

Multi-Stress Creep and Recovery Test Method New Specification

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Problem-High Temperature Binder Criteria

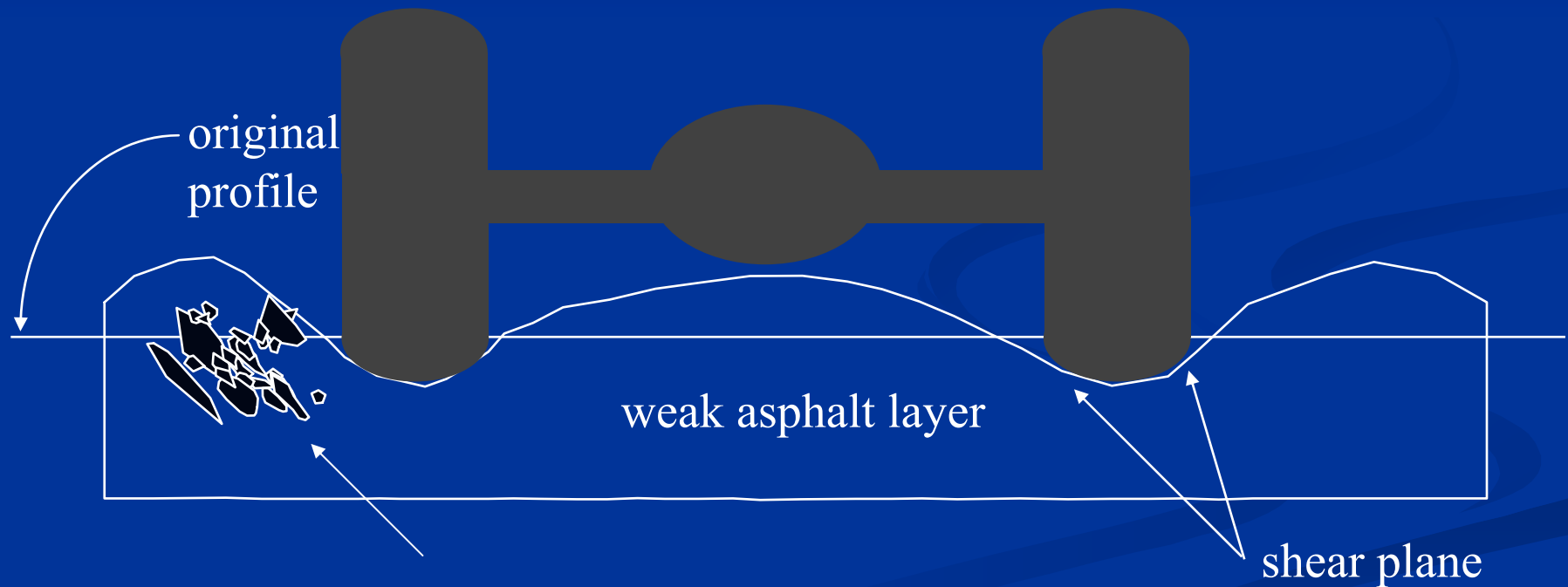
- Does $G^*/\sin\delta$ reflect rutting performance of modified binders.
 - General anecdotal data says no.

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-Stress Creep and Recovery Work

Rutting in Asphalt Layer

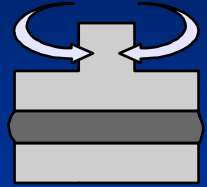


Movement and rotation of aggregate creates very high strain in the binder.

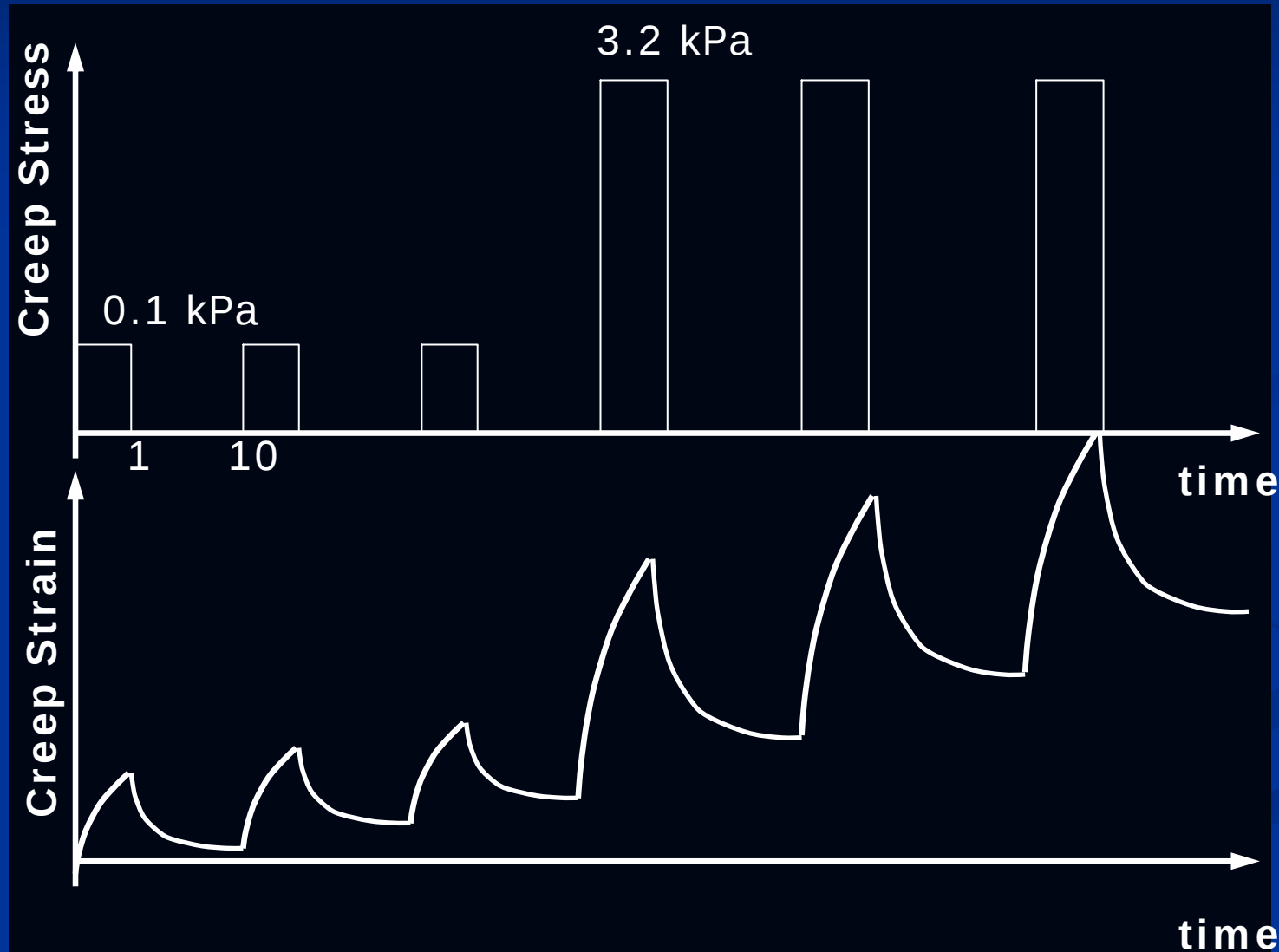
Aggregate reorientation during Rutting



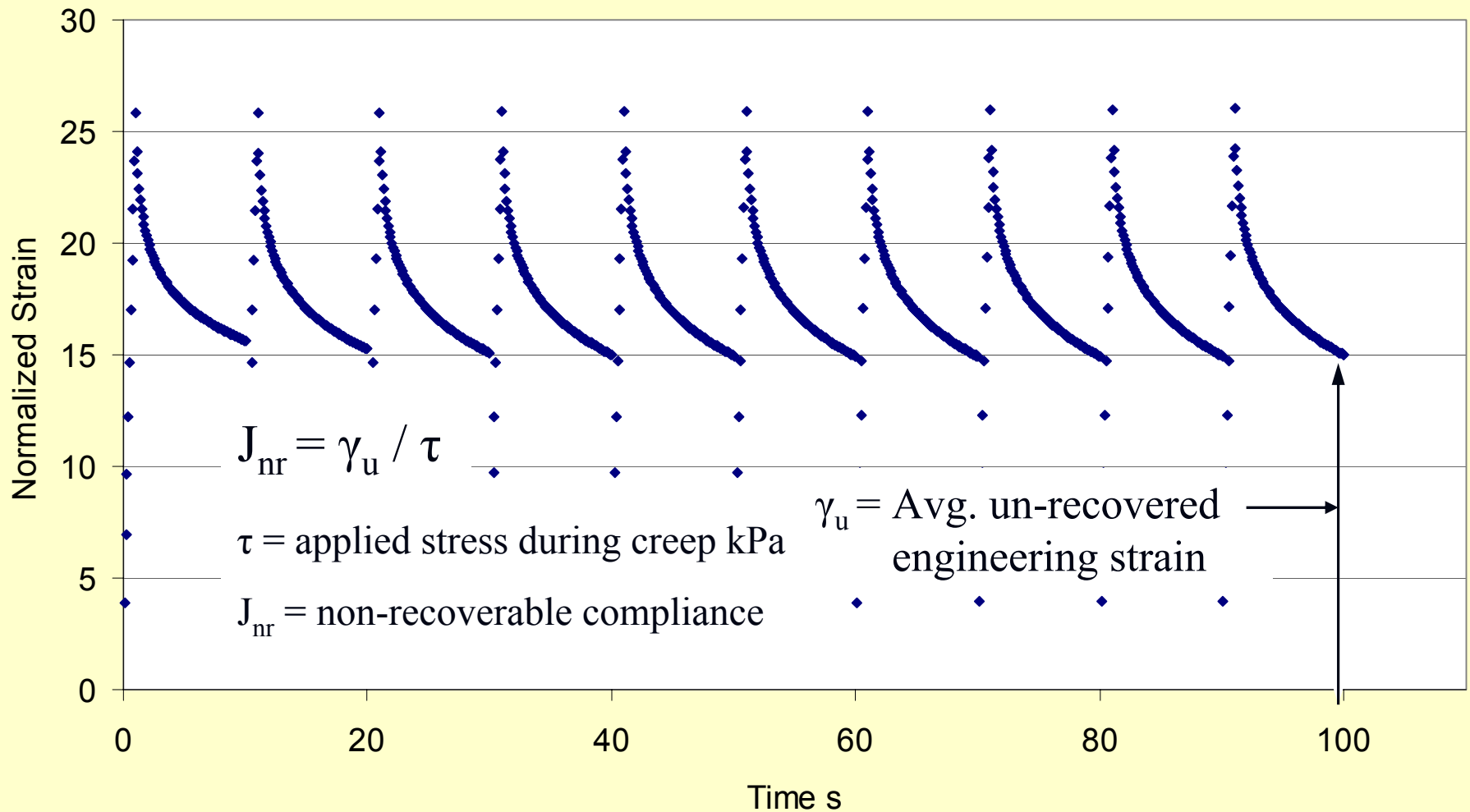
Multi Stress Creep and Recovery



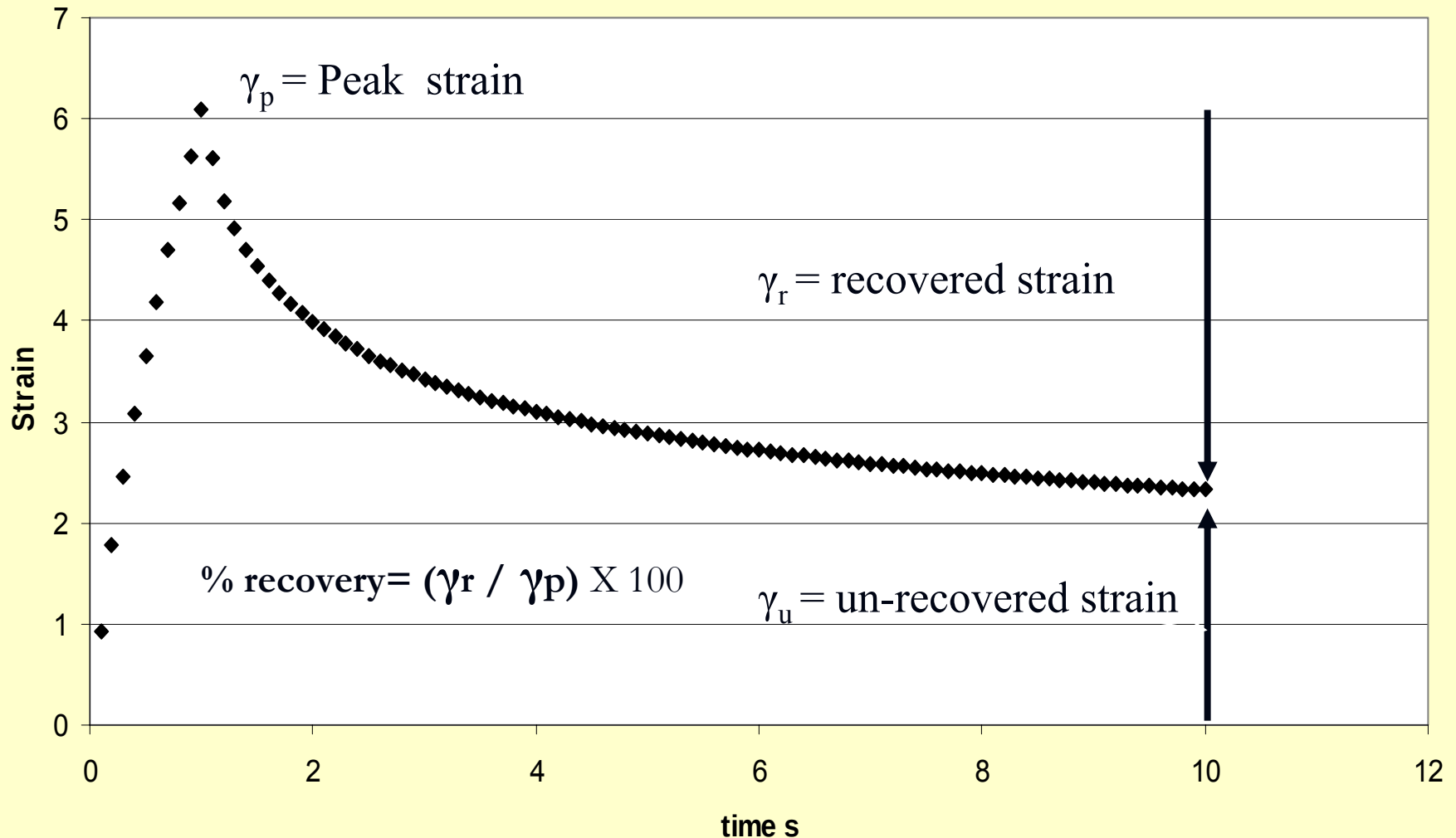
Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.



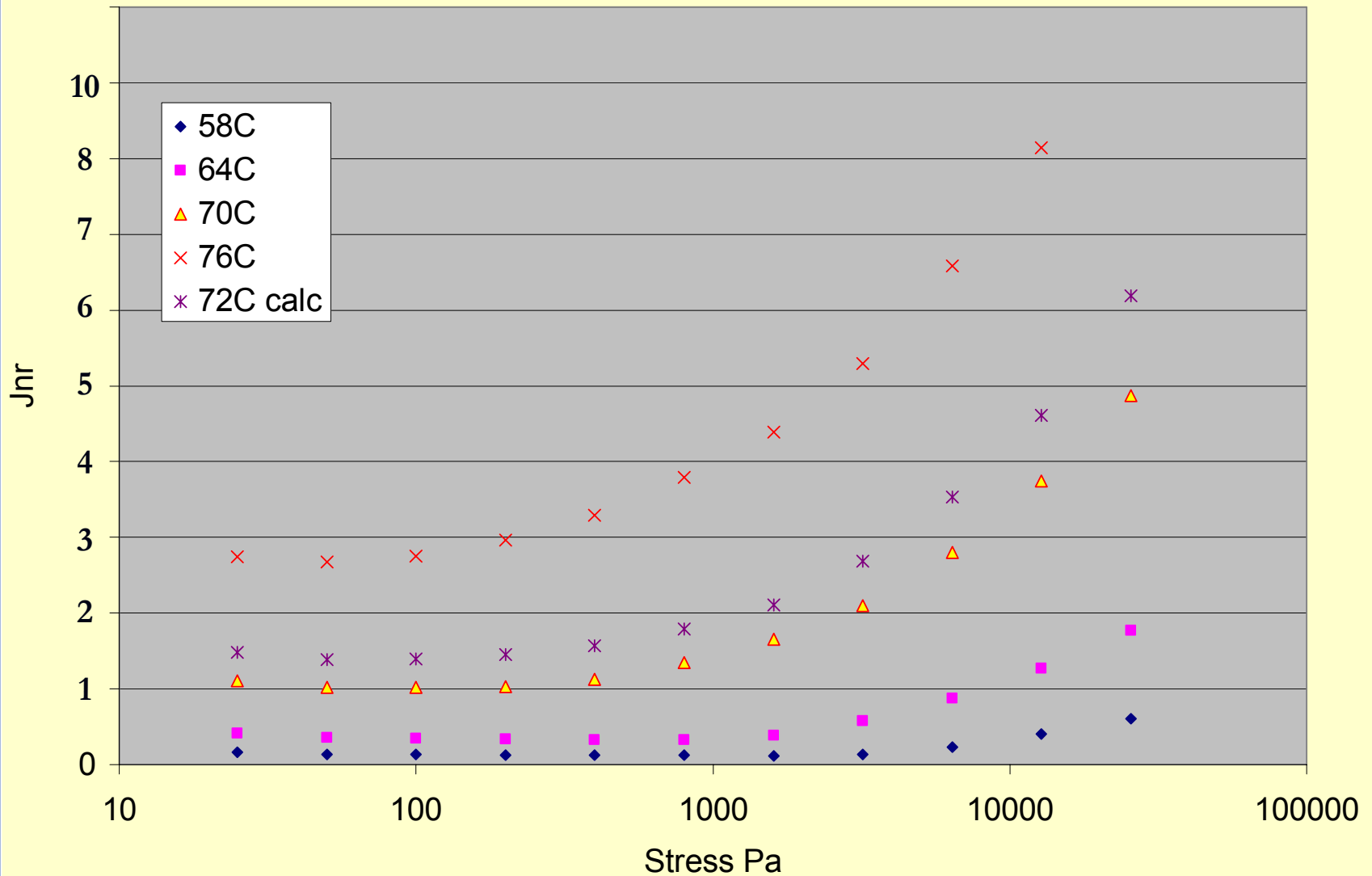
Determination of J_{nr}



What is % Recovered Strain



SBS PG 70-28

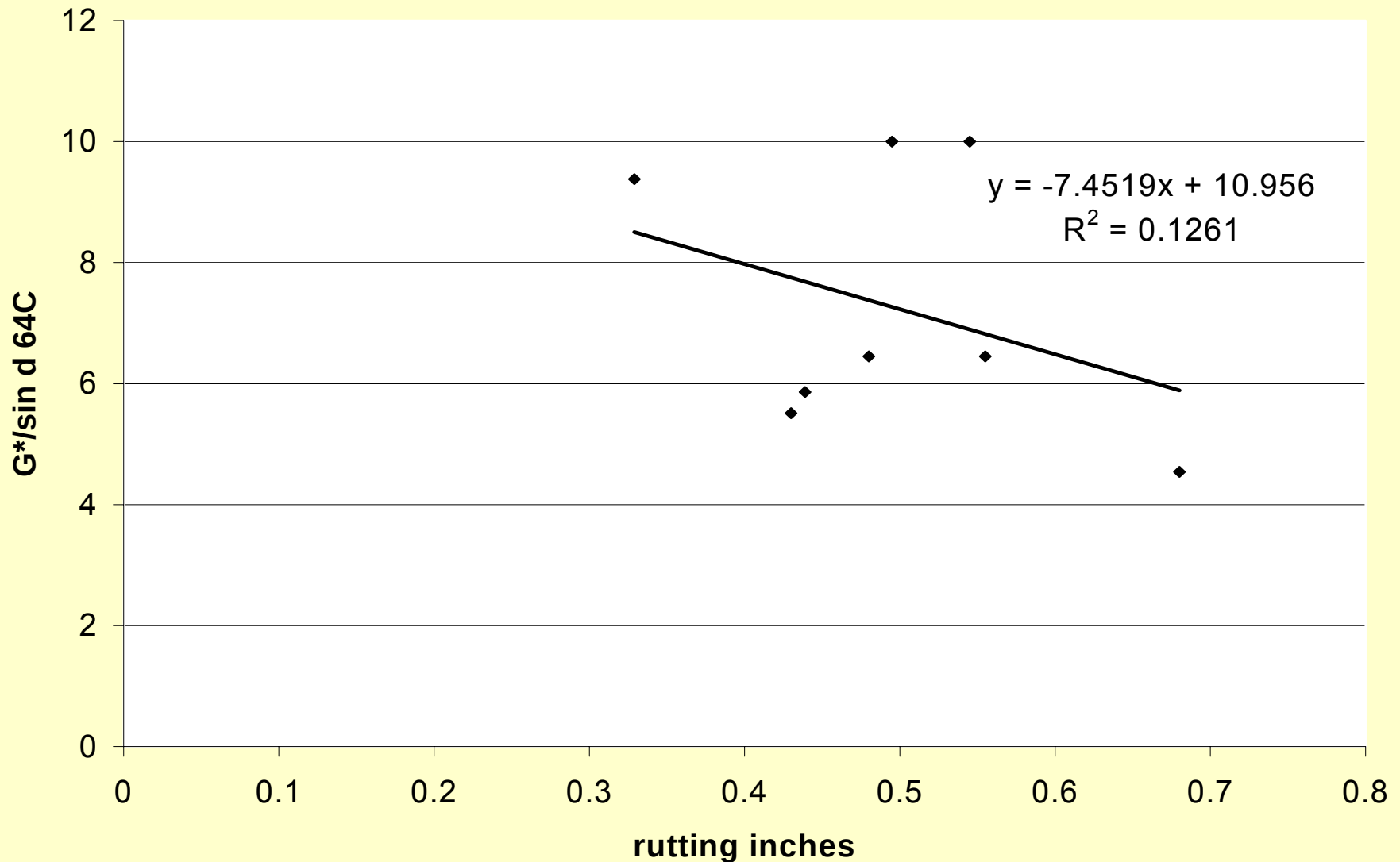


7 Asphalt Binders



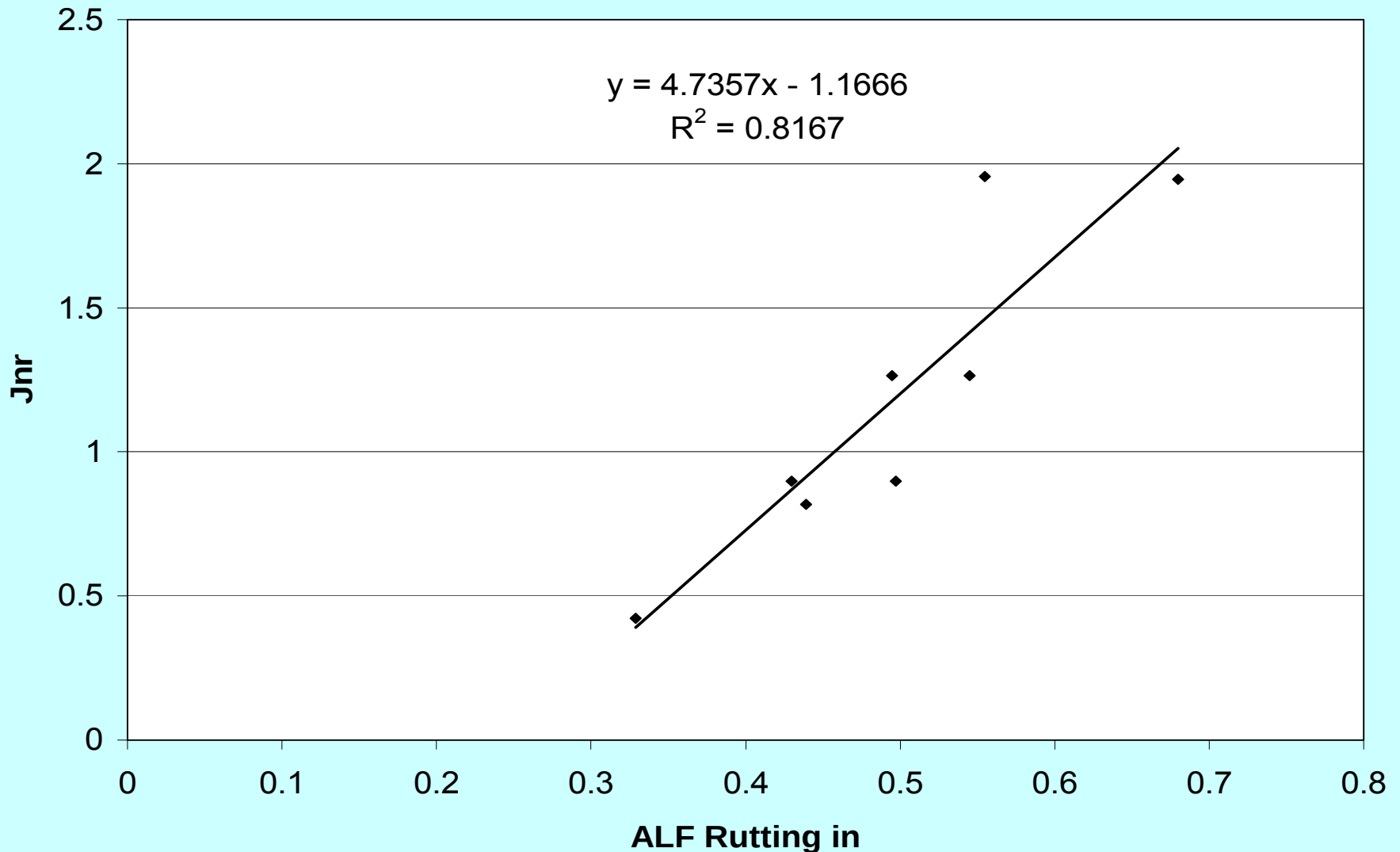
											
											
AZ CRM ---- 70-22	PG 70-22 Control	Air Blown	SBS	TX TBCR	TP	PG 70-22 + Fibers	PG 70-2264-40	SBS	Air Blown	SBS	TP
1	2	3	4	5	6	7	8	9	10	11	12

Relationship between $G^*/\sin\delta$ and ALF rutting



Relationship between Jnr and ALF rutting

25.6kPa

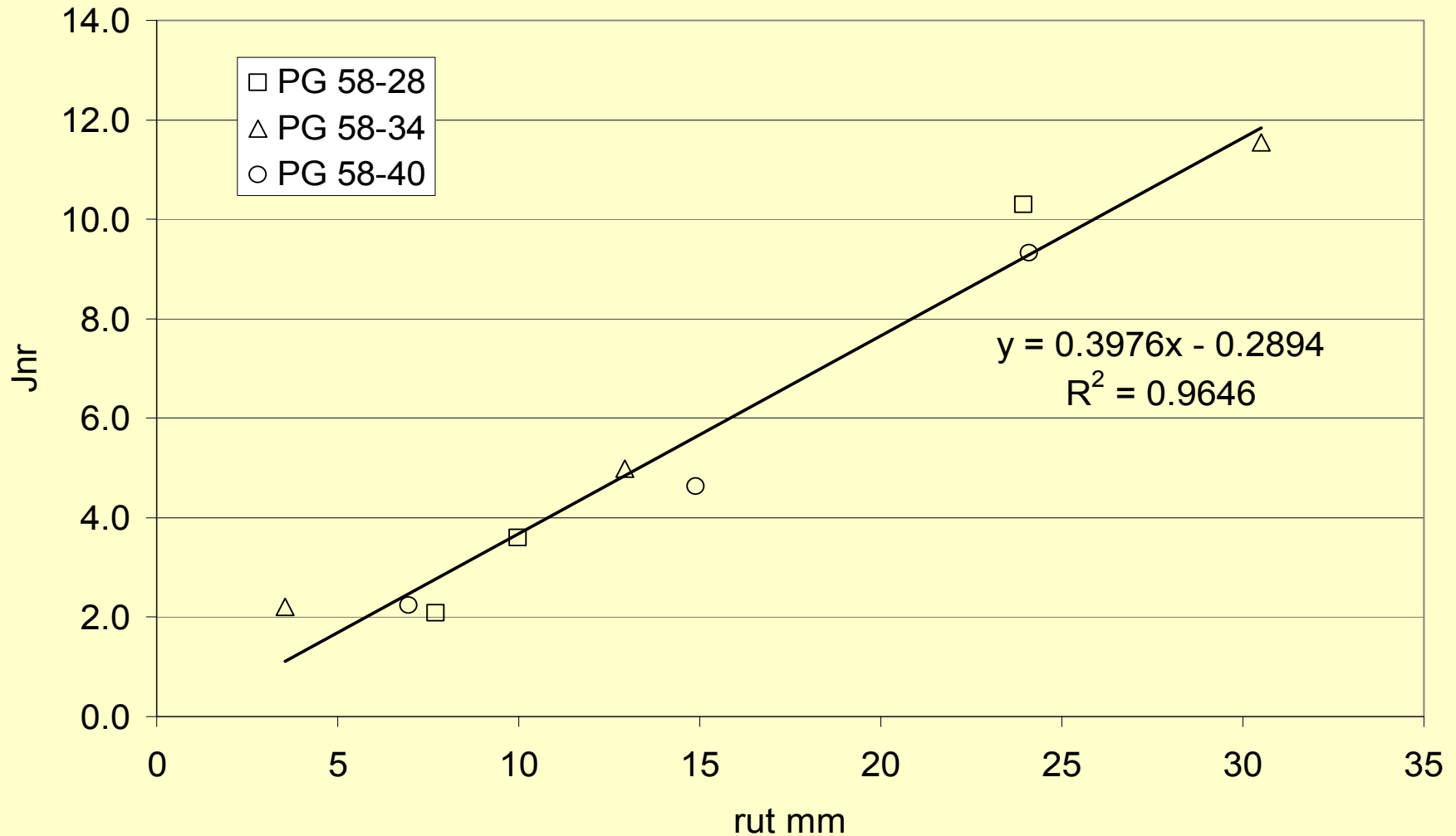


High Temperature Binder Criteria

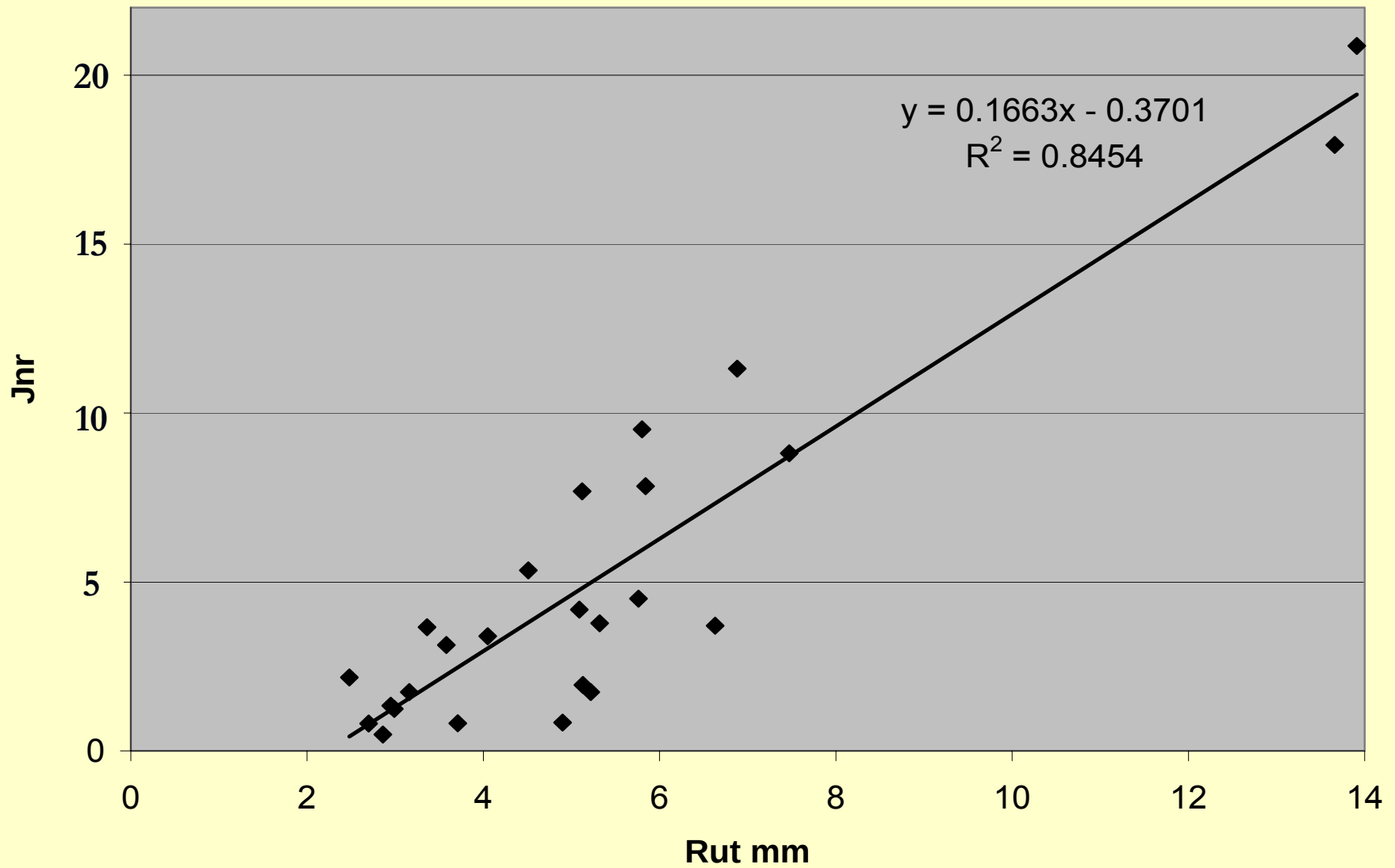
- Linear binder tests will not correlate with high temperature mix failure test unless the binder is a viscous fluid at those temps.
- To accurately address mix failure non-linear binder properties have to be evaluated.
- Creep & Recovery testing of the binder at different stress levels is needed to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

Hamburg Rut testing MINN Road mixes

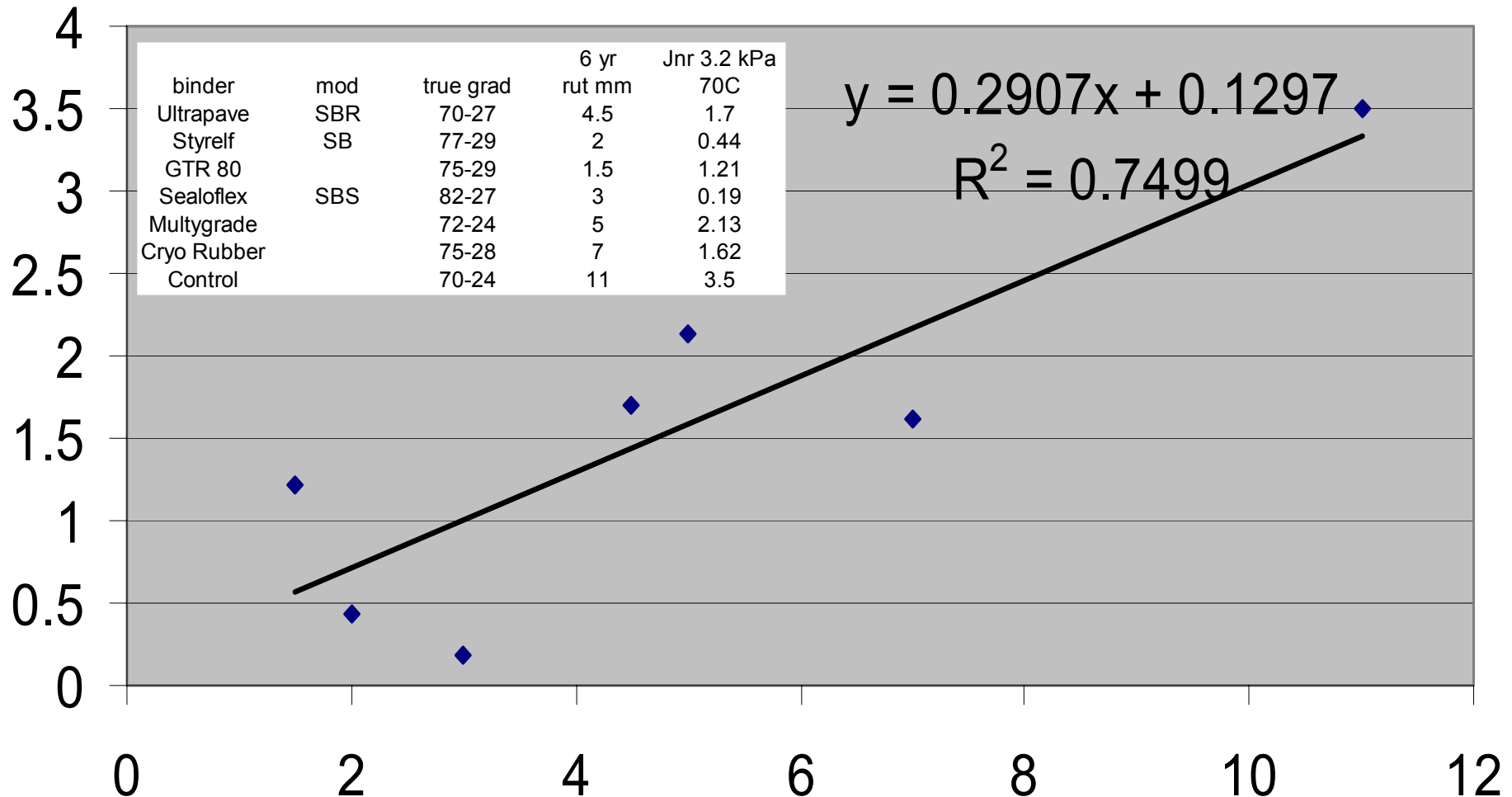
Jnr 12.8kPa



Hamburg Rutting 8 binders one mix, Jnr 12.8 kPa



Miss I55 6yr rut Jnr 3.2 kPa



High Temperature Binder Criteria

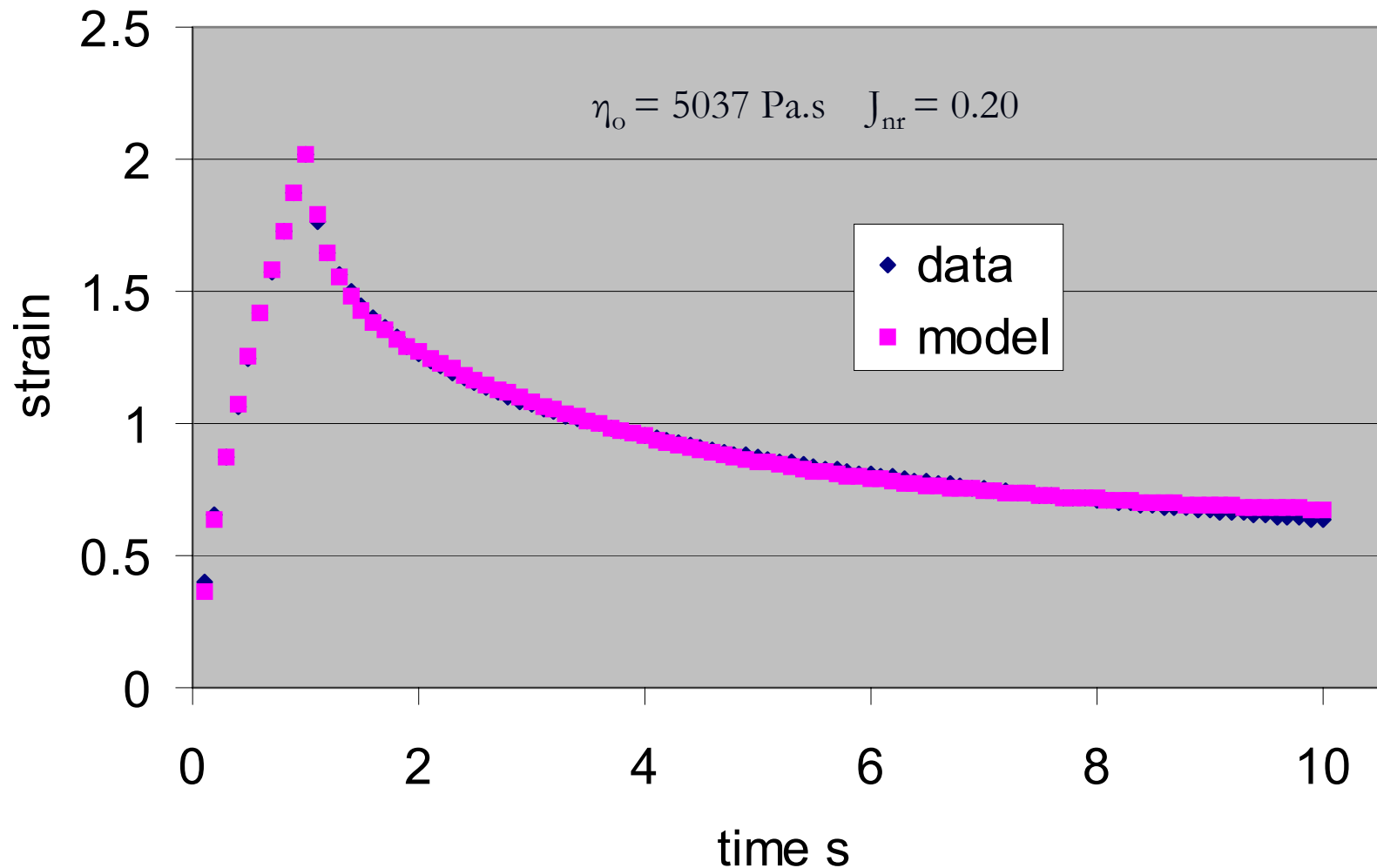
- Non-recoverable compliance of the binder describes the stress dependency of the binder.
- Creep and recovery testing done at multiple stress levels on one sample can be run to describe the stress dependency of the binder.
- Creep and recovery non-recoverable compliance can be correlated to mix testing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

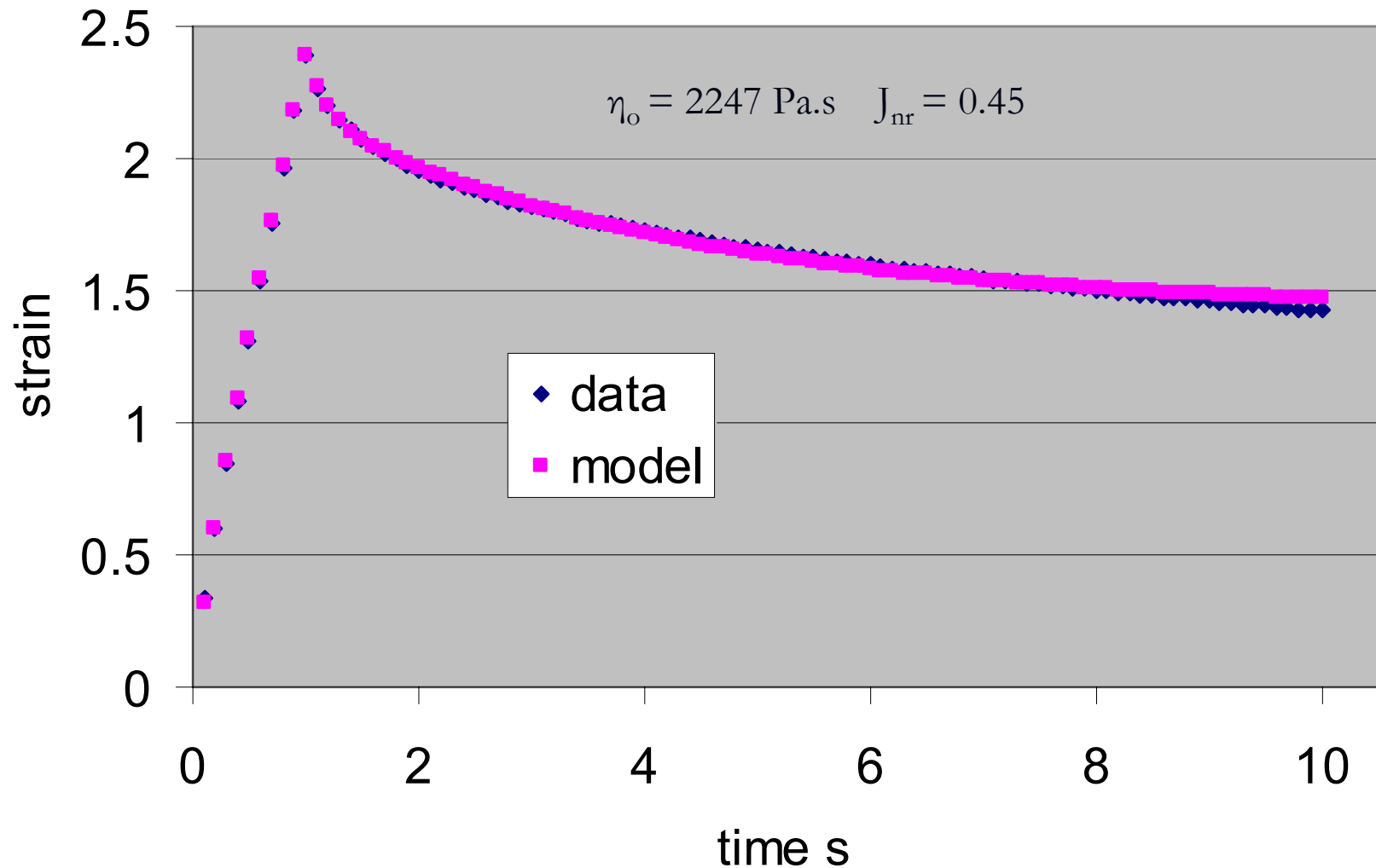
70-28 Elvaloy 3.2 kPa 58C

3 element Burgers Model



70-28 Latex 3.2 kPa 58C

3 element Burgers Model



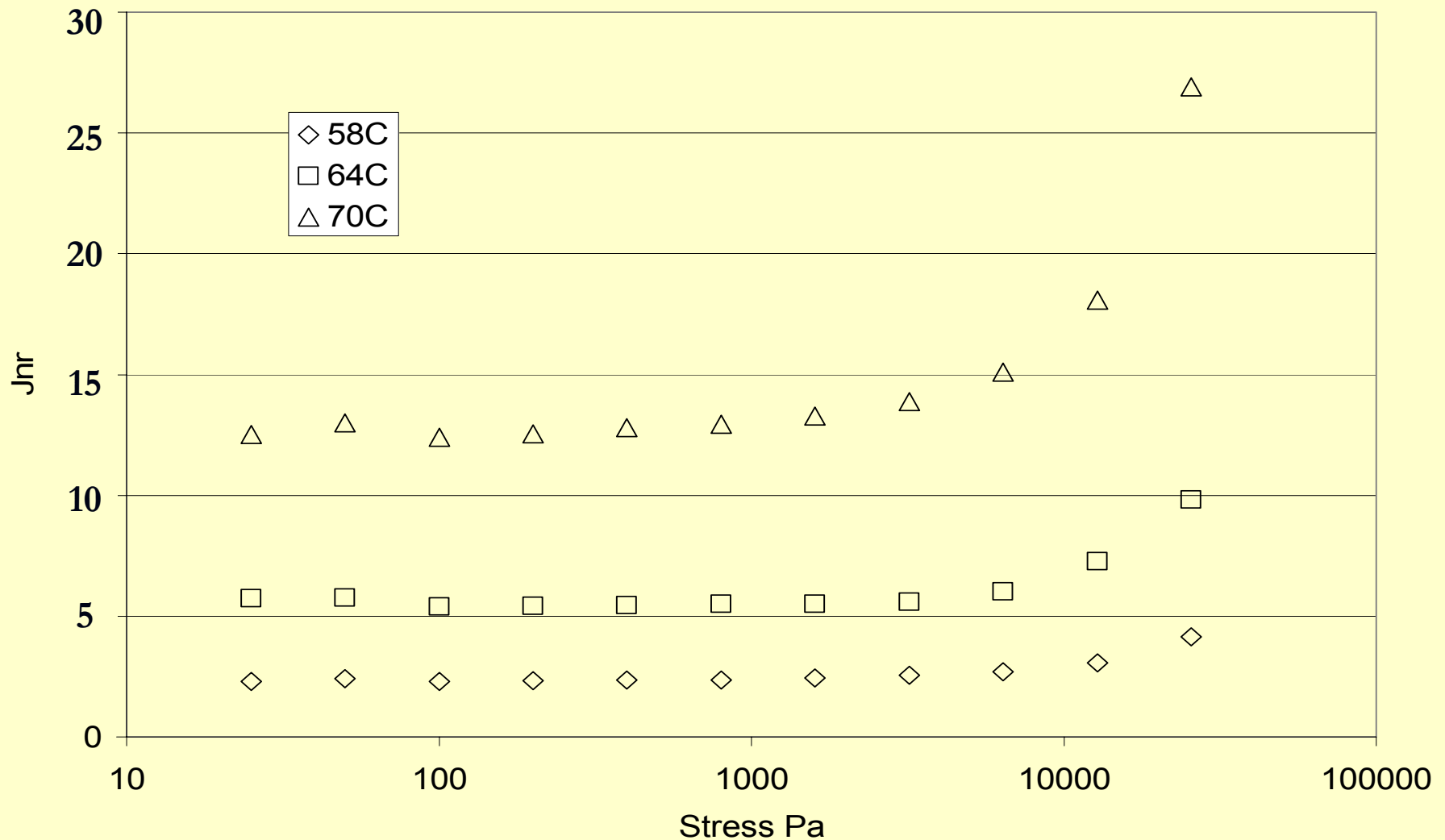
Burger Model results 3 binders

Binder	temp	η_0	G_1	λ_1	G_2	λ_2	G_3	λ_3	τ_0
PG 58-28	58	434.22	16389.82	1.81	14320.03	1.80	29053.98	0.27	0.1
PG 58-28	58	421.94	20686.40	1.79	19277.56	1.79	38600.55	0.23	0.8
PG 58-28	58	392.77	79798.67	1.77	76816.35	1.75	244413.92	0.09	3.2
PG 70-28 SBS	70	856.65	617.60	3.07	517.20	3.07	2374.91	0.22	0.1
PG 70-28 SBS	70	733.03	716.49	2.91	662.41	2.91	2455.32	0.22	0.8
PG 70-28 SBS	70	493.12	1388.90	2.68	1515.66	2.48	3356.62	0.17	3.2
PG 70-28 SBS	76	349.07	229.74	2.73	4135.94	0.27	3194.99	0.14	0.1
PG 70-28 SBS	76	269.88	466.08	2.69	2019.00	0.41	5893.90	0.08	0.8
PG 70-28 SBS	76	193.78	3083.40	1.62	3139.35	1.58	4800.83	0.15	3.2
PG 70-28 Elvaloy	70	1039.72	920.83	2.74	887.15	2.72	2113.11	0.22	0.1
PG 70-28 Elvaloy	70	954.24	1067.15	2.64	953.88	2.60	2181.73	0.21	0.8
PG 70-28 Elvaloy	70	784.06	1230.33	2.50	1323.82	2.38	2522.91	0.18	3.2

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



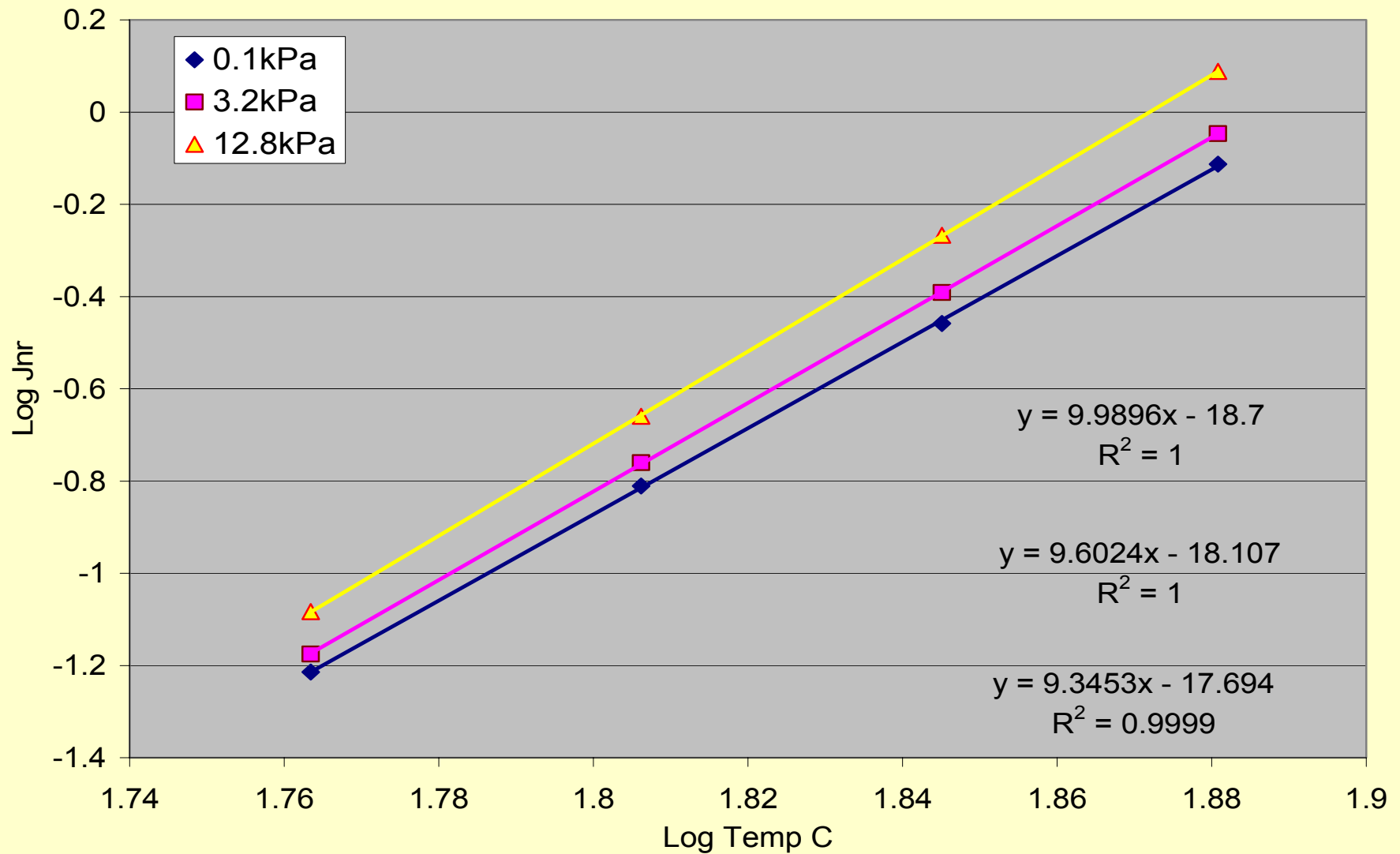
Evaluation of Straight run binders

Sample ID	Name	Grade	true grade	Temp	Jnr 3.2kPa
ALF 6727	Control	70-22	72.7-74.2	72.7	4.39
BBRS3	straight	64-22	66.1-27.3	66.1	4.18
MN county rd 112	neat Valero	58-28	60.8-33.4	60.8	3.68
MN county rd 112	neat Citgo	58-28	59.5-29.8	59.5	5.30
MN county rd 112	AshlandM	58-28	60.7-31.4	60.7	4.30
Minn Road	straight	58-28	61.8-30.8	61.8	3.03
Miss I-55	CSL	67-22	68.3-25.1	68.3	2.67
Shandong	straight	64-22	64.4-23.5	64.4	4.44
BBRS3	straight	70-22	71.4-24.8	71.4	4.81
BBRS3	straight	58-28	61.3-30	61.3	4.00
MD project	straight	64-28	64.8-29.6	64.8	4.59
average					4.13

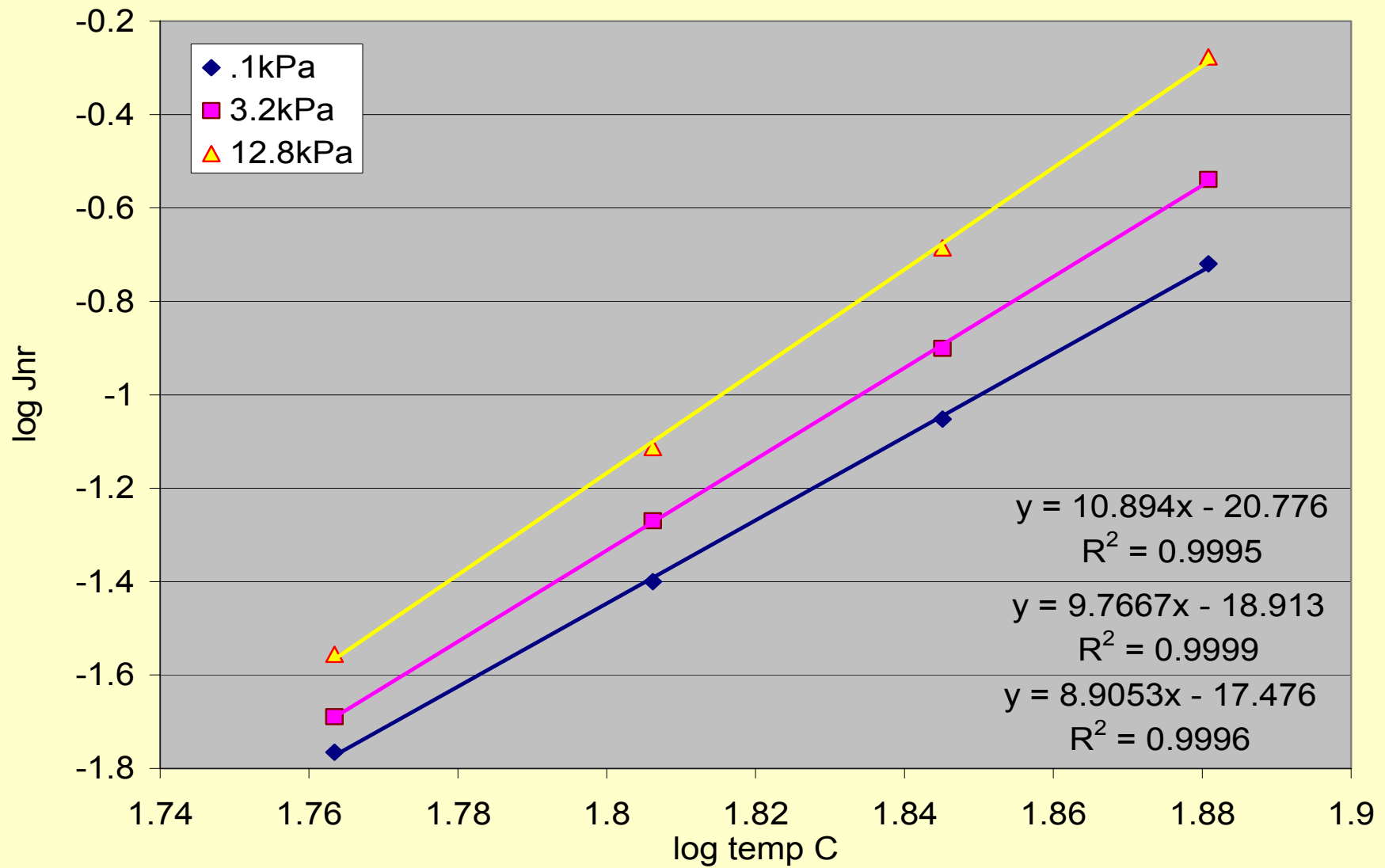
Grade Bumping

- In SHRP grade bumping is done by increasing the test temp. and assuming that one time temperature shift function is good for all binders, 6°C change will double or half the stiffness. Does this work for all binders, polymers?

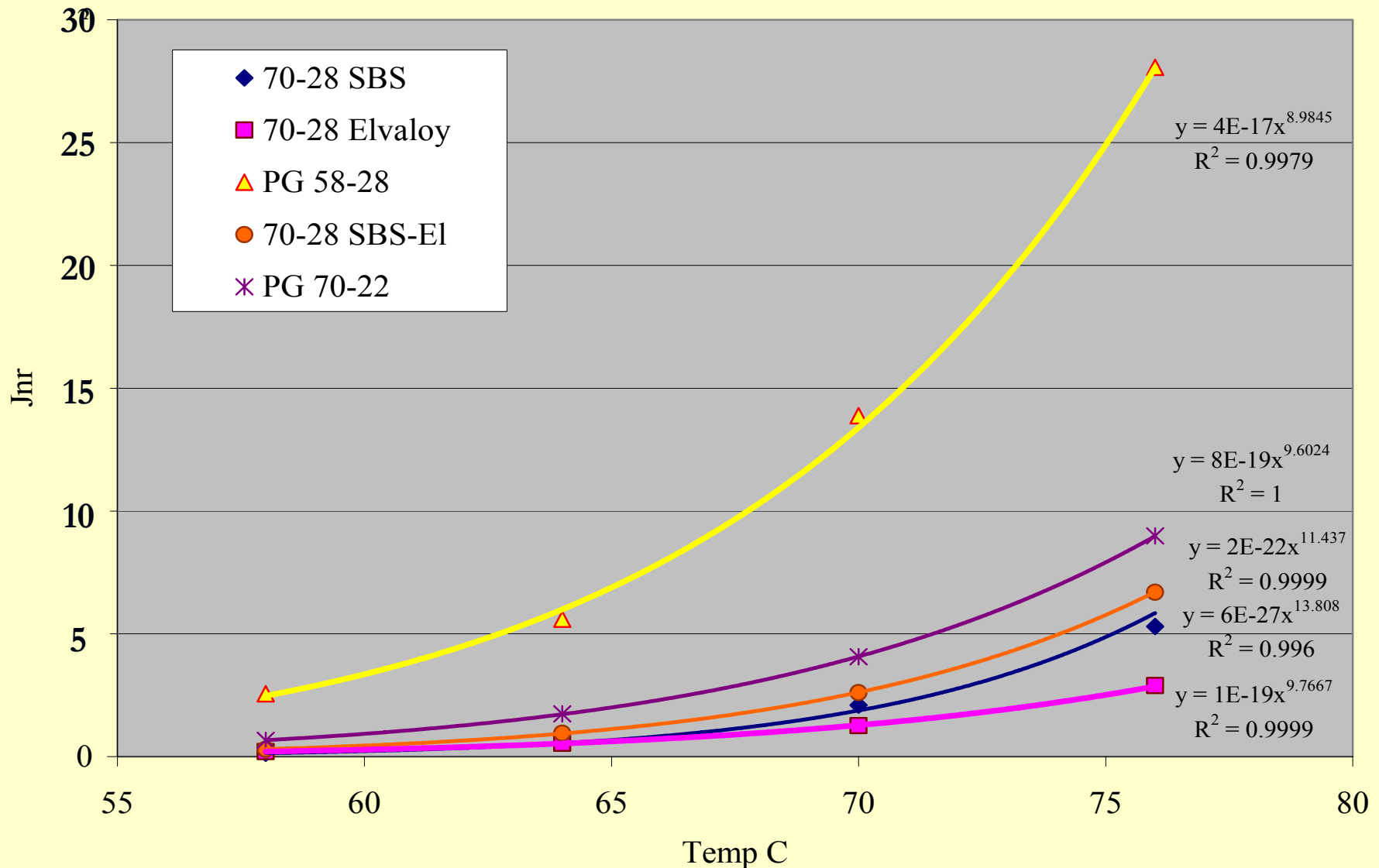
Temp sensitivity of PG70-22 Neat



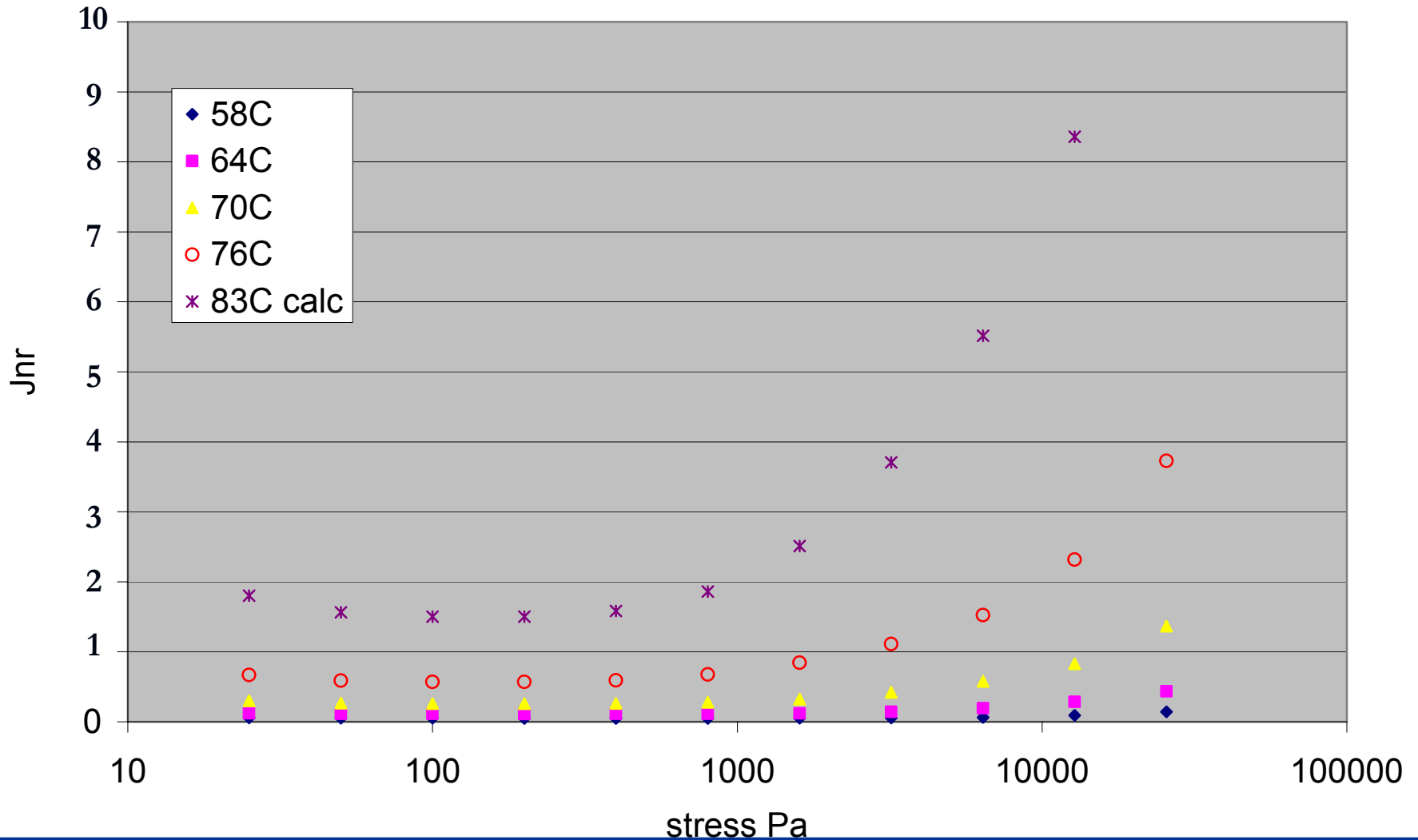
Temp sensitivity of PG70-28 Elvaloy



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 J_{nr} value of existing neat binders 0.4 .
- For high traffic the J_{nr} value should be reduced by half at the grade temp to 0.2 .
- For standing traffic the J_{nr} 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 $J_{nr} \leq 4.0$
 - PG 64H-XX $J_{nr} \leq 2.0$
 - PG 64V-XX $J_{nr} \leq 1.0$

New MSCR Binder Spec

Original					
DSR $G^*/\sin\delta$ 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 $G^*\sin\delta$ Max 5000	28	25	22	19	16
H & V grade DSR $G^*\sin\delta$ Max 6000	28	25	22	19	16

Low temp BBR and DTT remain unchanged

MSCR vs. PG Properties

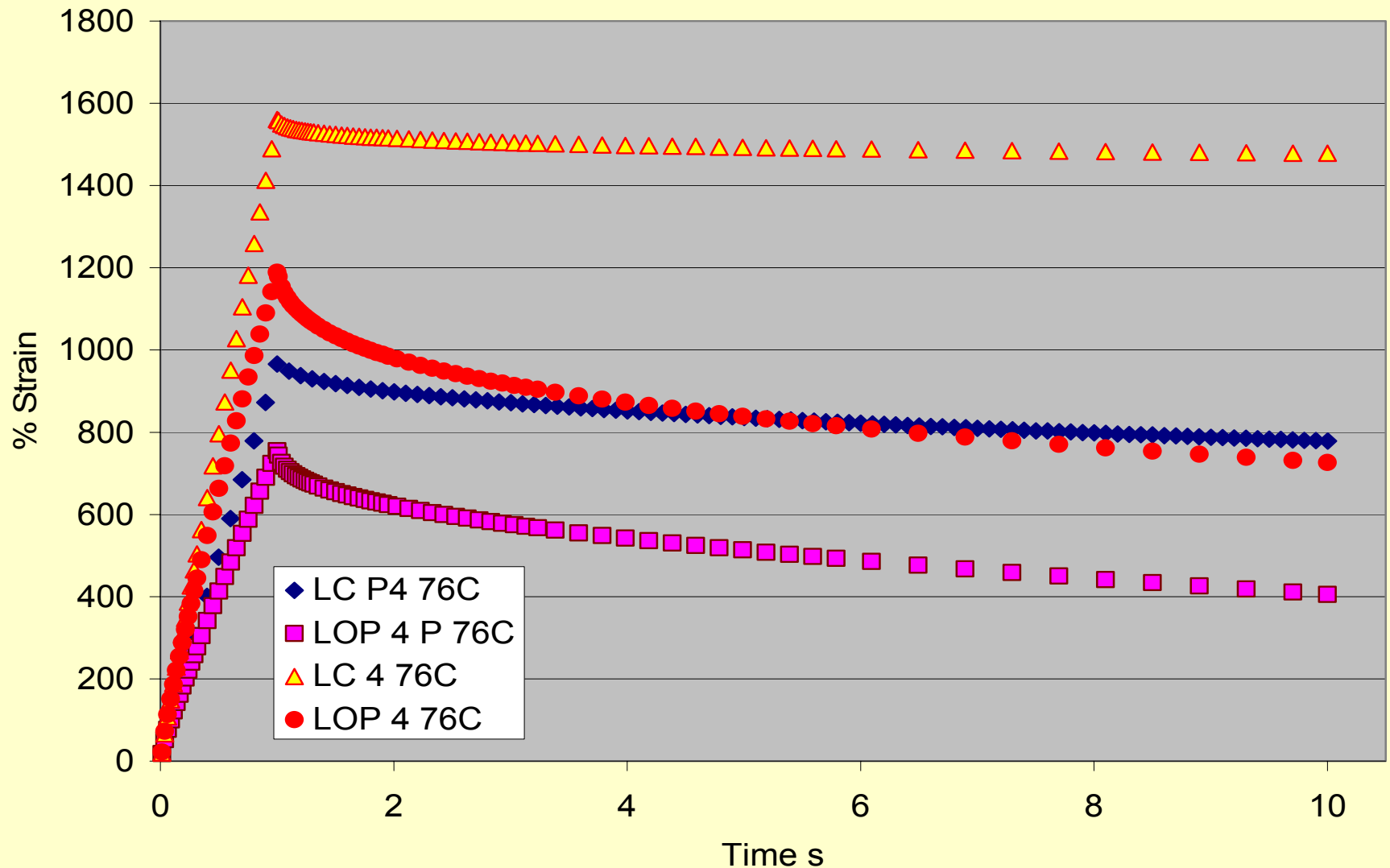
(WIS DOT, 2007, 1st Quarter Data)

Property		# Participants	% Recovery				
			Avg	SD	CV	High	Low
MSCR _{64°C}	100 Pa	41	69.84	4.66	6.68	83.5	63.3
	3,200 Pa		63.39	4.03	6.36	73.6	56.6
Rotational Viscosity _{135°C}	Pa•s	43	Viscosity				
			0.78	0.038	5.58	0.858	0.637
ODSR _{64°C}	kPa	43	G* / sinδ				
			1.28	0.038	2.96	1.34	1.22
RDSR _{64°C}	kPa	43	2.64	0.148	5.61	3.05	2.33
PAV DSR _{19°C}	kPa	43	G* • sinδ				
			1,597	173.6	10.87	2,043	1,257
Mass Loss _{163°C}	%	43	-0.520	0.134	25.78	-0.705	-0.299
BBR – S	MPa	43	226	11.74	5.202	245	189
BBR – m	--	43	0.327	0.007	2.030	0.337	0.309

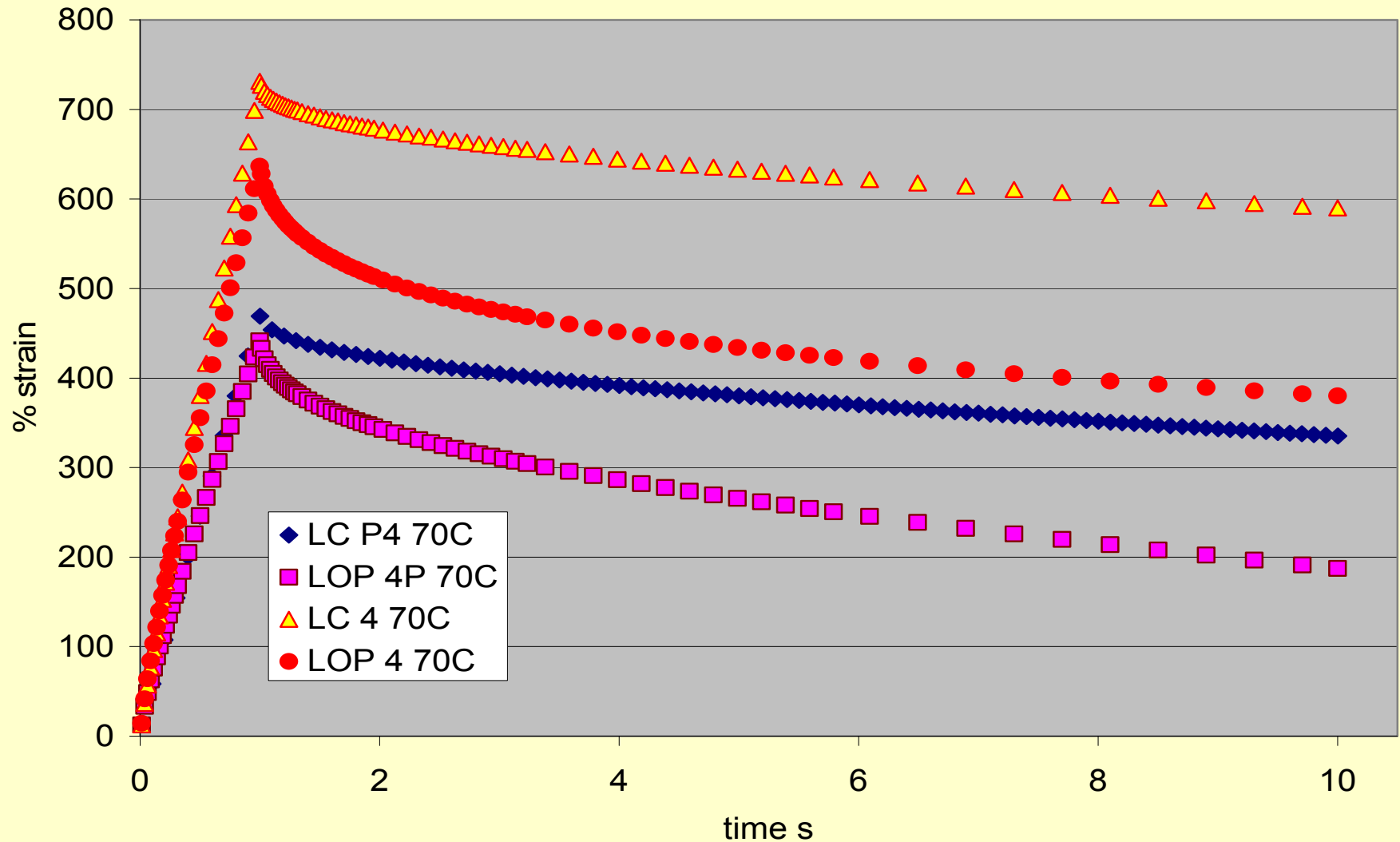
WTCG Round Robin 8 labs

			DUCT. - 4 C - 5 CM/MIN	RES DUCT - 4 C - 5 CM/MIN	ELASTIC - RECOVERY - 25 C	CREEP RECOVERY % @ 100	CREEP RECOVERY % @ 3200
	TOUGHNESS	TENACITY					
AVERAGE	169	155	63.57	27.45	79.63	54.38	37.91
MAXIMUM	236	248	83.00	34.00	86.00	59.50	41.80
MINIMUM	236	97	55.00	21.00	75.00	50.82	34.31
RANGE	122	151	28.00	13.00	11.00	8.68	7.49
STANDAR	35.08	41.88	8.66	2.98	2.89	3.40	2.89

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	3.12	5	0
LC 4	75.7-22.3	4% SBS	0	70C	1.85	73.8	19.2
				76C	4.55		5.96
LC P4	81.2-22.2	4% SBS	0.50%	70C	1.06	93.8	28.4
				76C	2.40		20.55
LOP 4	76.6-25.2	4% SBS from Concentrate	0	70C	1.18	86	40.3
				76C	2.35		37.02
LOP 4P	81.6-24.5	4% SBS from Concentrate	0.50%	70C	0.67	83	52.05
				76C	1.38		42.52

Fluorescence Micro-graphs at 250 magnification

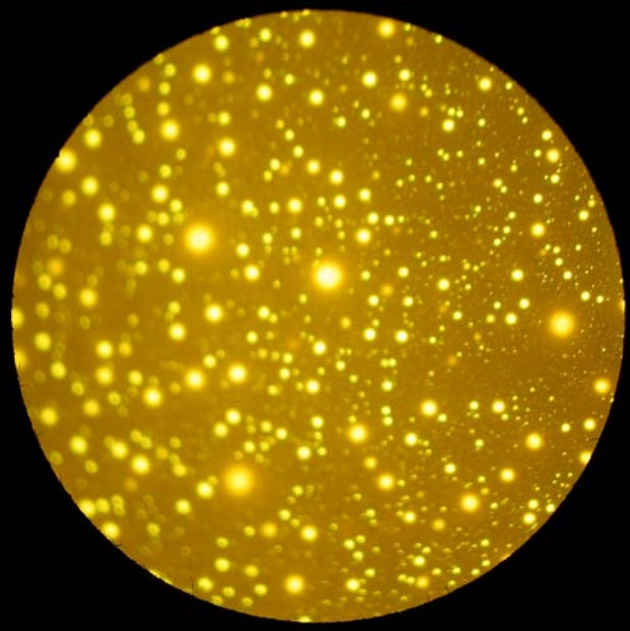
LC 4

LC 4P

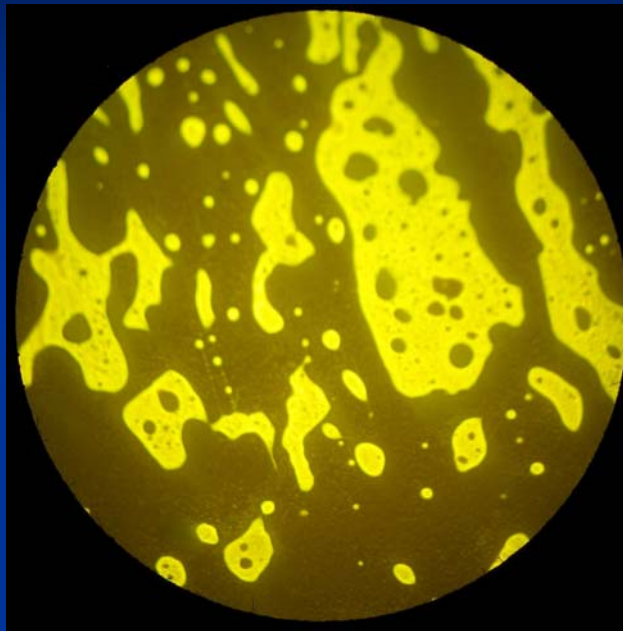
LOP 4

LOP 4P

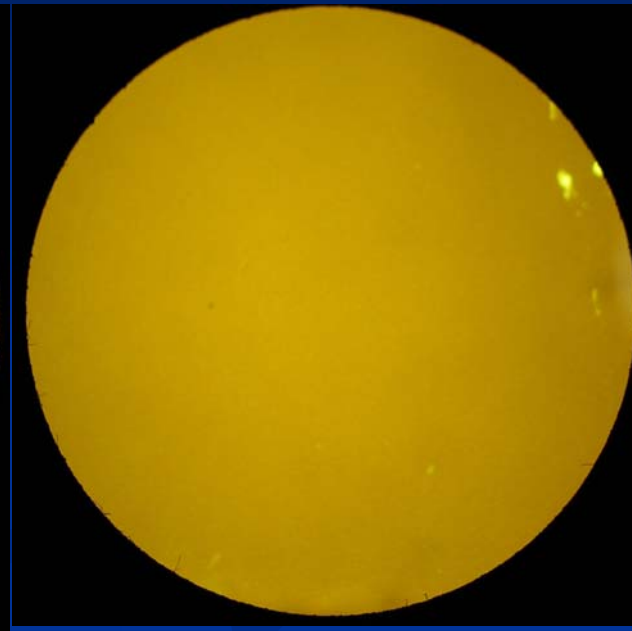
More Micrographs



**CAN 3%
annealed**

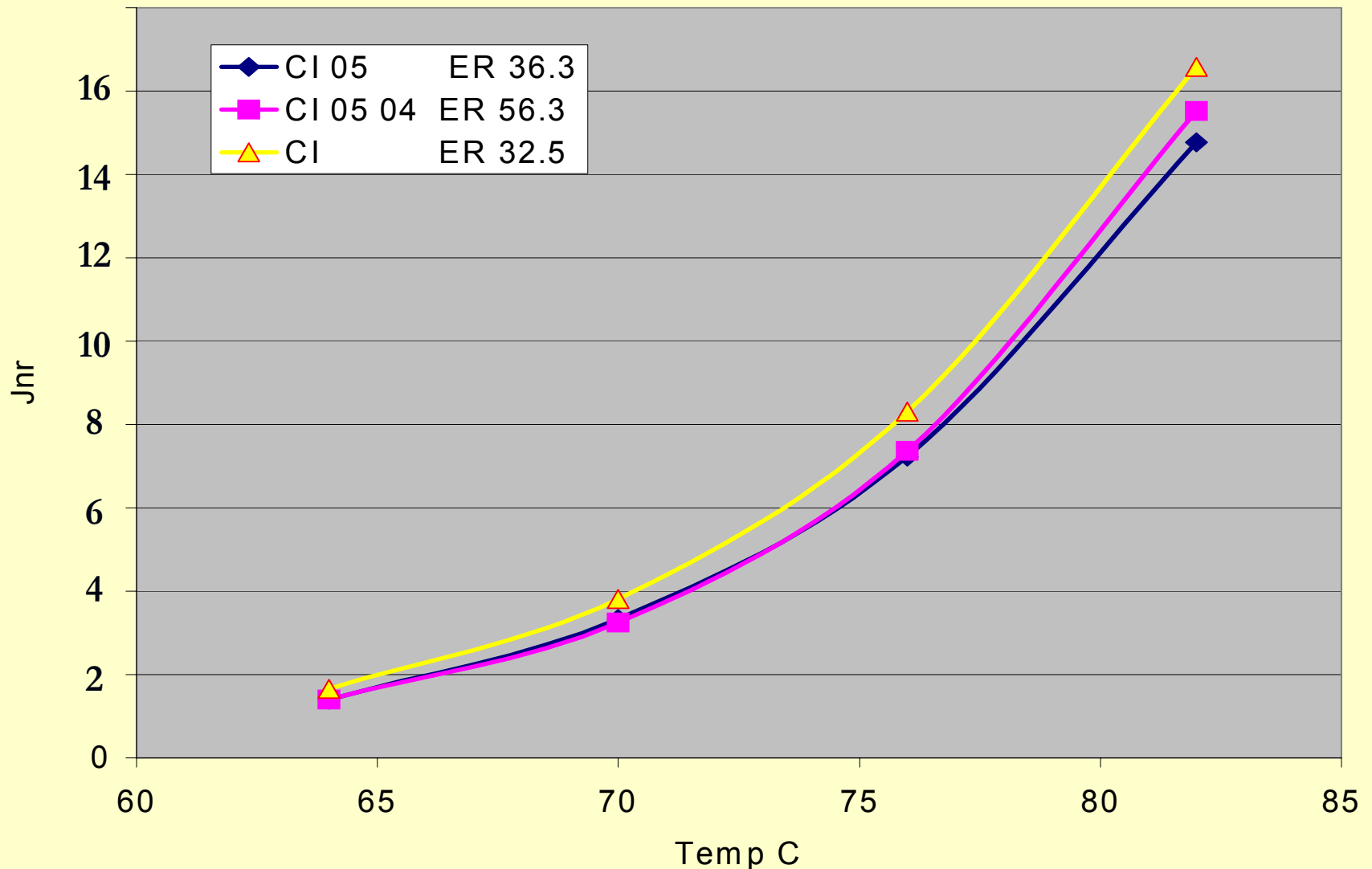


**MIDCON 3%
annealed**

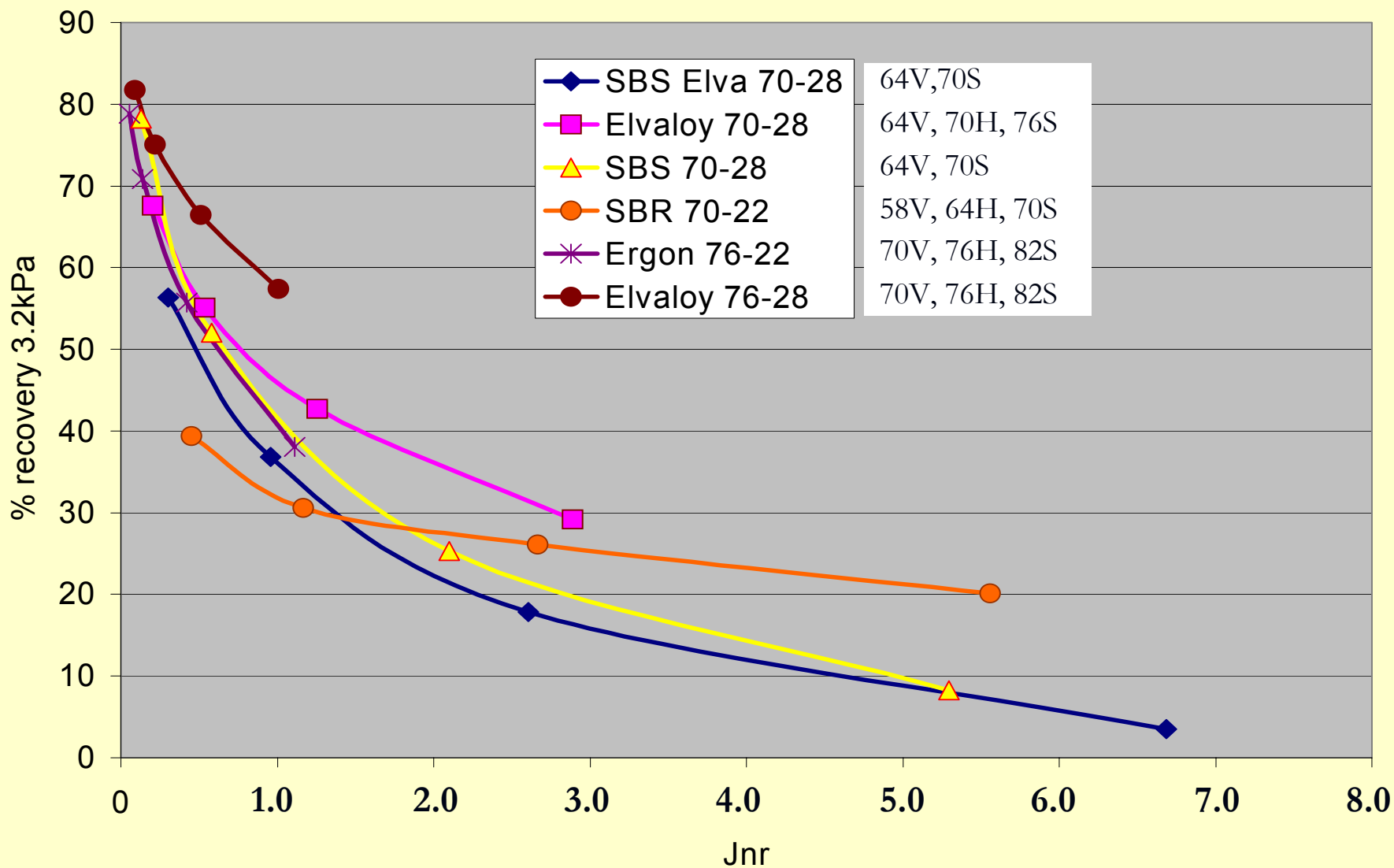


**CAN 3% + S
annealed**

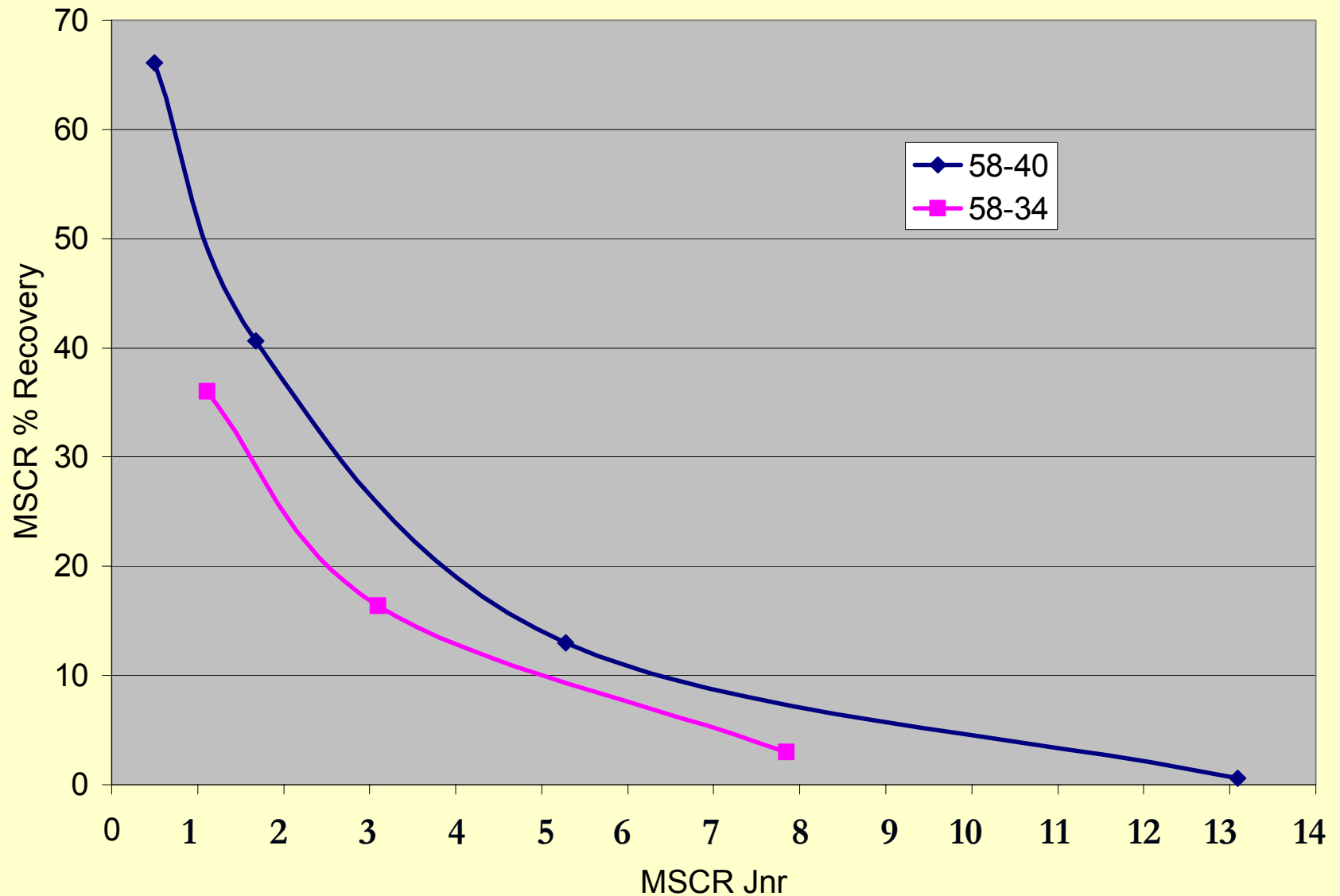
Effect of X-linking on ER



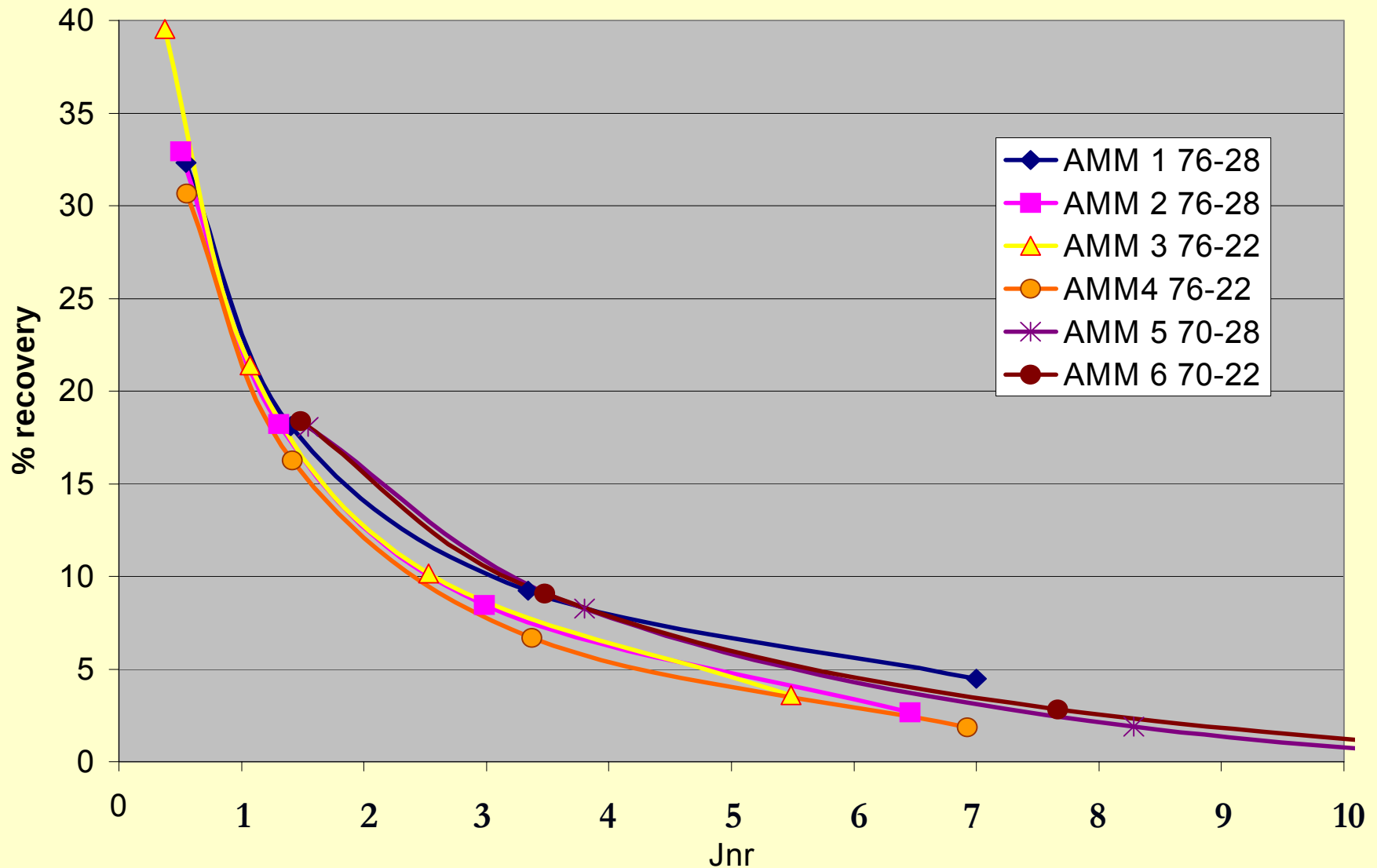
BRRS Study



MinnRoad Study



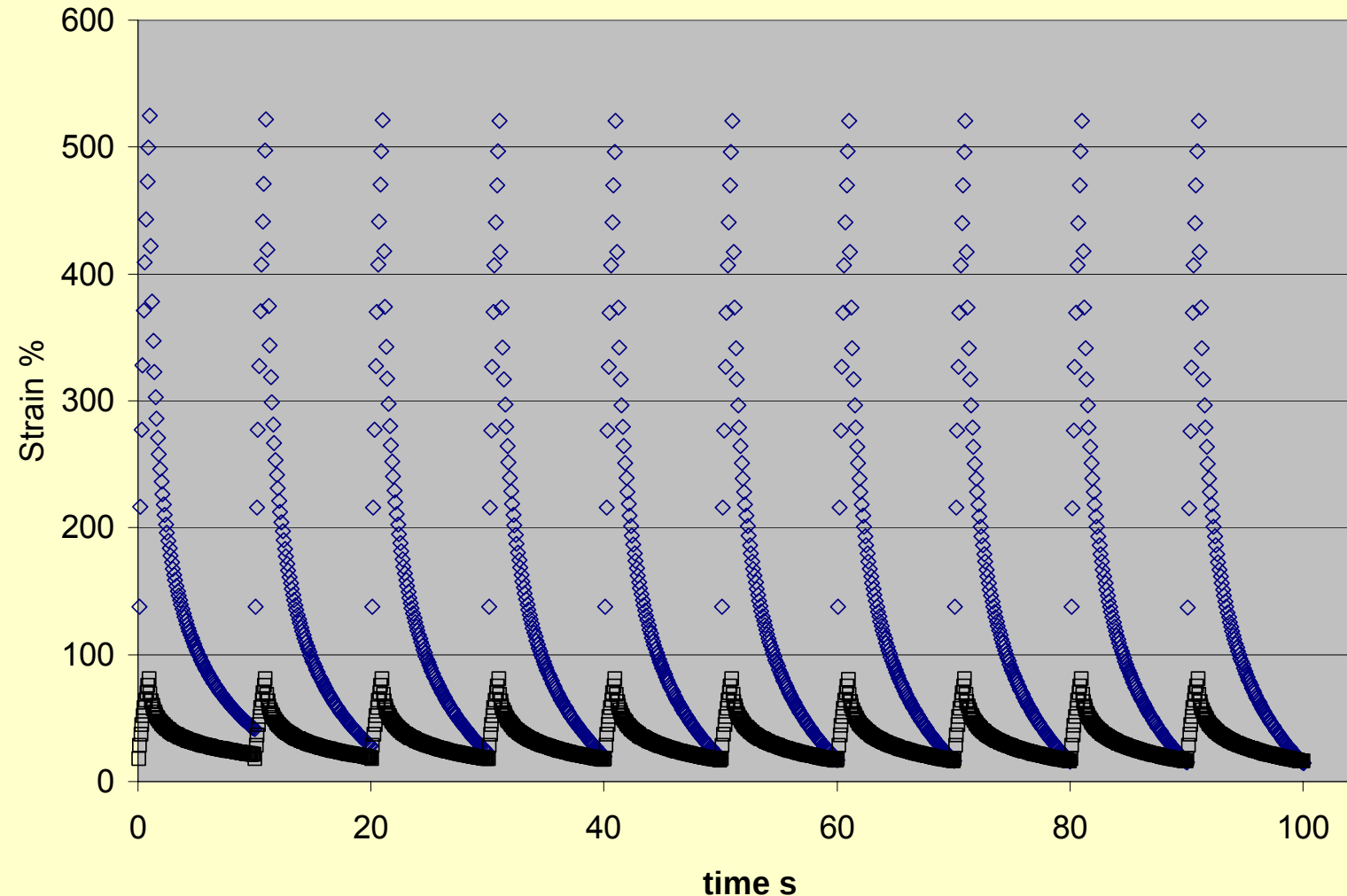
Crumb Rubber study



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 same Jnr
0.06

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 J_{nr} 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