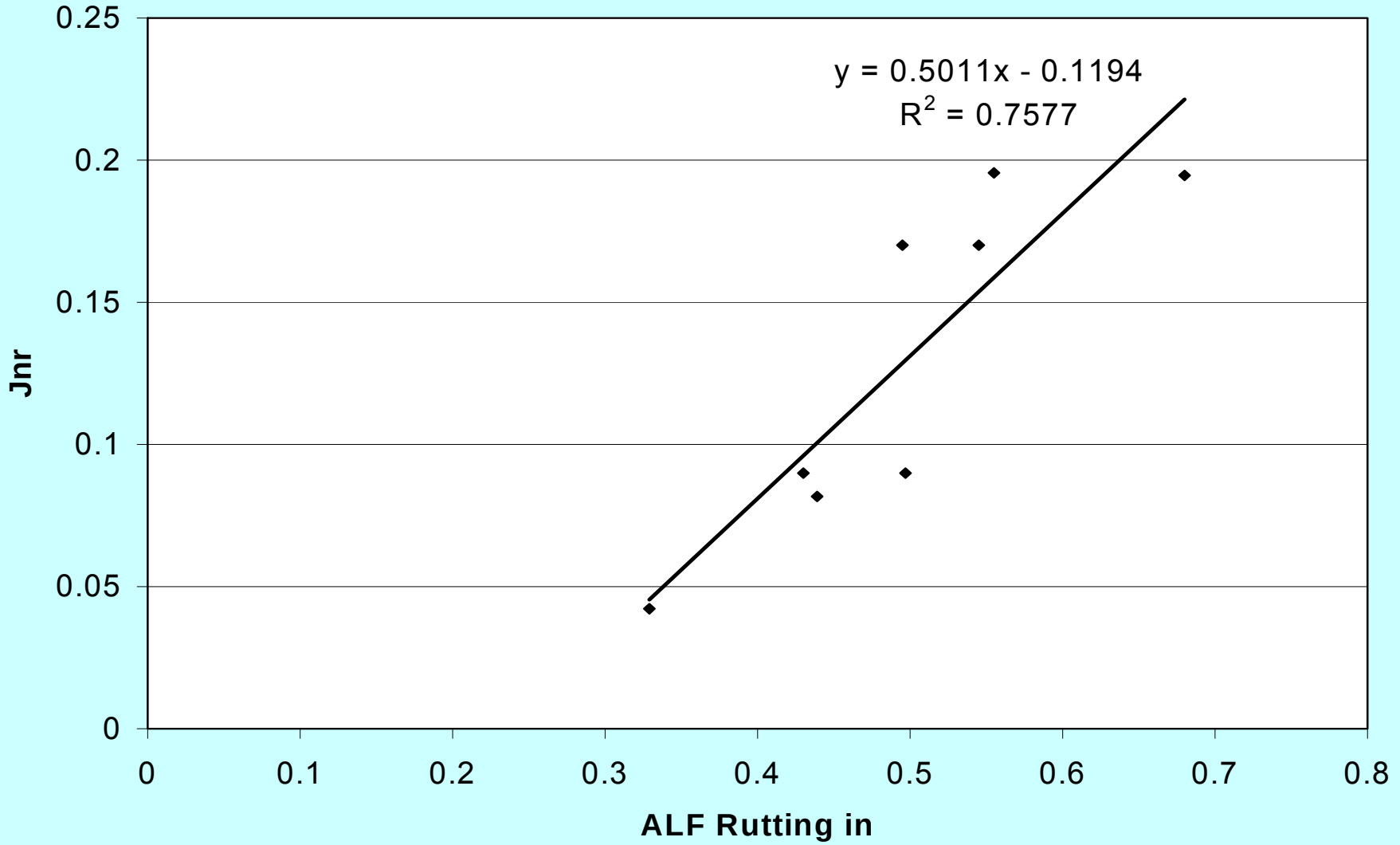
AZ CRM ---- 70-22	PG 70-22 Control	Air Blown	SBS	TX TBCR	TP	PG 70-22 + Fibers	PG 70-22	SBS 64-40	Air Blown	SBS	TP
1	2	3	4	5	6	7	8	9	10	11	12

Relationship between G*/ sinδ and ALF rutting



Relationship between Jnr and ALF rutting

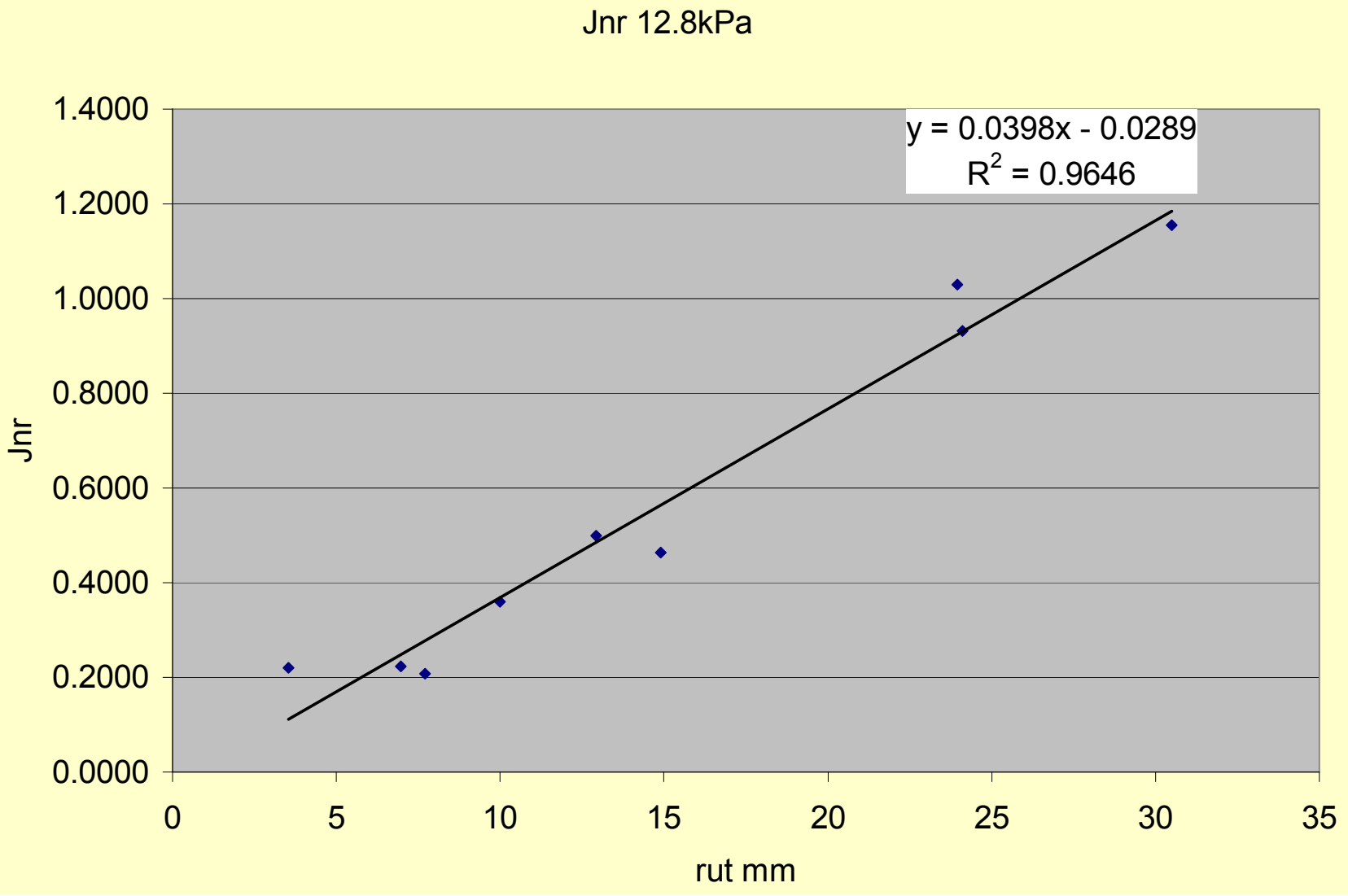
25.6kPa



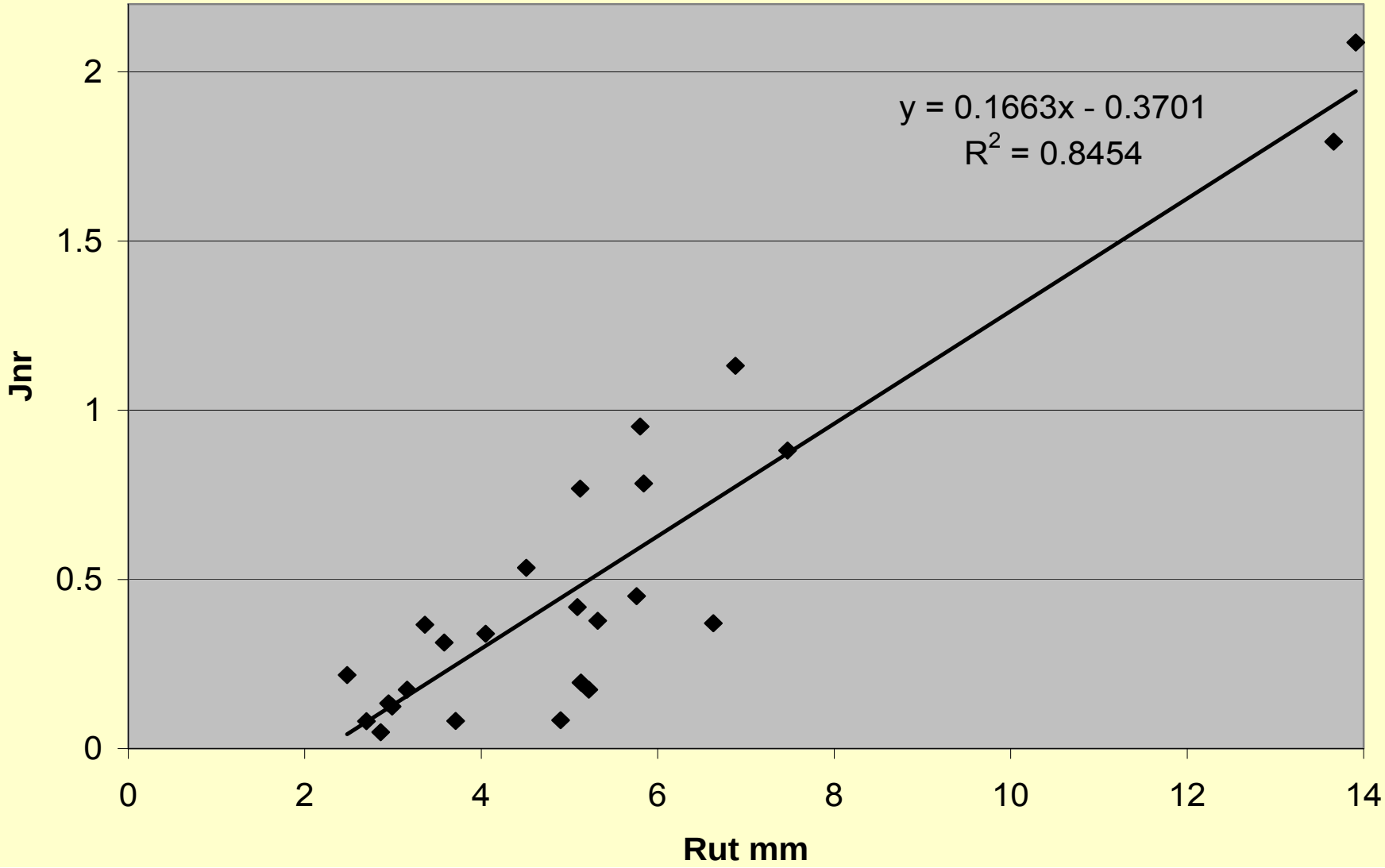
High Temperature Binder Criteria

- 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.

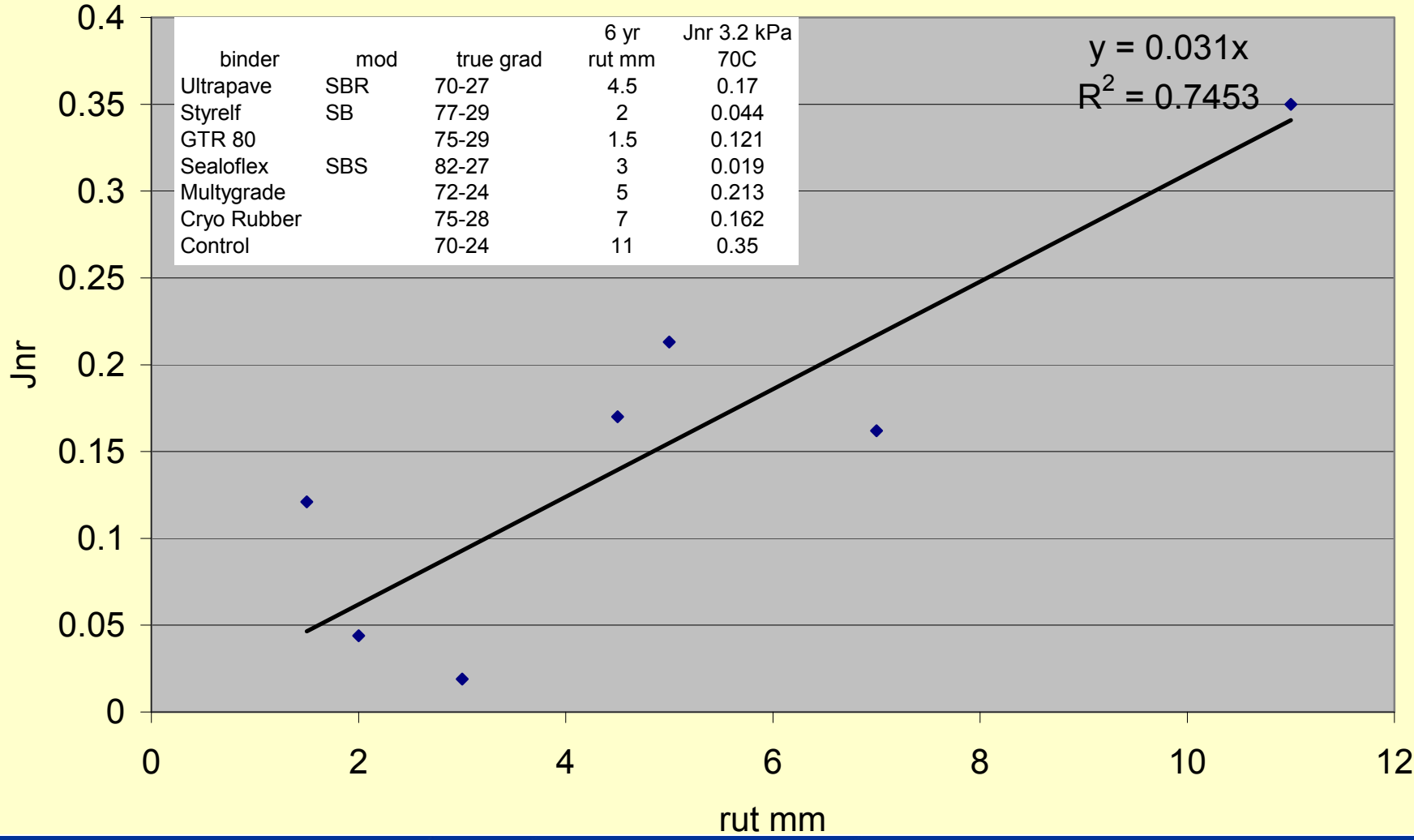
Hamburg Rut testing MINN Road mixes



Hamburg Rutting 8 binders one mix, Jnr 12.8 kPa



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

High Temperature Binder Criteria

- Non-recoverable compliance of the binder describes the stress dependency of the binder.
- Creep and recovery testing done 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 and related to performance.

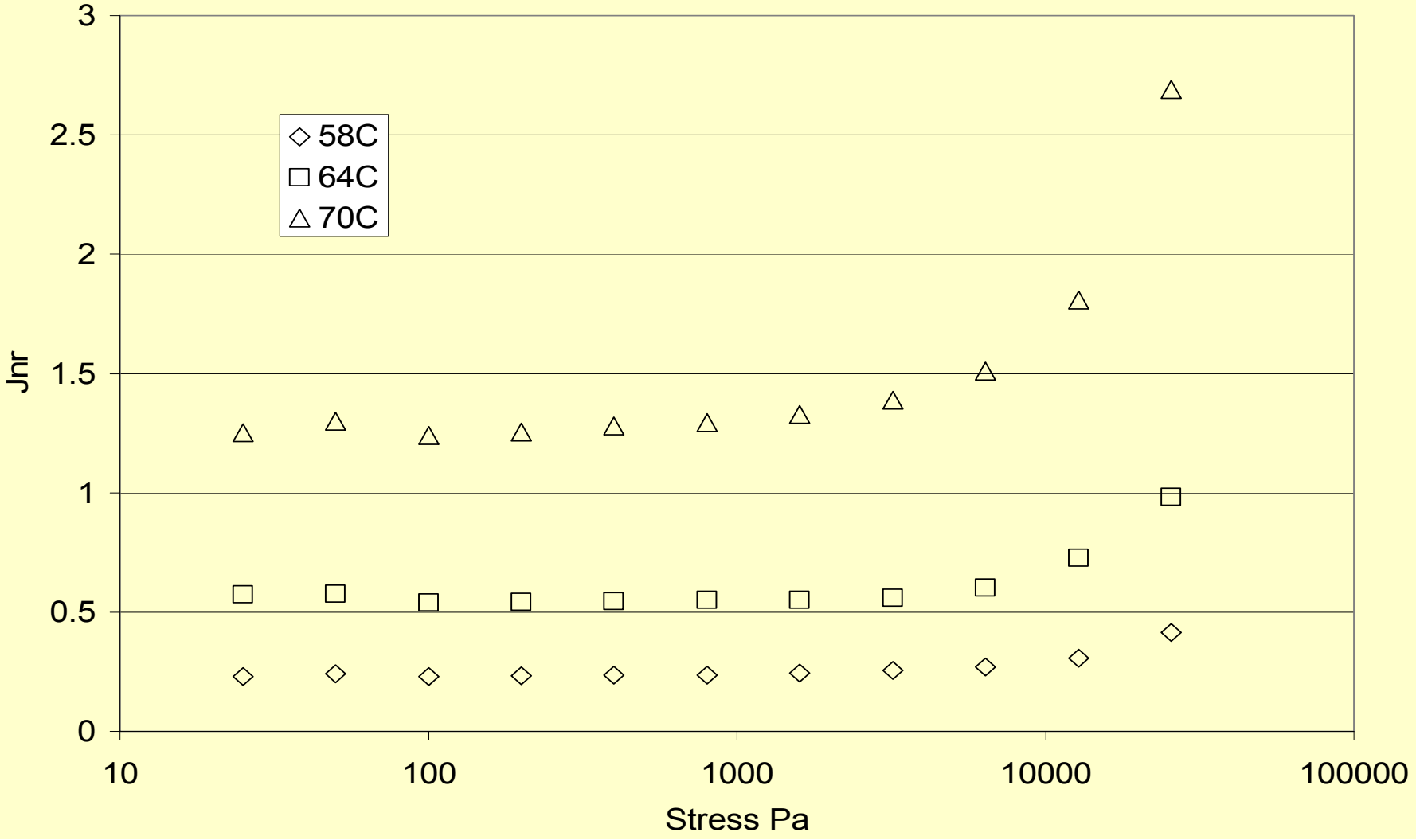
Affect of Jnr on Rutting

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

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. Most neat binders remain linear up to 3.2 kPa stress.

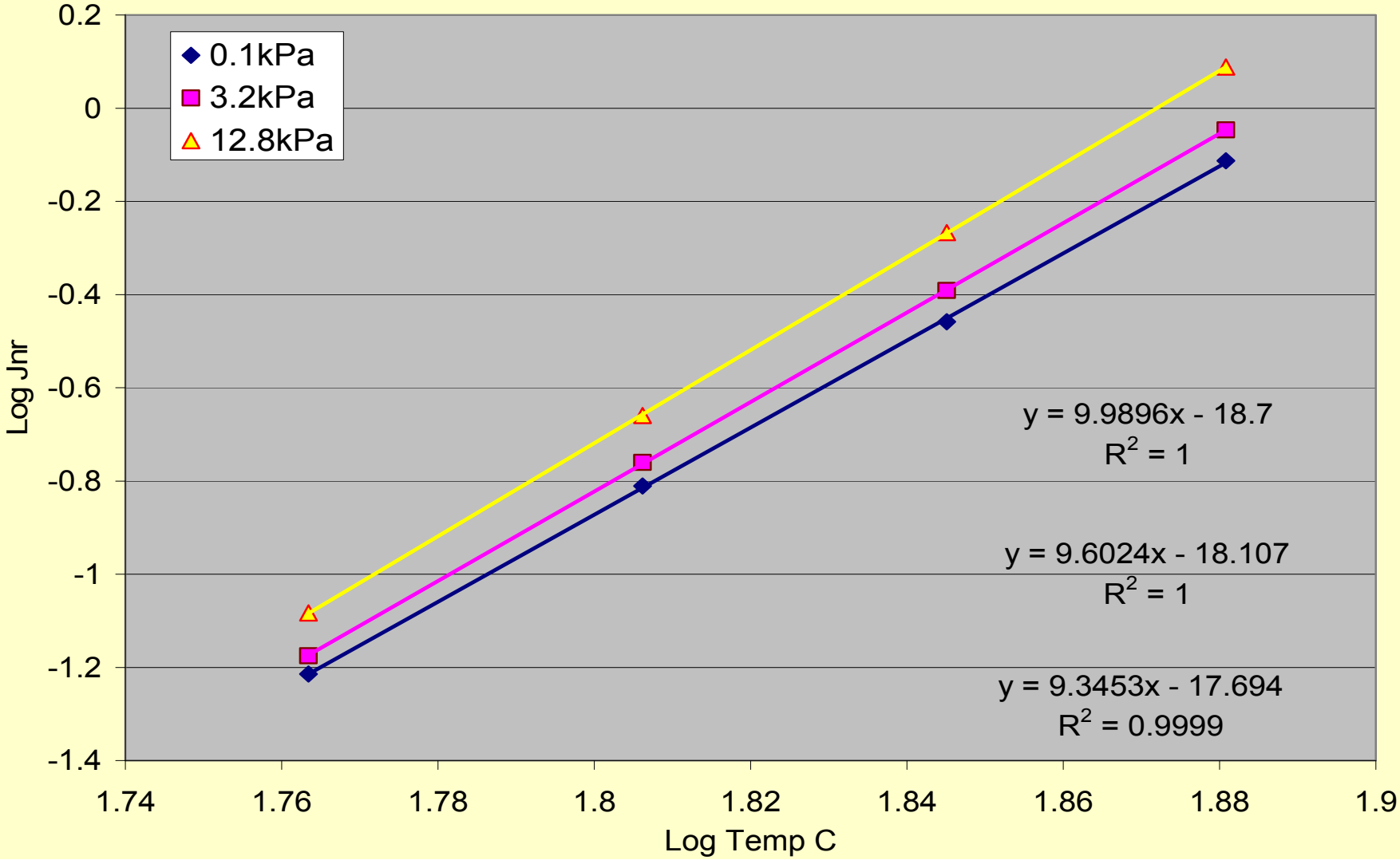
PG58-28 at multiple temperatures



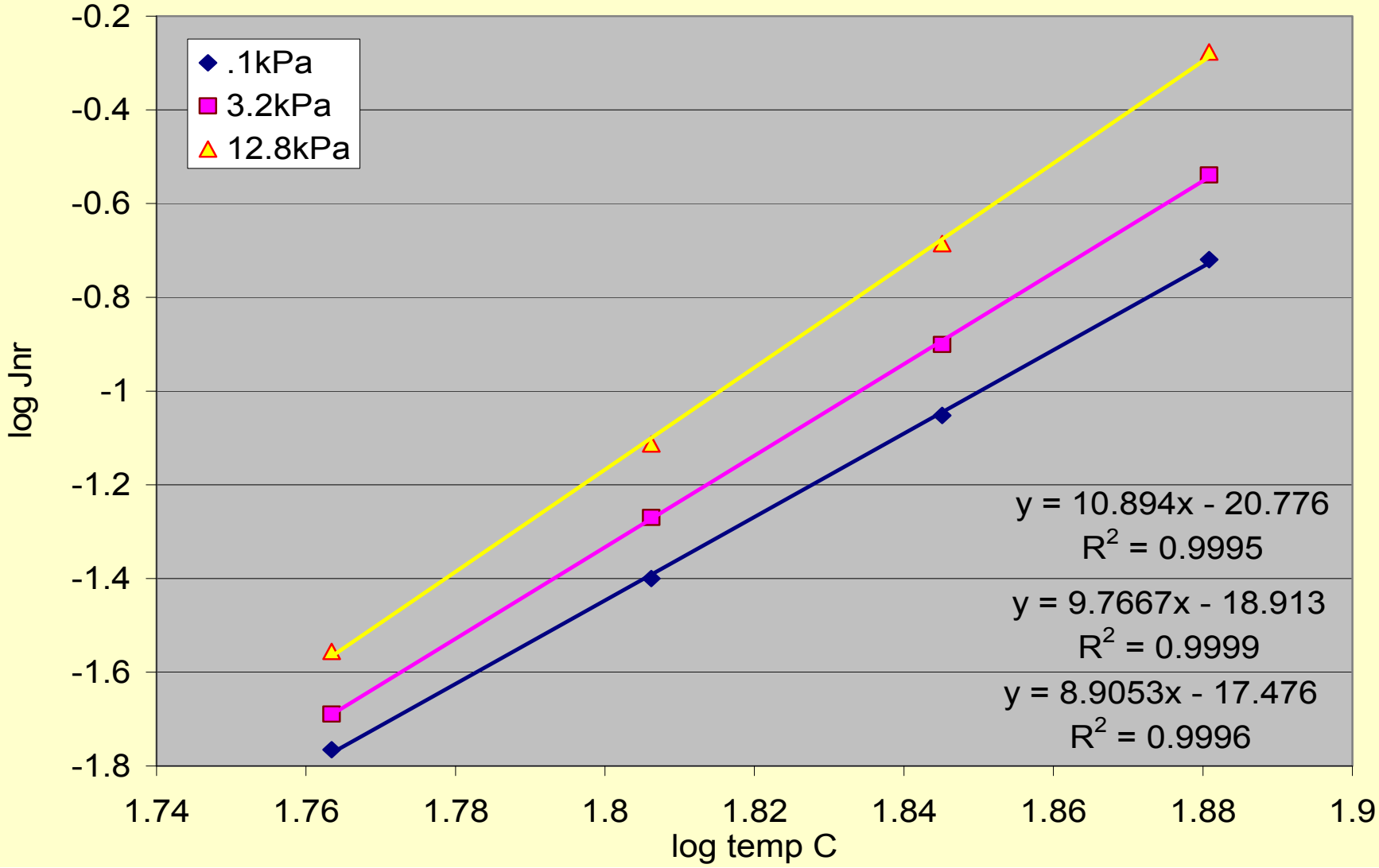
Evaluation of Straight run binders

Sample ID	Name	Grade	true grade	Temp	Jnr 3.2kPa
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

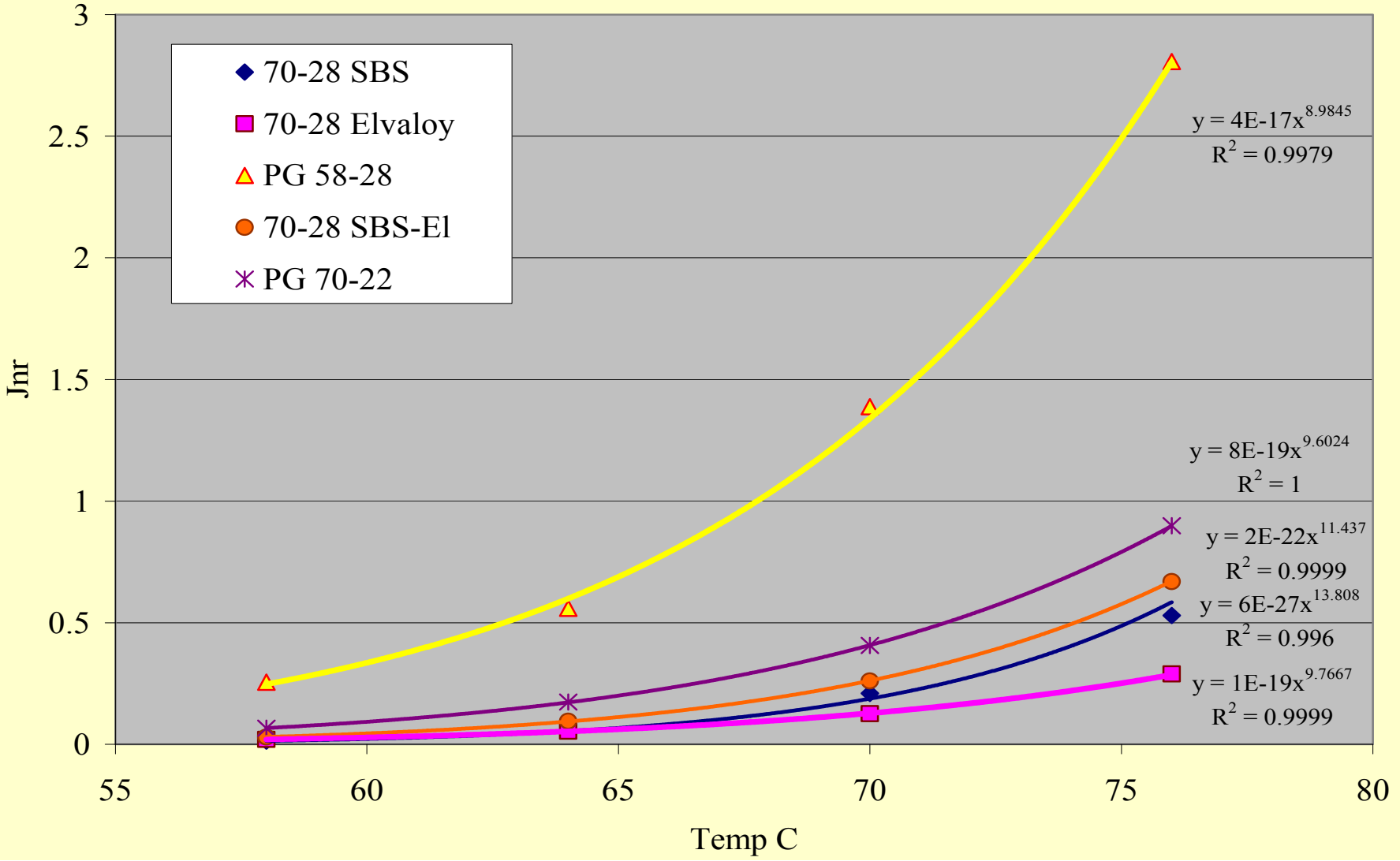
Temp sensitivity of PG70-22 Neat



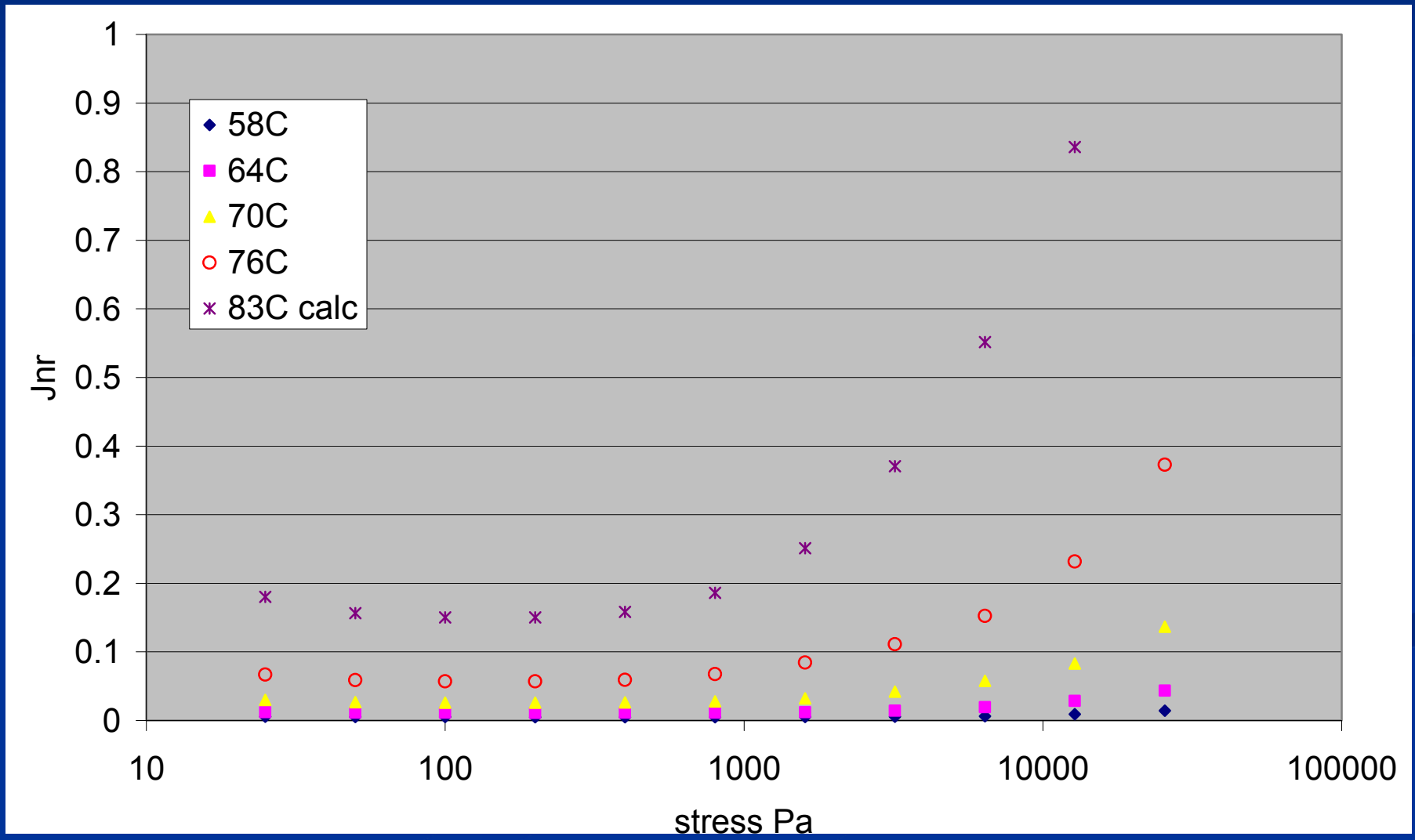
Temp sensitivity of PG70-28 Elvaloy



Variations in Temp sensitivity 3.2kPa



Ergon PG 82-22



Grade bumping recommendation

- All testing should be done at the environmental grade temp one shift factor does not work for polymer binders.
- The standard grade should be based on the Jnr value of existing neat binders 0.4 .
- For high traffic the Jnr value should be reduced by half at the grade temp to 0.2 .
- For standing traffic the Jnr value should be reduced by half again 0.1 .

New high Temp Spec

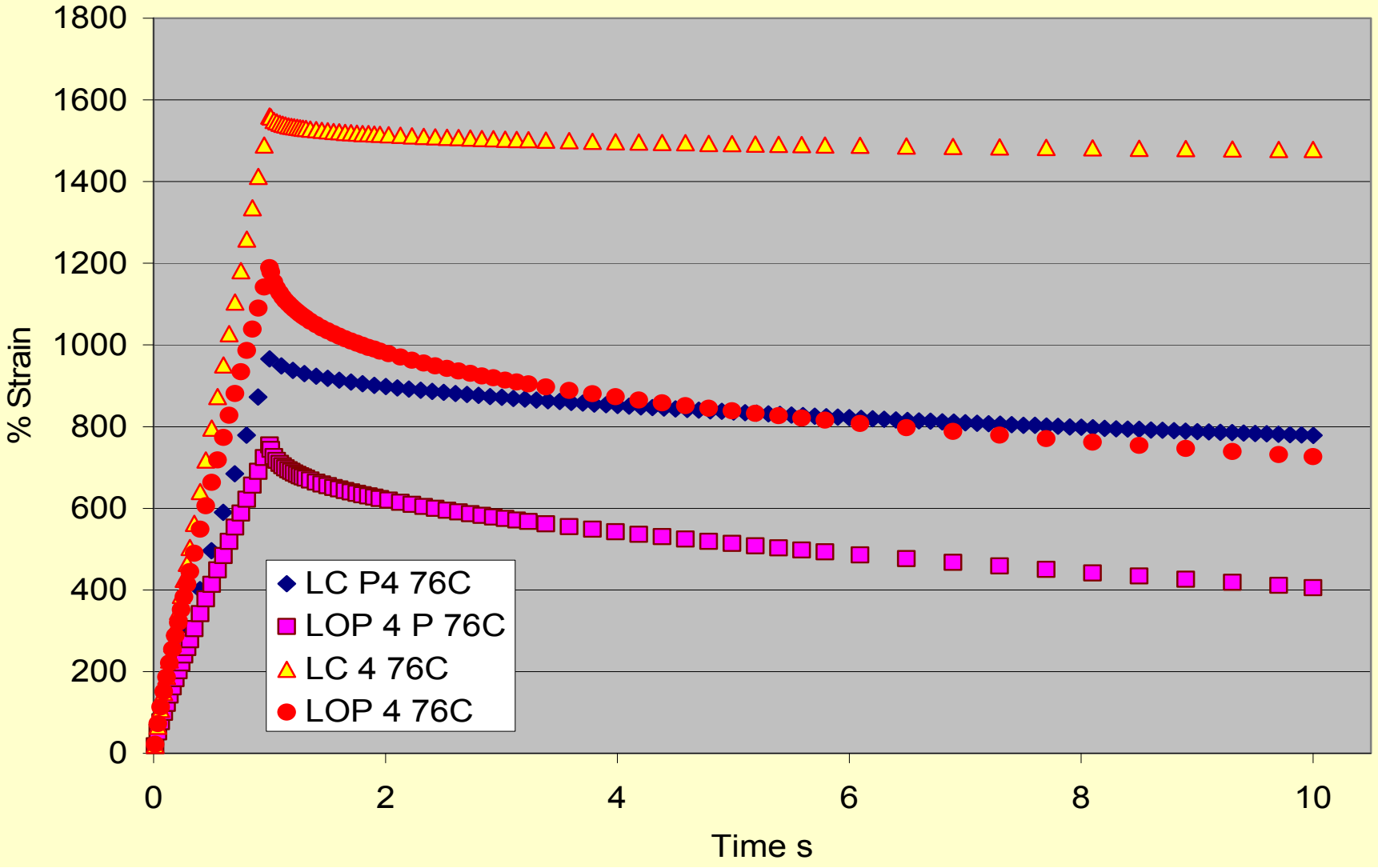
- PG 64 (Standard, Heavy, Very heavy) based on traffic.
  - PG 64S-XX J_{nr} =< 0.4
  - PG 64H-XX J_{nr} =< 0.2
  - PG 64V-XX J_{nr} =< 0.1

New MSCR Binder Spec

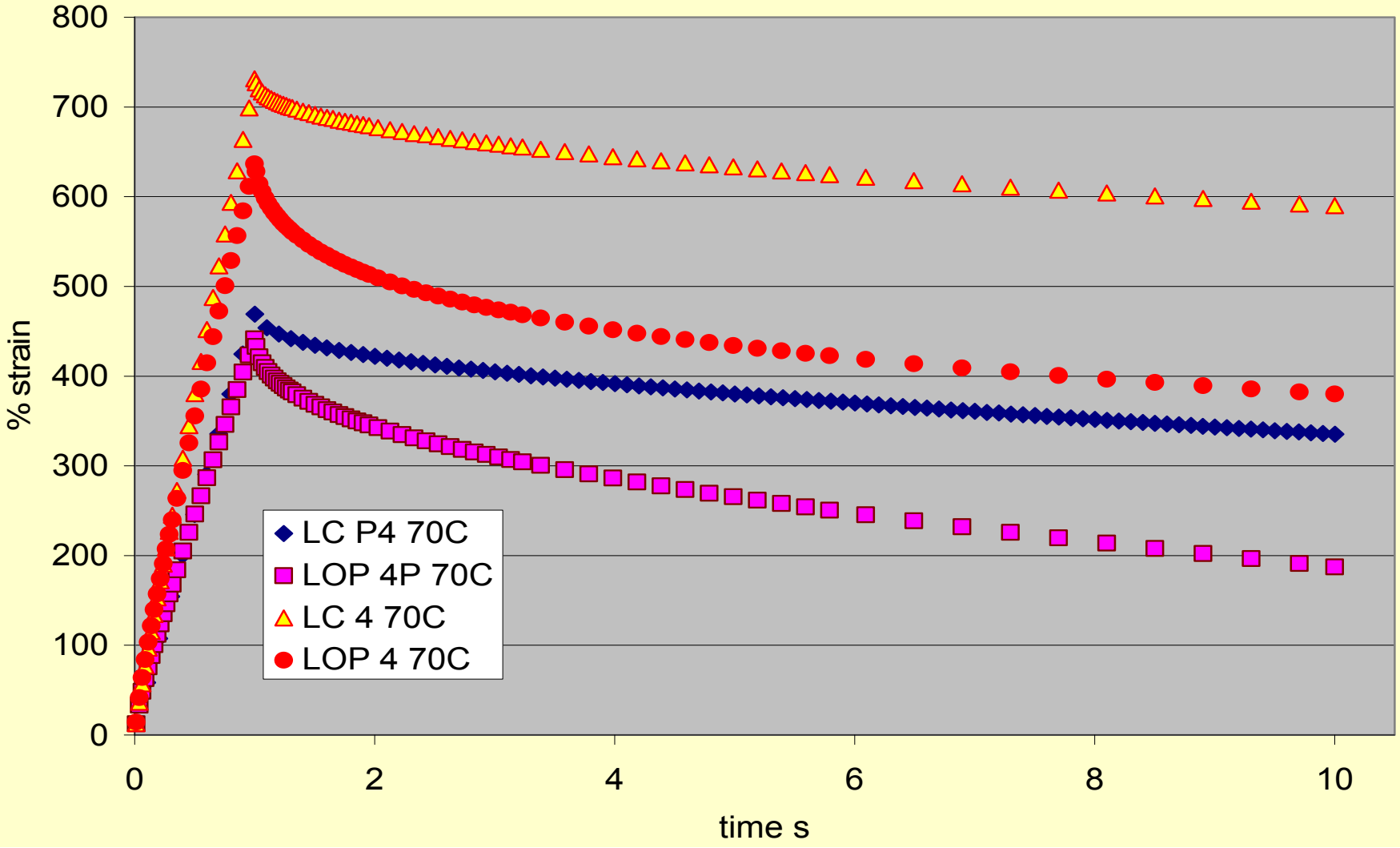
Original					
DSR G*/sinδ Min 1.0	64				
RTFOT					
64 Standard MSCR <0.4	64				
64 Heavy MSCR <0.2	64				
64 Very heavy MSCR <0.1	64				
PAV					
S grade DSR G*sinδ Max 5000	28	25	22	19	16
H & V grade DSR G*sinδ Max 6000	28	25	22	19	16

Low temp BBR and DTT remain unchanged

Effect of blending and formulation one base one polymer content different blending process.



Polymer network effects responce

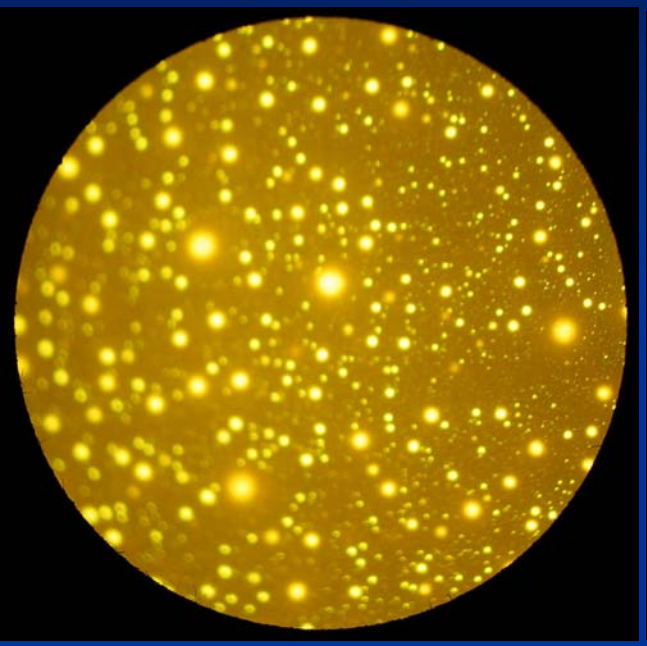


MSCR does a far better job of distinguishing between binders

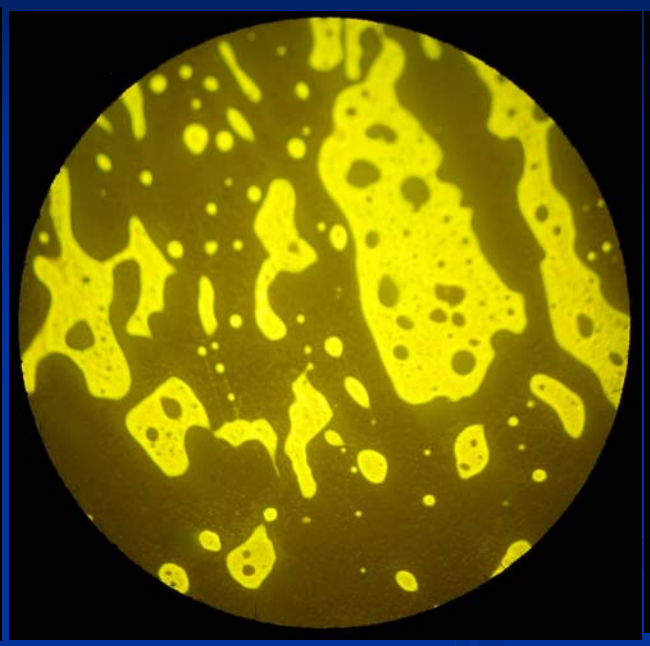
Sample ID	Continuous Grade	Polymer	Acid	Temp C	J_{nr} 3.2kPa	ER	% Recovery 3.2kPa
LC	66.7-24.1		0	64C	0.312	5	0
LC 4	75.7-22.3	4% SBS	0	70C	0.185	73.8	19.2
				76C	0.455		5.96
LC P4	81.2-22.2	4% SBS	0.50%	70C	0.106	93.8	28.4
				76C	0.24		20.55
LOP 4	76.6-25.2	4% SBS from Concentrate	0	70C	0.118	86	40.3
				76C	0.235		37.02
LOP 4P	81.6-24.5	4% SBS from Concentrate	0.50%	70C	0.067	83	52.05
				76C	0.138		42.52

Kraton slide

More Micrographs



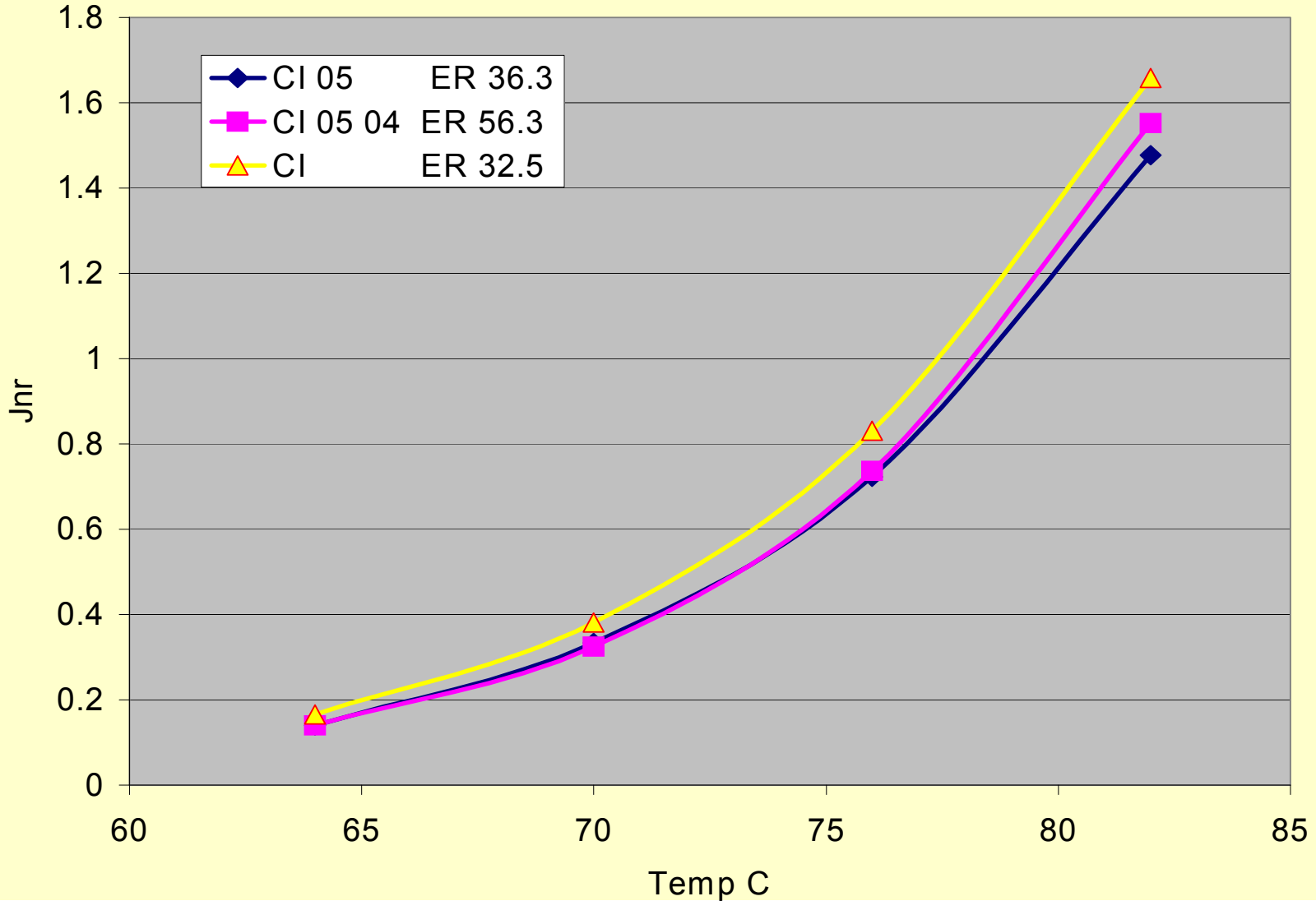
CAN 3%
annealed



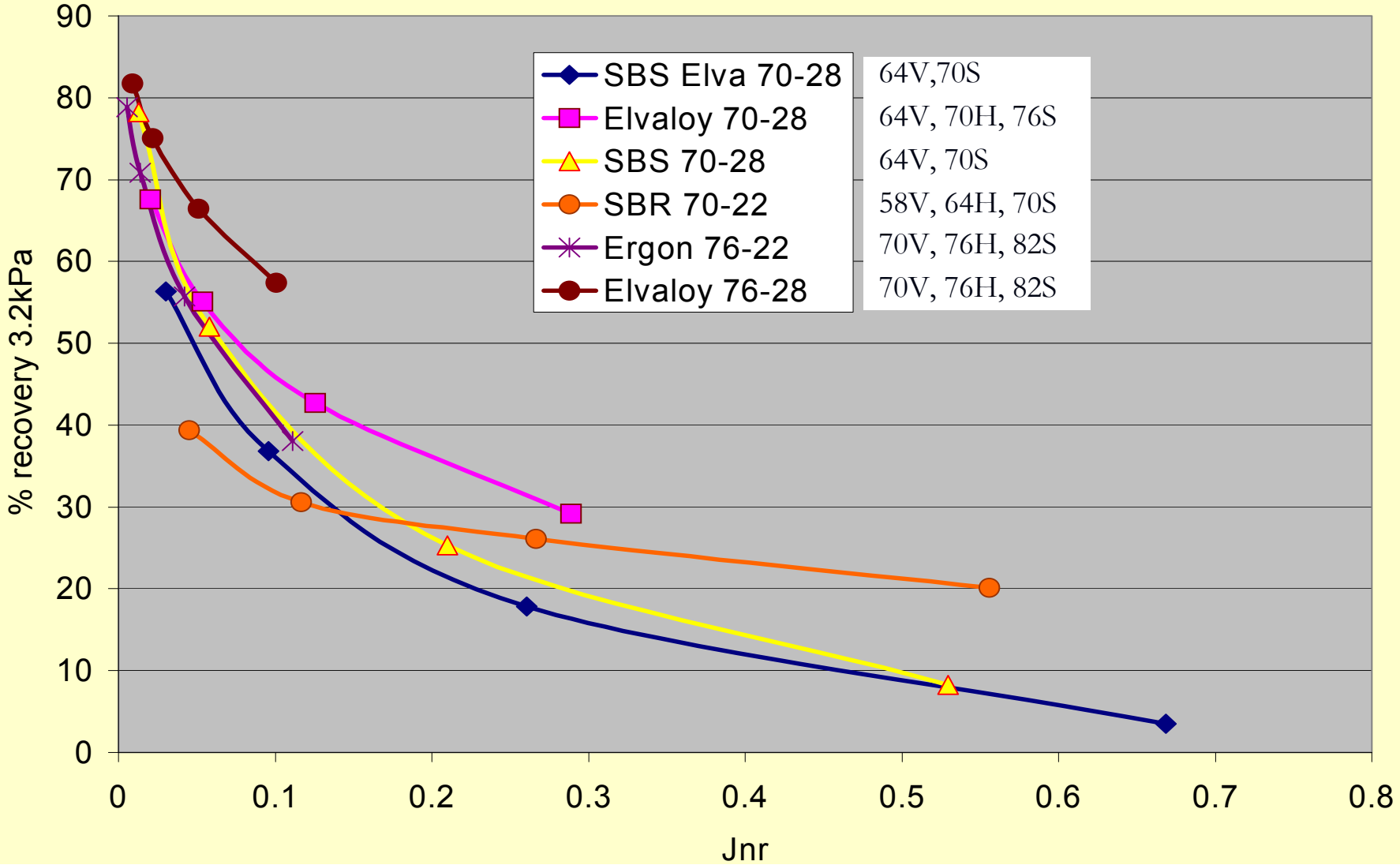
MIDCON 3%
annealed

CAN 3% + S
annealed

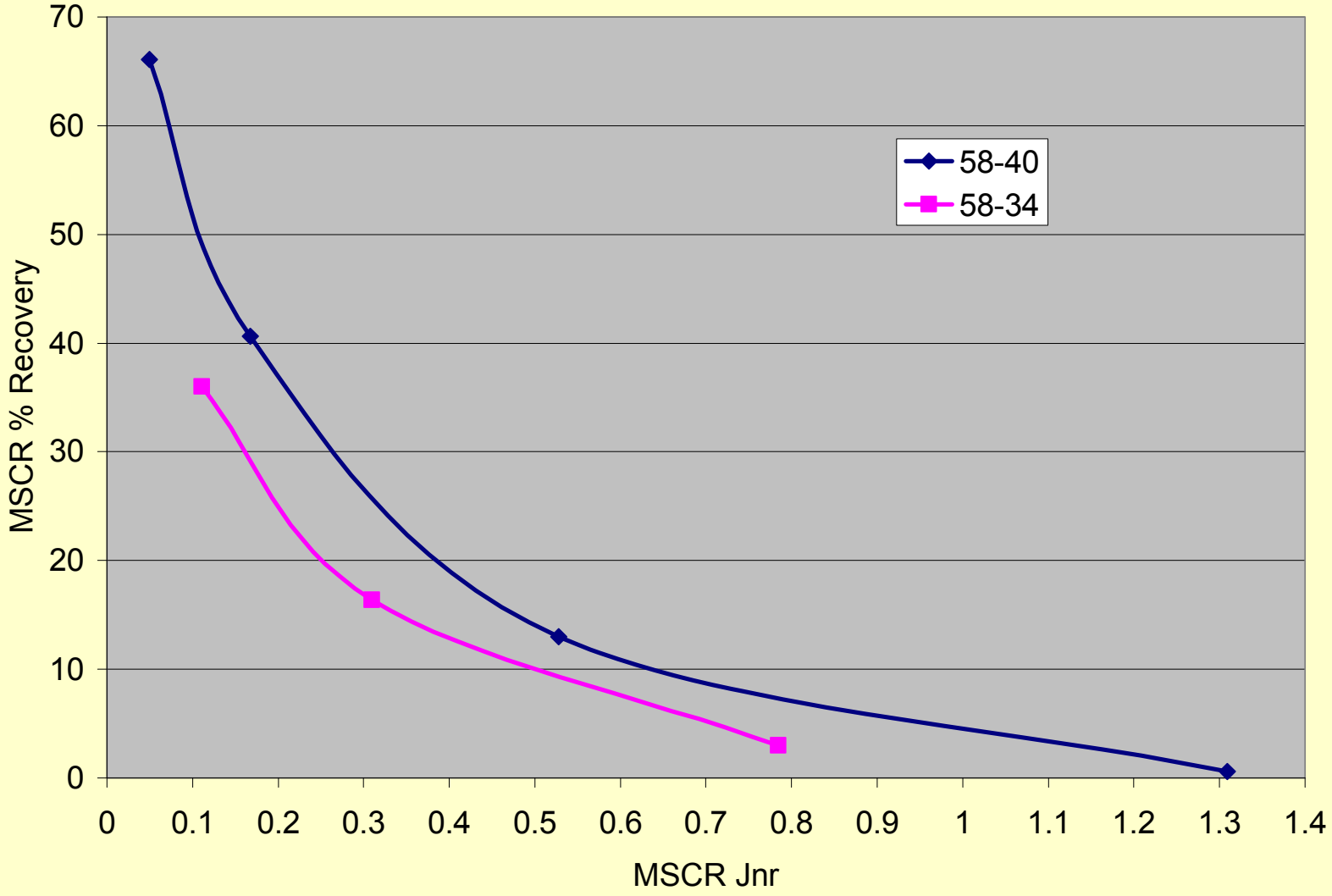
Effect of X-linking on ER



BBRS Study


% recovery 3.2kPa
Jnr
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
SBS Elva 70-28
Elvaloy 70-28
SBS 70-28
SBR 70-22
Ergon 76-22
Elvaloy 76-28
64V,70S
64V, 70H, 76S
64V, 70S
58V, 64H, 70S
70V, 76H, 82S
70V, 76H, 82S

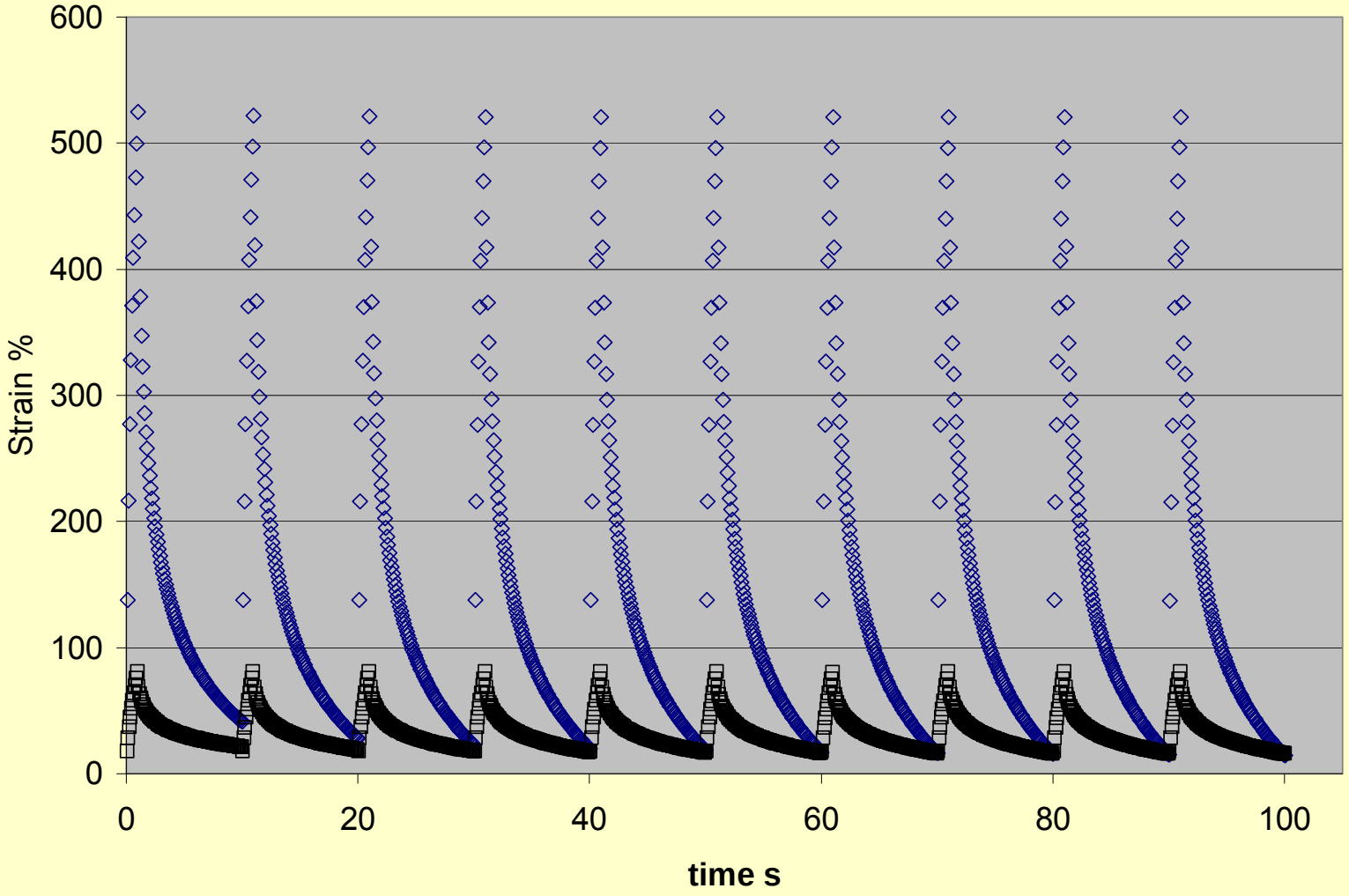
MinnRoad Study



New MSCR Binder Grade

- Note For H and V grades MSCR % recovery can be added to validate polymer modification
  - H grade 25% Recovery
  - V grade 35% Recovery

C&R Plot PG 64-34 @64C & PG 76-22 @ 58C



64-34 has 95% recovery

76-22 has 75% recovery Both have the save Jnr 0.006

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 to reflect response at actual operating temperatures.
- 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.

Conclusions

- MSCR can identify how the polymer, binder and processing will affect performance in one simple test.
- The use of PPA and x-linker seem to work together to improve the performance properties of the binder as opposed to being used individually.

Continued Work

- Does % recovery in the MSCR relate to durability and fatigue?

Thank You