Asphalt Institute Modified Asphalt Binder Research Activities

Mike Anderson

Association of Modified Asphalt Producers Annual Meeting
February 18-20, 2013
New Orleans, LA

Acknowledgments

- DTFH61-08-H-00030 and DTFH61-11-H-00033
  - Cooperative Agreements between the FHWA and the Asphalt Institute
  - John Bukowski, AOTR
  - Michael Arasteh, AOTR
- Member Companies of the Asphalt Institute
  - Technical Advisory Committee

Modified Asphalt Binder Research Activities

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- Modified Asphalt Binder Research Activities
  - MSCR
  - Linear Amplitude Sweep (LAS)
  - Mixing and Compaction Temperatures
  - Laboratory Performance of Mixtures Containing RAP and Modified Asphalt Binders

Precision of the MSCR and Commonly-Used PG-Plus Tests: PCCAS Interlaboratory Study

Mike Anderson

PCCAS Binder Committee Meeting

1 October 2013

Reno, NV

Test Procedure – AASHTO TP70

- Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
  - Shear Stress Levels
    - 0.1 kPa
    - 3.2 kPa
  - Output
    - Recovery
    - Jnr
    - Stress Sensitivity (Jnr-Diff)

Test Procedures – PG-Plus Tests

- Elastic Recovery
  - AASHTO T301
  - Output
    - Calculated Recovery at 25°C
- Ring & Ball Softening Point
  - AASHTO T53
  - Output
    - Average Temperature

Test Procedures – PG-Plus Tests

- Ductility
  - AASHTO T51
  - Original and RTFO-aged Binder
  - Output
    - Measured Ductility at 4°C
- Toughness & Tenacity
  - ASTM D5801
  - Output
    - Toughness and Tenacity at 25°C

2013 PCCAS ILS

- Sixteen (16) Labs
  - 8 Users
  - 5 Producers
  - 3 Others

2013 PCCAS ILS

- Five Asphalt Binders
  - PG 76-28 (Binder A)
  - PG 70-22ER (Binder B)
  - PG 64-28NV (Binder C)
  - PG 64-28PM (Binder D)
  - PG 58-34PM (Binder E)
- Two RTFO-Aged Binders (MSCR-only)
  - Aged by Asphalt Institute
    - PG 76-28 (Binder A-AI)
    - PG 58-34 (Binder E-AI)

2013 PCCAS ILS

- Testing Program
  - Randomized test sequence
    - Three replicate tests for each asphalt binder/test temperature (MSCR only)
  - Technicians
    - Familiar with test
    - Prefer one technician for each of three replicates
      - Can use second technician for different asphalt binder

2013 PCCAS ILS

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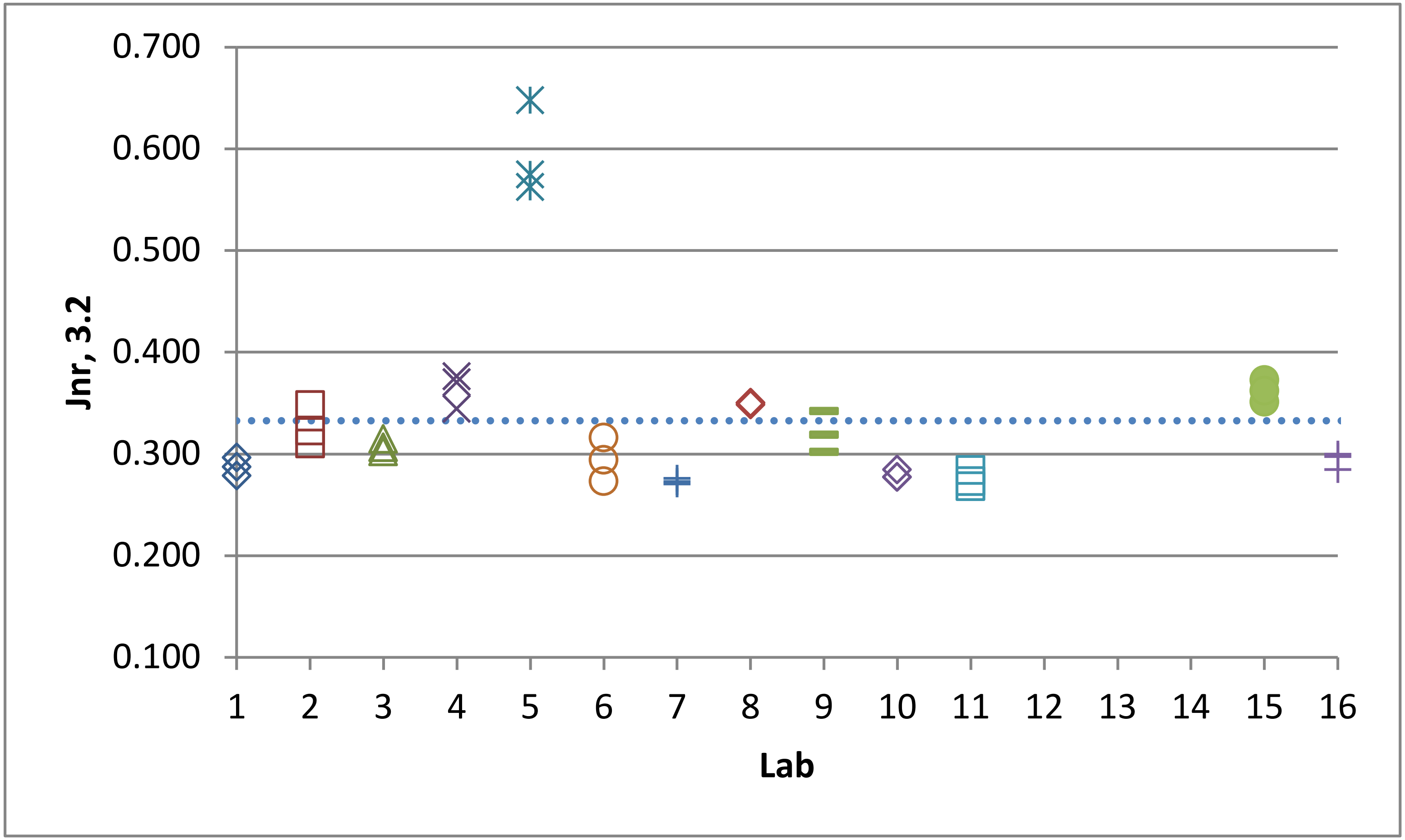
	MSCR	ER	R&B SP	Ductility (O)	Ductility (R)	T&T
Binder A	64	25				
Binder A-AI	64					
Binder B	64,70	25				
Binder C	58,64			4	4	25
Binder D	58,64	25	x			25
Binder E	58	25	x			25
Binder E-AI	58					

MSCR, ER tests performed on RTFO-aged binder
R&B Softening Point, Toughness and Tenacity tests performed on original binder
Ductility tests performed on both original and RTFO-aged binder

Binder B (PG 70-22ER): Jnr-3.2 at 64°C (all data)



Consistency Analysis

- Purpose
  - Identify potential outliers in data set
    - Reproducibility
    - “h” value
  - Identify inconsistency within testing lab
    - Repeatability
    - “k” value

Consistency Analysis

h

Critical Value = 2.49		2.44	2.41	2.38	2.49	2.41	2.49	2.41

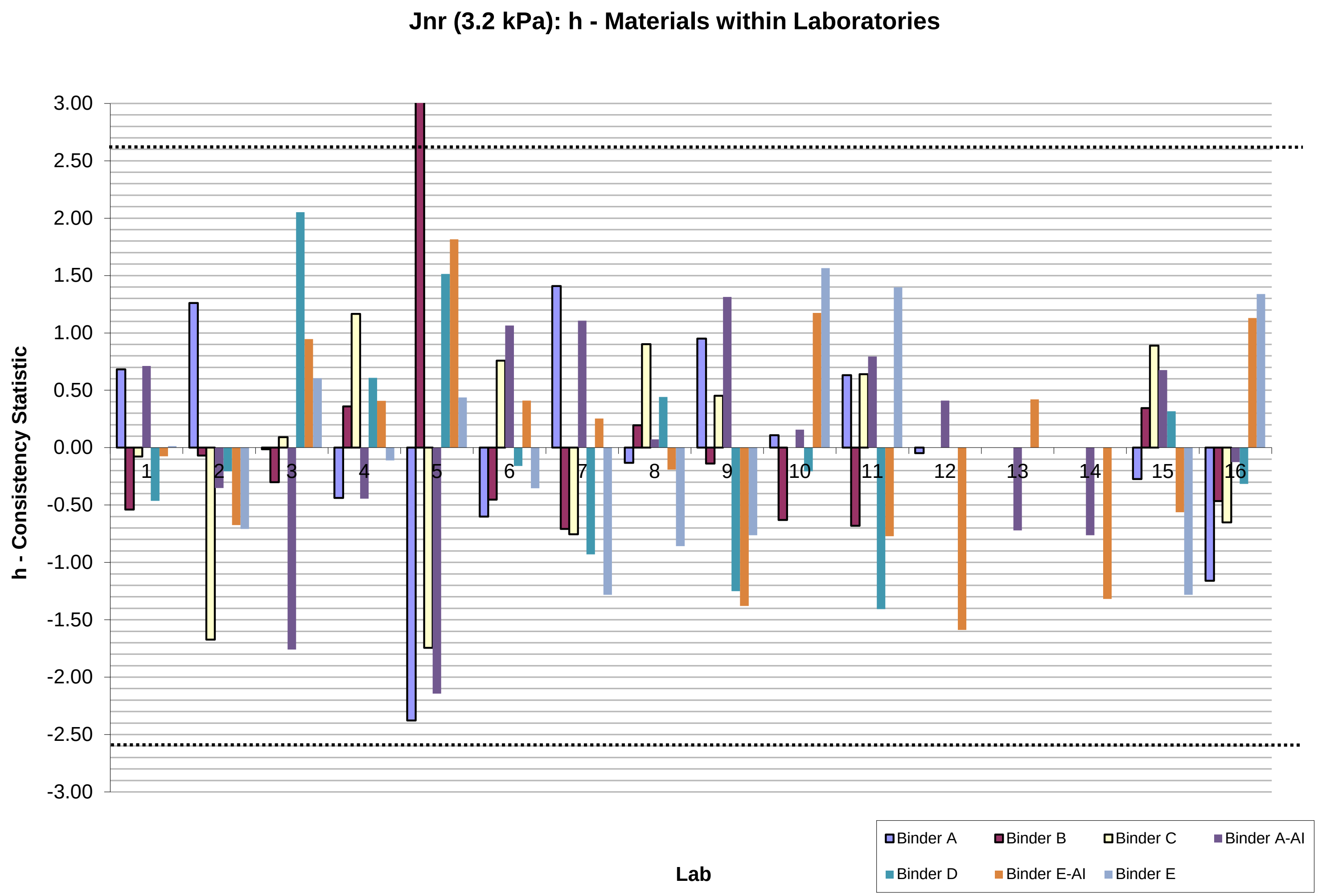
Jnr (3.2 kPa)

Lab No.	Lab Name	Material Binder A	Binder B	Binder C	Binder A-AI	Binder D	Binder E-AI	Binder E
1		0.68	-0.54	-0.08	0.71	-0.46	-0.07	0.01
2		1.26	-0.07	-1.67	-0.35	-0.20	-0.67	-0.71
3		-0.01	-0.30	0.09	-1.76	2.05	0.95	0.60
4		-0.44	0.36	1.17	-0.44	0.61	0.41	-0.11
5		-2.38	3.09	-1.74	-2.14	1.51	1.82	0.44
6		-0.60	-0.45	0.76	1.06	-0.16	0.41	-0.35
7		1.41	-0.71	-0.75	1.11	-0.93	0.25	-1.28
8		-0.13	0.20	0.90	0.07	0.44	-0.19	-0.86
9		0.95	-0.14	0.45	1.31	-1.25	-1.38	-0.76
10		0.11	-0.63		0.16	-0.20	1.17	1.57
11		0.63	-0.68	0.64	0.80	-1.41	-0.77	1.40
12		-0.05			0.41		-1.59	
13					-0.72		0.42	
14					-0.76		-1.32	
15		-0.27	0.34	0.89	0.68	0.32	-0.56	-1.28
16		-1.16	-0.47	-0.65	-0.12	-0.32	1.13	1.34
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								

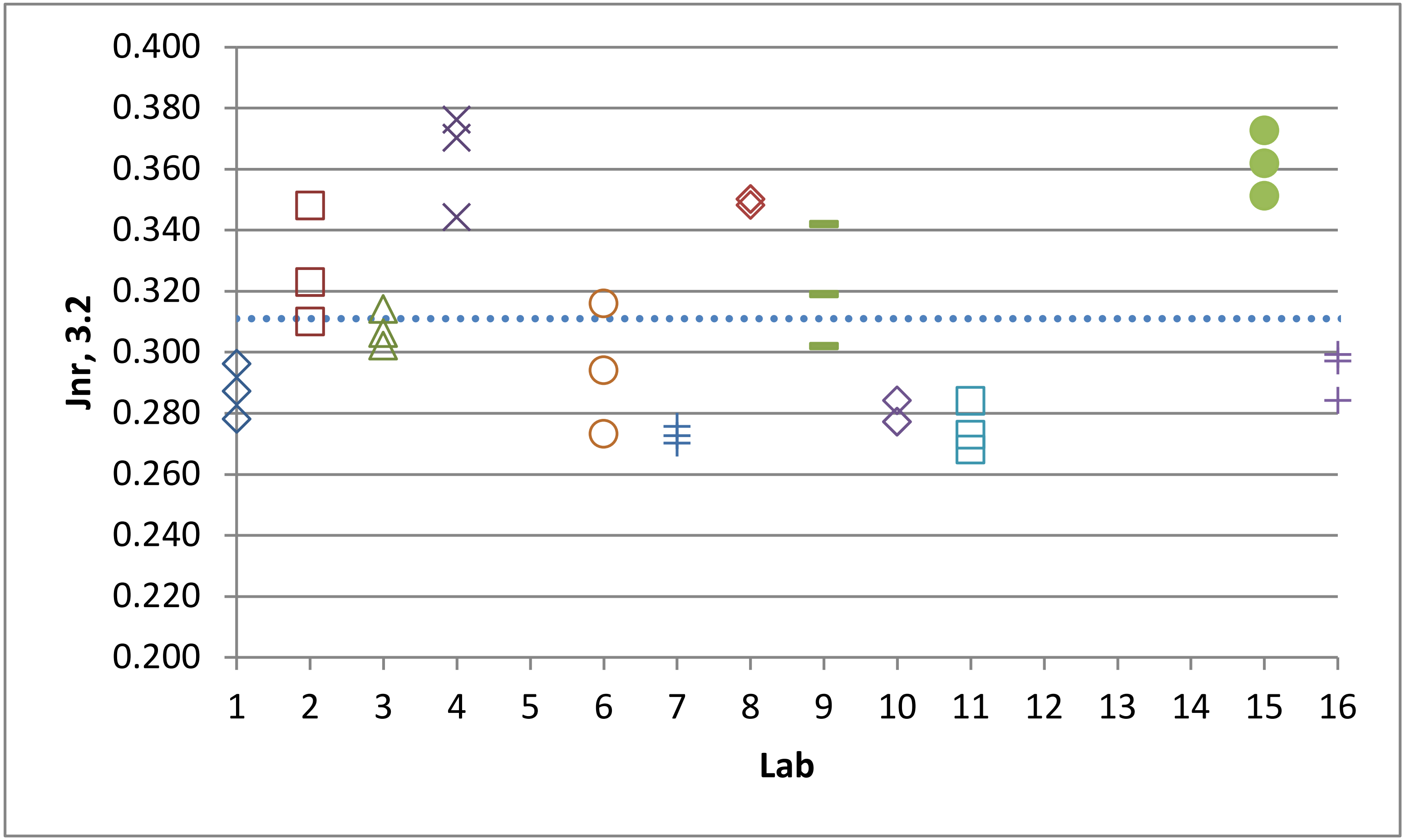
exceeds h

exceeds h-0.5

Consistency Analysis



Binder B (PG 70-22ER): Jnr-3.2 at 64°C (outlier removed)



Effect on Repeatability (r) and Reproducibility (R)?

Binder B: Jnr-3.2	w/ Lab 5	w/o Lab 5
Average	0.333	0.311
1s (within lab)	0.018	0.013
d2s (within lab)	0.049	0.035
d2s% (within lab)	14.8%	11.4%
1s (between labs)	0.086	0.035
d2s (between labs)	0.241	0.097
d2s% (between labs)	72.3%	31.3%

Outlier Analysis: Excluded Labs

Binder	Labs	Jnr-0.1	Jnr-3.2	Rec-0.1	Rec-3.2	Jnr-Diff
A	14	none	none	none	Lab 5	Lab 12
A-AI	16	none	none	none	none	none
B	13	Lab 5	Lab 5	Lab 5	Lab 5	Lab 5
C	12	none	none	none	none	none
D	13	none	none	none	none	none
E	13	none	none	none	none	none
E-AI	16	Lab 12	none	Lab 12	none	Lab 12

Repeatability and Reproducibility Estimates (after removal of outliers)

Jnr (0.1 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	0.06832	0.04350	0.02345	0.04752	0.06565	0.13307	34.3%	96.1%	69.6%	194.8%
B	PG 70-22ER	0.25900	0.02498	0.00890	0.02602	0.02493	0.07285	3.4%	9.6%	10.0%	28.1%
C	PG 64-28NV	0.31328	0.04090	0.04173	0.05323	0.11684	0.14905	13.3%	37.3%	17.0%	47.6%
A-AI	PG 76-28	0.06168	0.04299	0.02722	0.04840	0.07623	0.13551	44.1%	123.6%	78.5%	219.7%
D	PG 64-28PM	0.20026	0.01718	0.00779	0.01832	0.02181	0.05128	3.9%	10.9%	9.1%	25.6%
E-AI	PG 58-34PM	0.37354	0.02659	0.02324	0.03267	0.06508	0.09148	6.2%	17.4%	8.7%	24.5%
E	PG 58-34PM	0.38778	0.06351	0.01864	0.06531	0.05220	0.18286	4.8%	13.5%	16.8%	47.2%

Repeatability and Reproducibility Estimates (after removal of outliers)

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Jnr (0.1 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	0.06832	0.04350	0.02345	0.04752	0.06565	0.13307	34.3%	96.1%	69.6%	194.8%
B	PG 70-22ER	0.25900	0.02498	0.00890	0.02602	0.02493	0.07285	3.4%	9.6%	10.0%	28.1%
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Repeatability and Reproducibility Estimates (after removal of outliers)

Jnr (0.1 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	0.06832	0.04350	0.02345	0.04752	0.06565	0.13307	34.3%	96.1%	69.6%	194.8%
B	PG 70-22ER	0.25900	0.02498	0.00890	0.02602	0.02493	0.07285	3.4%	9.6%	10.0%	28.1%
C	PG 64-28NV	0.31328	0.04090	0.04173	0.05323	0.11684	0.14905	13.3%	37.3%	17.0%	47.6%
A-AI	PG 76-28	0.06168	0.04299	0.02722	0.04840	0.07623	0.13551	44.1%	123.6%	78.5%	219.7%
D	PG 64-28PM	0.20026	0.01718	0.00779	0.01832	0.02181	0.05128	3.9%	10.9%	9.1%	25.6%
E-AI	PG 58-34PM	0.37354	0.02659	0.02324	0.03267	0.06508	0.09148	6.2%	17.4%	8.7%	24.5%
E	PG 58-34PM	0.38778	0.06351	0.01864	0.06531	0.05220	0.18286	4.8%	13.5%	16.8%	47.2%

Repeatability and Reproducibility Estimates (after removal of outliers)

Jnr (3.2 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	0.74765	0.24396	0.11529	0.26149	0.32281	0.73218	15.4%	43.2%	35.0%	97.9%
B	PG 70-22ER	0.31097	0.03317	0.01263	0.03474	0.03538	0.09727	4.1%	11.4%	11.2%	31.3%
C	PG 64-28NV	0.44802	0.06917	0.06077	0.08513	0.17016	0.23836	13.6%	38.0%	19.0%	53.2%
A-AI	PG 76-28	0.76755	0.29522	0.20365	0.33883	0.57023	0.94872	26.5%	74.3%	44.1%	123.6%
D	PG 64-28PM	0.22736	0.01803	0.00846	0.01930	0.02368	0.05405	3.7%	10.4%	8.5%	23.8%
E-AI	PG 58-34PM	0.50642	0.05447	0.03327	0.06087	0.09317	0.17043	6.6%	18.4%	12.0%	33.7%
E	PG 58-34PM	0.53192	0.07799	0.02204	0.08004	0.06172	0.22410	4.1%	11.6%	15.0%	42.1%

Repeatability and Reproducibility Estimates (after removal of outliers)

Recovery (0.1 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	88.51823	5.50877	2.31179	5.82319	6.47302	16.30492	2.6%	7.3%	6.6%	18.4%
B	PG 70-22ER	66.64153	1.81929	0.66924	1.89958	1.87386	5.31883	1.0%	2.8%	2.9%	8.0%
C	PG 64-28NV	67.89339	4.20319	3.63383	5.14490	10.17474	14.40571	5.4%	15.0%	7.6%	21.2%
A-AI	PG 76-28	90.01160	5.24616	3.22069	5.86834	9.01792	16.43134	3.6%	10.0%	6.5%	18.3%
D	PG 64-28PM	74.99253	1.06392	0.56261	1.15885	1.57531	3.24479	0.8%	2.1%	1.5%	4.3%
E-AI	PG 58-34PM	85.32803	1.12050	0.84137	1.31432	2.35582	3.68010	1.0%	2.8%	1.5%	4.3%
E	PG 58-34PM	84.95645	2.80493	0.59762	2.84706	1.67334	7.97177	0.7%	2.0%	3.4%	9.4%

Repeatability and Reproducibility Estimates (after removal of outliers)

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Recovery (3.2 kPa)

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-}bar}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	32.61388	9.77607	5.97846	10.92701	16.73969	30.59562	18.3%	51.3%	33.5%	93.8%
B	PG 70-22ER	59.69611	2.26340	0.82426	2.36134	2.30791	6.61175	1.4%	3.9%	4.0%	11.1%
C	PG 64-28NV	57.25127	5.90752	4.56446	6.98486	12.78050	19.55761	8.0%	22.3%	12.2%	34.2%
A-AI	PG 76-28	39.14691	18.39142	10.17235	20.17991	28.48257	56.50374	26.0%	72.8%	51.5%	144.3%
D	PG 64-28PM	73.10170	0.86664	0.43358	0.93616	1.21403	2.62124	0.6%	1.7%	1.3%	3.6%
E-AI	PG 58-34PM	79.78481	2.13462	0.88477	2.25355	2.47735	6.30993	1.1%	3.1%	2.8%	7.9%
E	PG 58-34PM	79.00384	3.44039	0.82022	3.50496	2.29663	9.81390	1.0%	2.9%	4.4%	12.4%

Repeatability and Reproducibility Estimates (after removal of outliers)

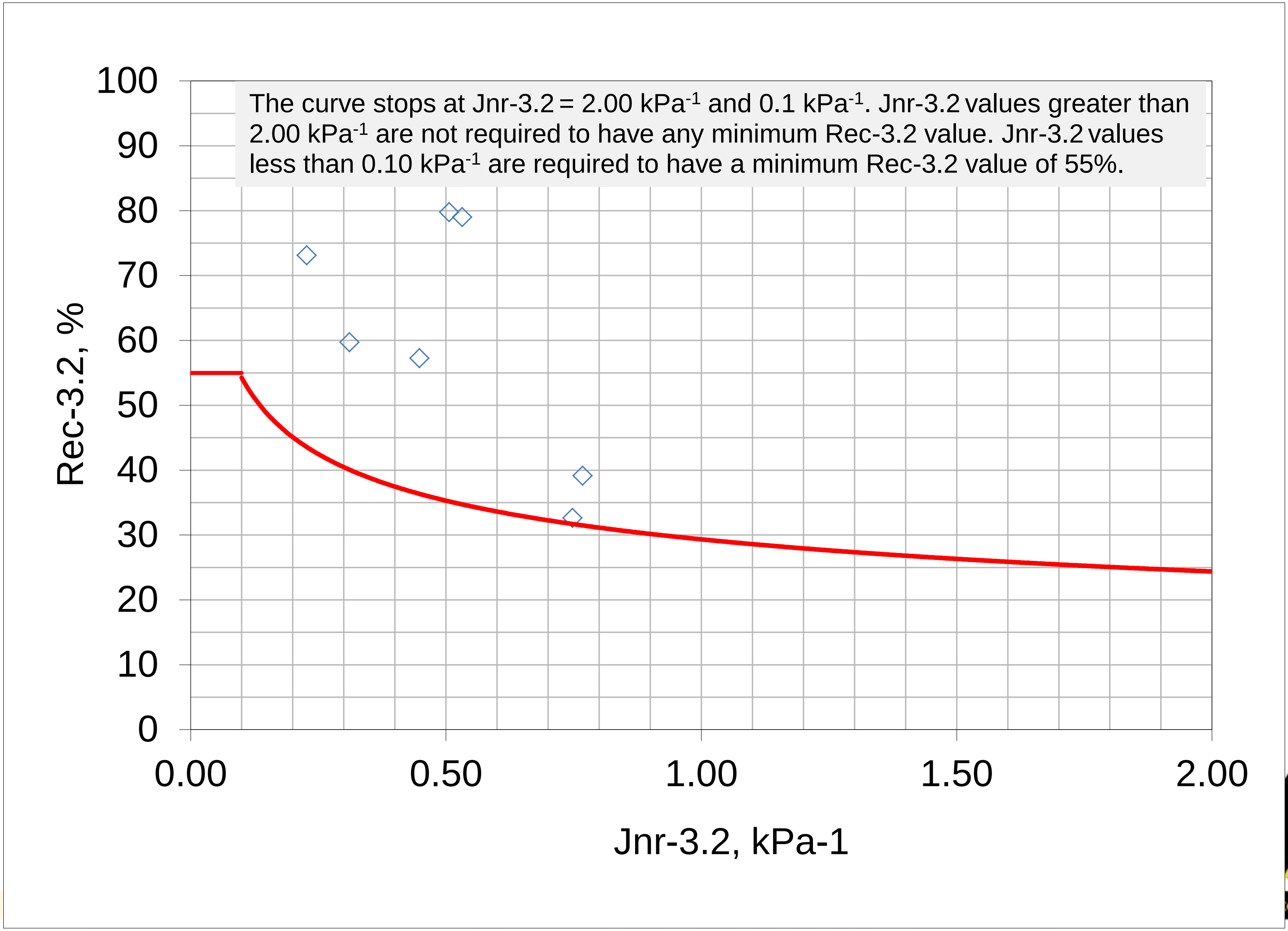
Jnr, Diff

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	1156.76130	632.87279	224.71206	658.93220	629.19376	1845.01015	19.4%	54.4%	57.0%	159.5%
B	PG 70-22ER	19.95906	2.93360	1.21229	3.09609	3.39441	8.66905	6.1%	17.0%	15.5%	43.4%
C	PG 64-28NV	42.41569	8.06038	6.32307	9.57204	17.70458	26.80171	14.9%	41.7%	22.6%	63.2%
A-AI	PG 76-28	1649.86033	1128.38420	459.16004	1189.03442	1285.64811	3329.29638	27.8%	77.9%	72.1%	201.8%
D	PG 64-28PM	13.73926	5.68585	3.47623	6.35492	9.73345	17.79377	25.3%	70.8%	46.3%	129.5%
E-AI	PG 58-34PM	37.41642	6.46850	8.16990	9.29191	22.87571	26.01735	21.8%	61.1%	24.8%	69.5%
E	PG 58-34PM	37.79233	7.18935	4.53436	8.08664	12.69621	22.64259	12.0%	33.6%	21.4%	59.9%

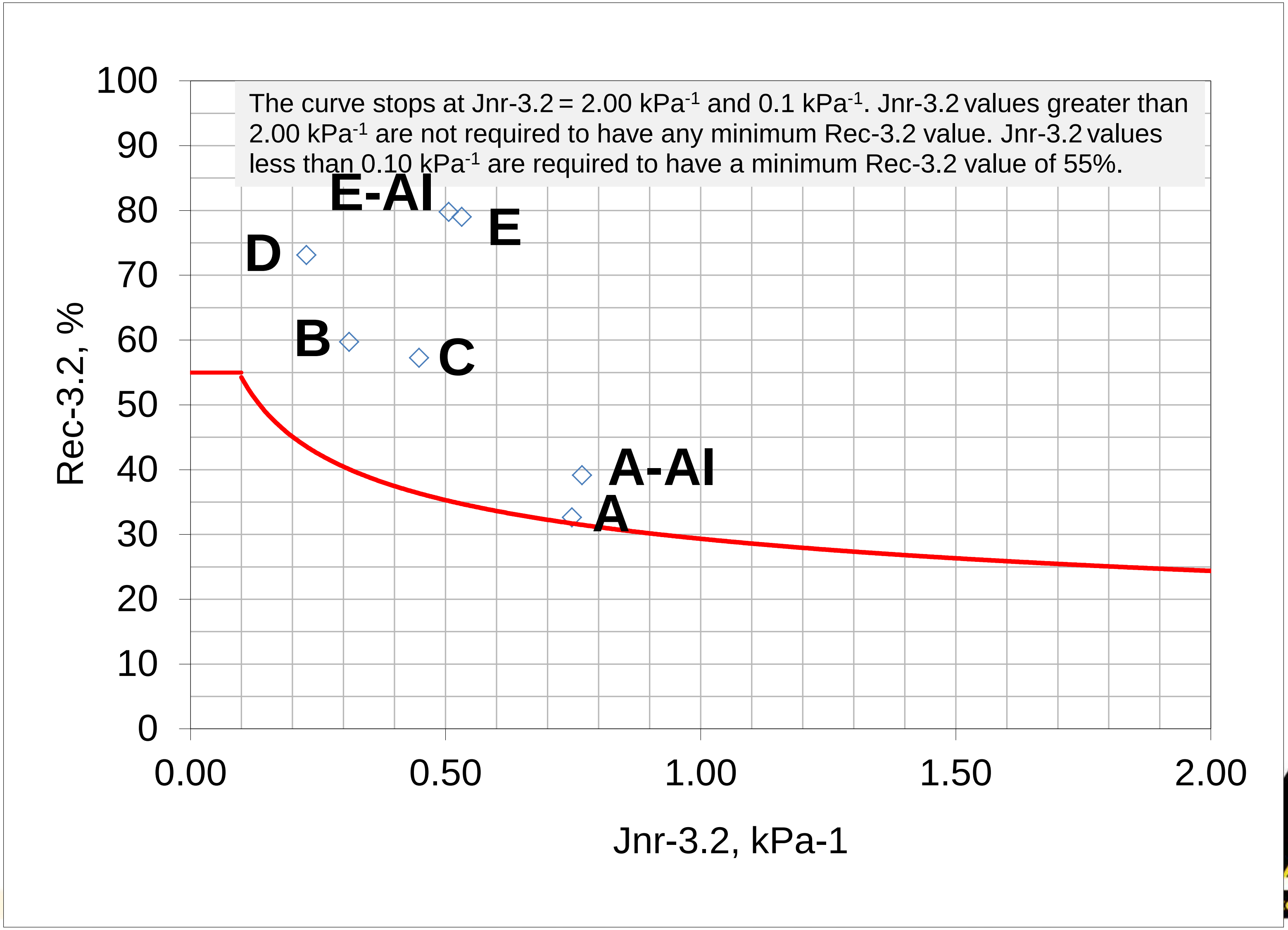
Multi-Lab Precision Estimates from AI ILS Studies

ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	13.8%	36.8%

Jnr-Recovery Curve



Jnr-Recovery Curve



Repeatability and Reproducibility Estimates (no removal of outliers)

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ER

								Repeatability		Reproducibility	
ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	1s%	d2s%	1s%	d2s%
A	PG 76-28	87.39091	5.50457	3.24948	6.11062	9.09853	17.10973	3.7%	10.4%	7.0%	19.6%
B	PG 70-22ER	78.38333	1.08960	1.24136	1.48813	3.47582	4.16678	1.6%	4.4%	1.9%	5.3%
C	PG 64-28NV										
D	PG 64-28PM	86.20909	1.13459	1.73642	1.81587	4.86197	5.08445	2.0%	5.6%	2.1%	5.9%
E	PG 58-34PM	90.69697	1.85677	0.67560	1.93698	1.89169	5.42355	0.7%	2.1%	2.1%	6.0%

11 Labs

Repeatability and Reproducibility Estimates (no removal of outliers)

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R&B Softening Point

ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	Repeatability 1s%	Repeatability d2s%	Reproducibility 1s%	Reproducibility d2s%
A	PG 76-28										
B	PG 70-22ER										
C	PG 64-28NV										
D	PG 64-28PM	138.71000	3.24037	1.65690	3.51144	4.63933	9.83204	1.2%	3.3%	2.5%	7.1%
E	PG 58-34PM	187.02963	5.47452	1.47020	5.60459	4.11655	15.69284	0.8%	2.2%	3.0%	8.4%

10 (9) Labs

Toughness

ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	Repeatability 1s%	Repeatability d2s%	Reproducibility 1s%	Reproducibility d2s%
A	PG 76-28										
B	PG 70-22ER										
C	PG 64-28NV	81.19333	8.75263	7.93881	10.89151	22.22866	30.49623	9.8%	27.4%	13.4%	37.6%
D	PG 64-28PM	128.96667	27.55502	5.04090	27.86071	14.11452	78.01000	3.9%	10.9%	21.6%	60.5%
E	PG 58-34PM	79.77333	8.58543	3.31803	9.00273	9.29049	25.20766	4.2%	11.6%	11.3%	31.6%

5 Labs

Repeatability and Reproducibility Estimates (no removal of outliers)

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Ductility (O)

ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	Repeatability 1s%	Repeatability d2s%	Reproducibility 1s%	Reproducibility d2s%
A	PG 76-28										
B	PG 70-22ER										
C	PG 64-28NV	91.41667	24.00560	5.85051	24.47627	16.38142	68.53357	6.4%	17.9%	26.8%	75.0%
D	PG 64-28PM										
E	PG 58-34PM										

10 Labs

Ductility (R)

ID	Binder	X-bar	$s_{X\text{-bar}}$	s_r	s_R	r	R	Repeatability 1s%	Repeatability d2s%	Reproducibility 1s%	Reproducibility d2s%
A	PG 76-28										
B	PG 70-22ER										
C	PG 64-28NV	49.67407	16.63203	3.45878	16.87009	9.68458	47.23624	7.0%	19.5%	34.0%	95.1%
D	PG 64-28PM										
E	PG 58-34PM										

9 Labs

2013 PCCAS ILS

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	MSCR Rec-3.2	ER	R&B SP	Ductility (O)	Ductility (R)	T&T Toughness
Binder A	32.6	87.4				
Binder A-AI	39.1					
Binder B	59.7	78.4				
Binder C	57.3			91.4	49.7	81.2
Binder D	73.1	86.2	138.7			129.0
Binder E	79.0	90.7	187.0			79.8
Binder E-AI	79.8					

MSCR, ER tests performed on RTFO-aged binder
R&B Softening Point, Toughness and Tenacity tests performed on original binder
Ductility tests performed on both original and RTFO-aged binder

Binder A-AI: Jnr-0.1

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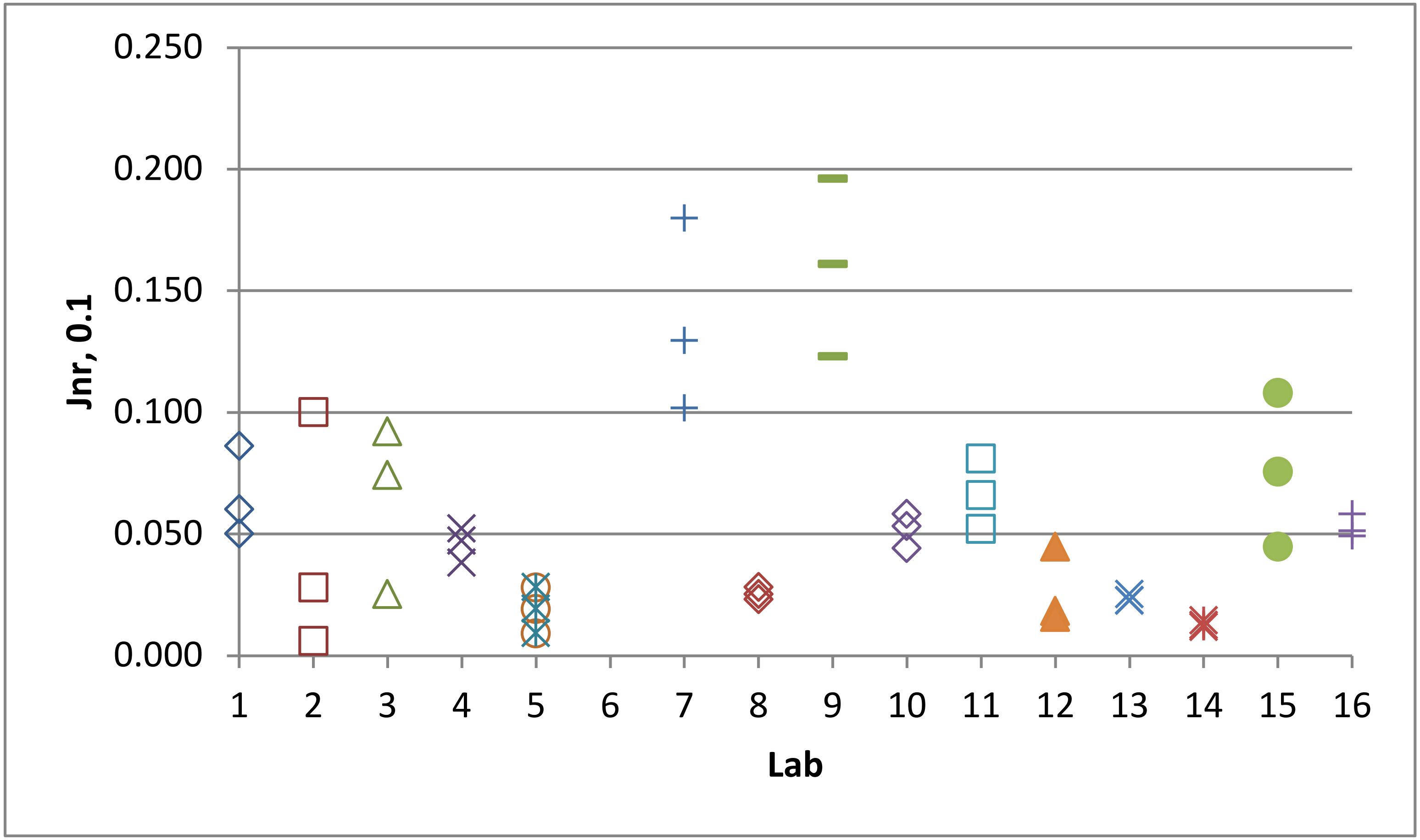

Binder A-AI: Rec-0.1

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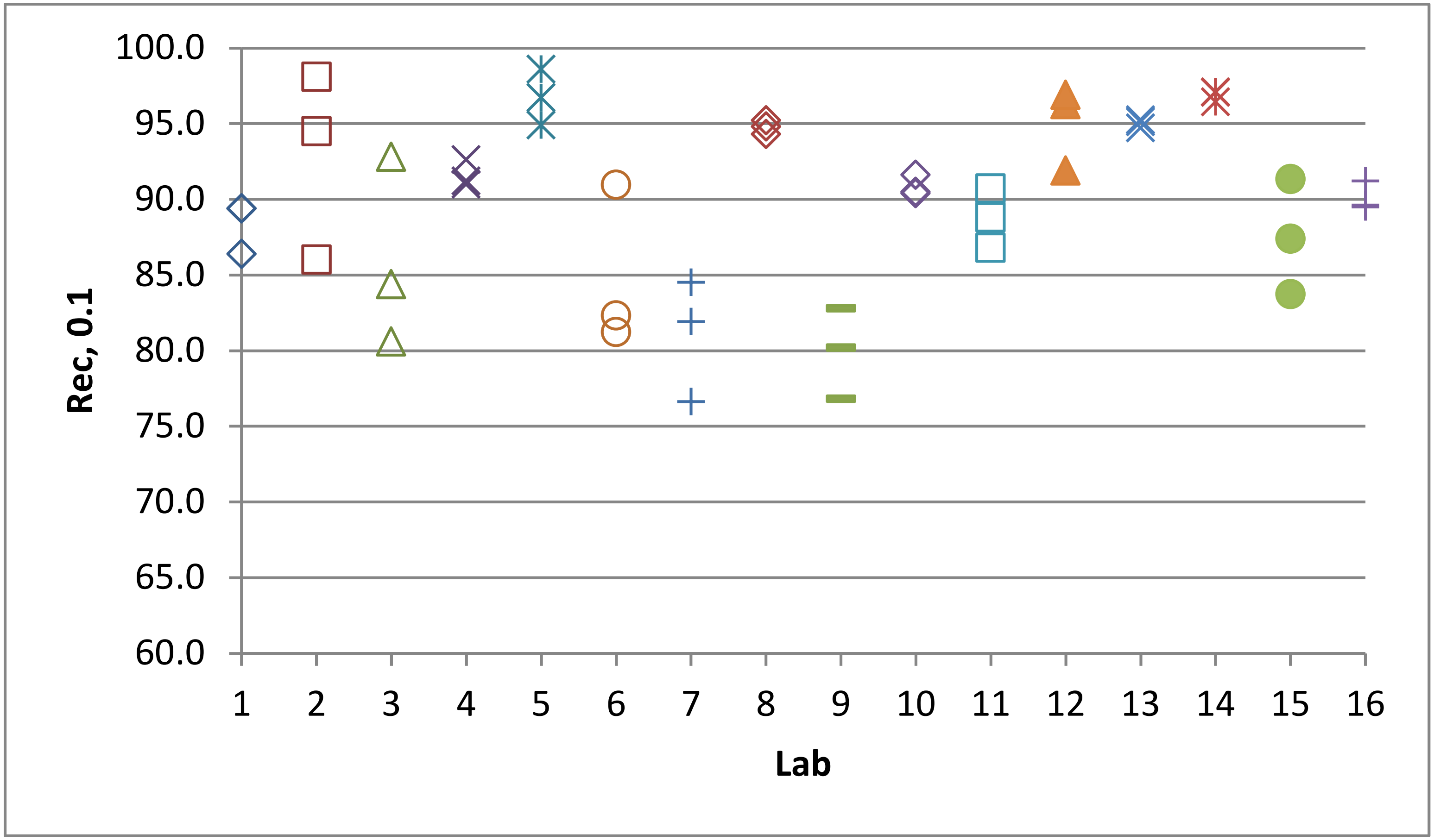
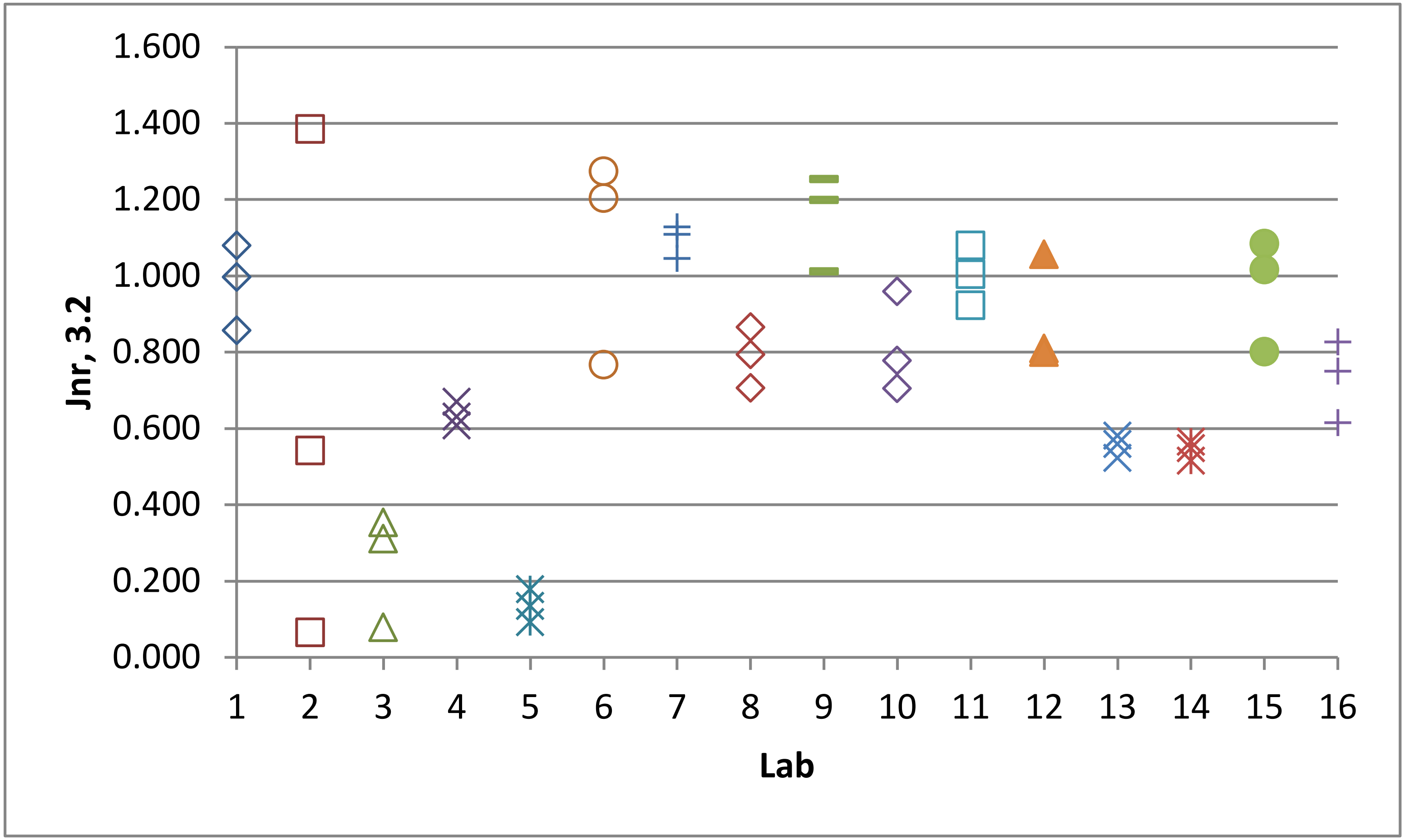
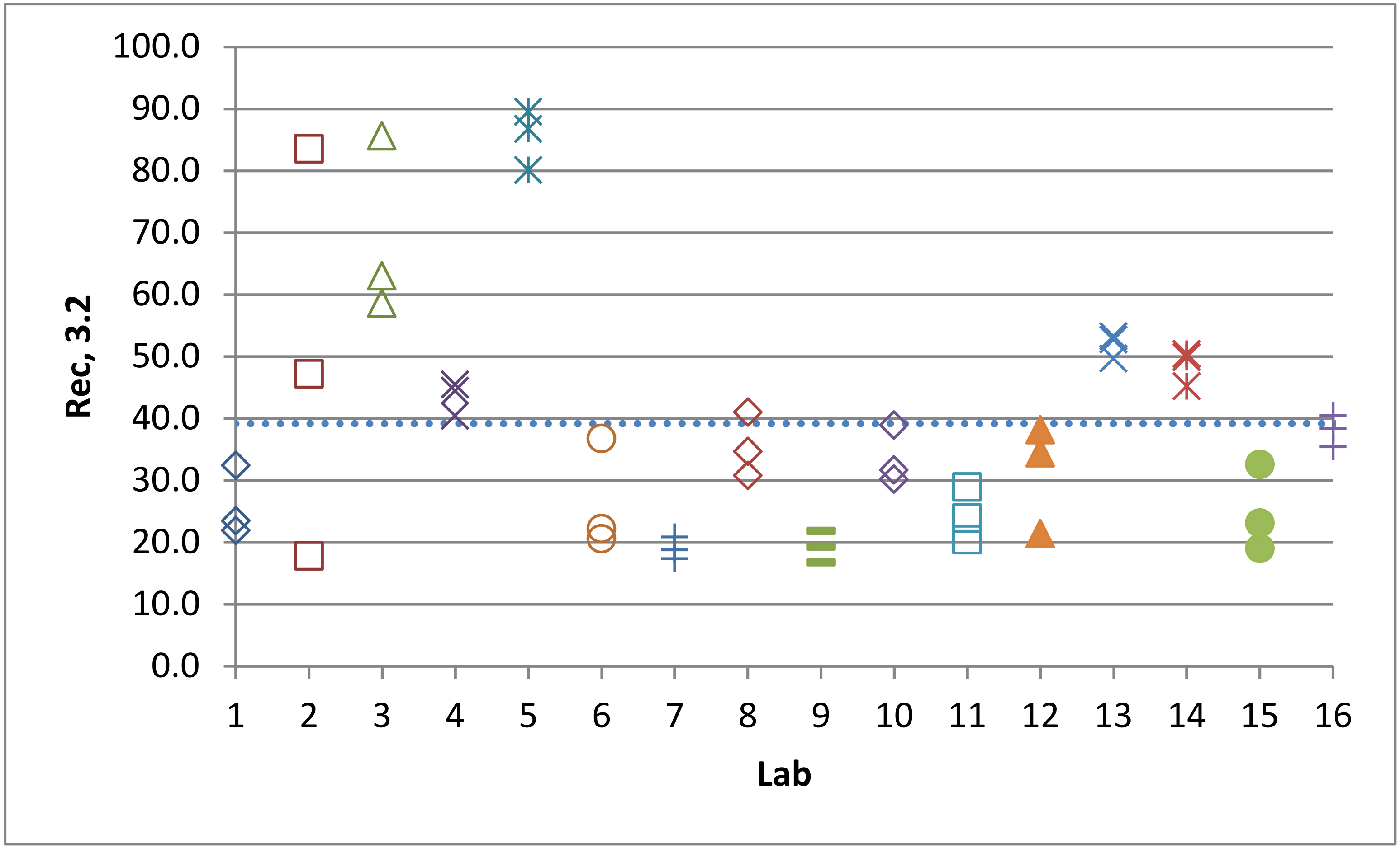


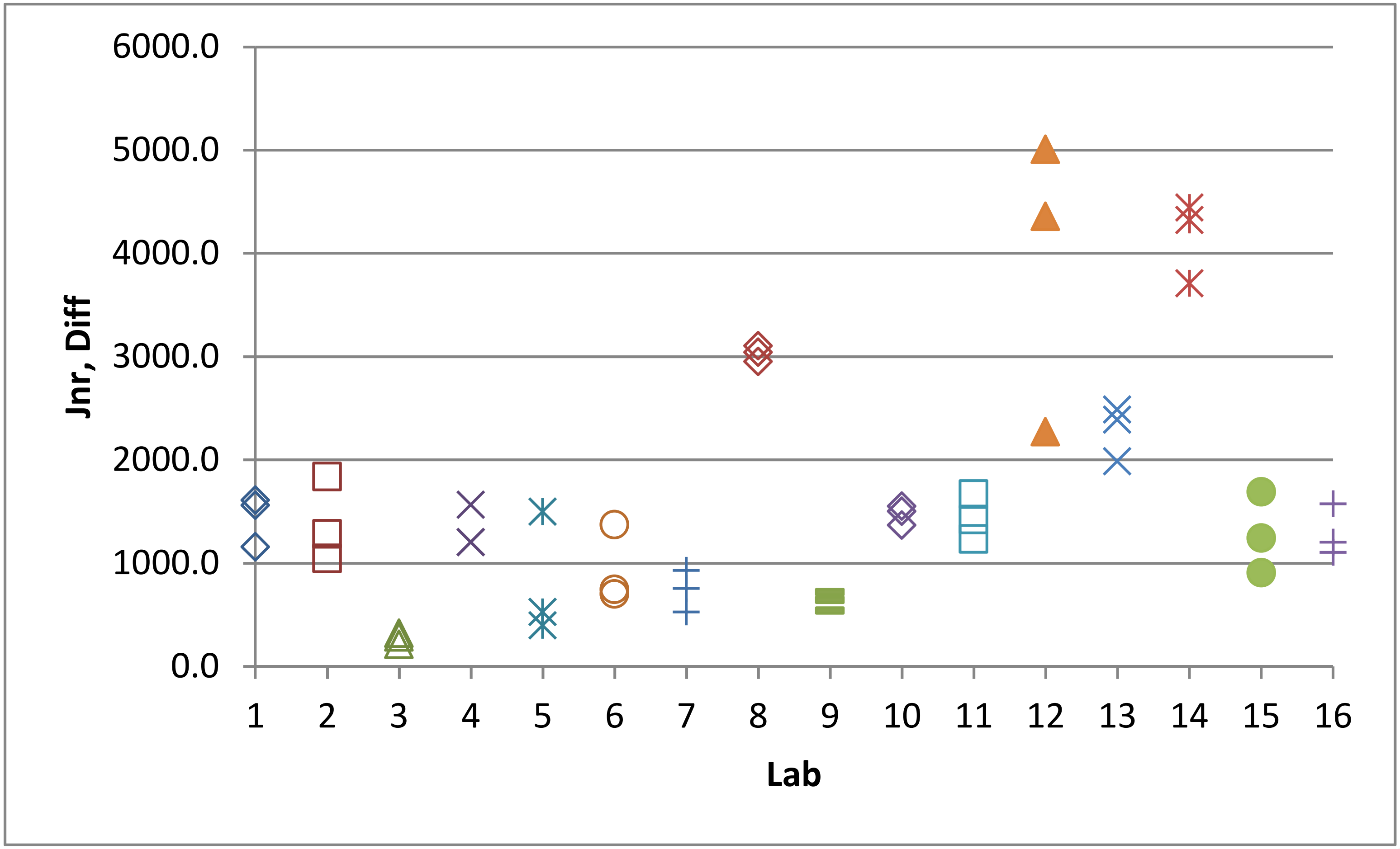
Binder A-AI: Jnr-3.2



Binder A-AI: Rec-3.2



Binder A-AI: Jnr-Diff



PCCAS 2013 ILS

- Summary
  - Preliminary analysis of MSCR results after outlier removal indicated similar precision as in other studies
  - High variability seen with Binder A
    - Test results indicate highly stress-sensitive binder
    - Meets MP19 criterion for PG64V-28
    - Meets Elasticity Evaluation by Jnr-Recovery curve
  - Some improvement in variability noted when aging was conducted by a single lab (AI)
    - Expected response since there is some inherent variability in RTFO procedure

PCCAS 2013 ILS

- Summary
  - PG-Plus tests not correlated directly with MSCR Rec-3.2
    - ER directionally correlated for 3 of 4 binders
    - Binder A indicated high ER value with low MSCR Rec-3.2
  - All binders analyzed to date plot above the Jnr-Recovery curve

MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
  - "The Multiple Stress Creep Recovery (MSCR) Procedure"
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"

MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - April 2010
    - Joint effort between AI TAC and FHWA
    - Purpose of the document is "…to provide guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test and specification using the MSCR test."

MSCR Guidance

asphalt institute

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"


Asphalt Institute Guidance Document

Implementation of the Multiple Stress Creep Recovery Test and Specification

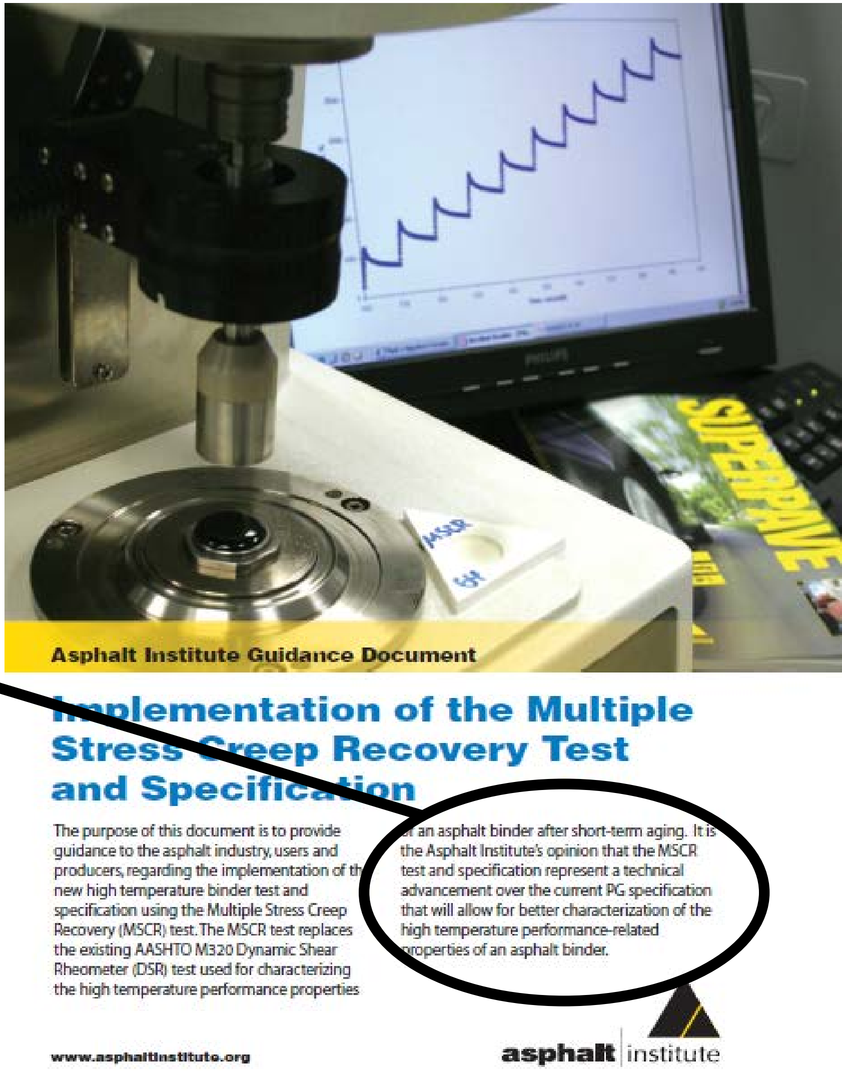
The purpose of this document is to provide guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test and specification using the Multiple Stress Creep Recovery (MSCR) test. The MSCR test replaces the existing AASHTO M320 Dynamic Shear Rheometer (DSR) test used for characterizing the high temperature performance properties of an asphalt binder after short-term aging. It is the Asphalt Institute's opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder.

www.asphaltinstitute.org

asphalt institute

MSCR Guidance

- "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
  - "It is the Asphalt Institute's opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder."



MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - Background
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and G*/sin δ?
        - » J_{nr} better correlated with rutting potential
        - » Works for both unmodified and modified binders

MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and G*/sin δ?
        - » Criterion to eliminate binders that are overly stress-sensitive

MSCR Guidance

asphalt institute

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - MSCR Test and Specification
      - Why is it an improvement compared to AASHTO T315 and G*/sin δ?
        - » MSCR Recovery faster/easier than other PG Plus tests and does better job of characterizing polymer modification
        - » Conducted at actual pavement temperature

MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - Implementation
      - Become familiar with the MSCR test
      - Become familiar with the specification
      - Conduct transitional testing as needed
      - Transition regionally and uniformly

MSCR Guidance

- Informational Documents
  - "Implementation of the Multiple-Stress Creep-Recovery Test and Specification"
    - Implementation
      - Use MSCR Recovery if there is a need to identify elastomeric modification in an asphalt binder…
      - …and eliminate the use of other PG Plus tests

MSCR Guidance

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - December 2010
    - AI Technical Advisory Committee
    - Recognize that many user agencies would prefer to use MSCR in conjunction with AASHTO M320

MSCR Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"

ASPHALT INSTITUTE

Guidance on the Use of the MSCR Test with the AASHTO M320 Specification

The Asphalt Institute (AI) Implementation Guidance Document, Implementation of the Multiple Stress Creep Recovery Test and Specification, provides guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test – the Multiple Stress Creep Recovery, MSCR, (AASHTO TP70) – and specification (AASHTO MP19). It is AI's opinion that the MSCR test and specification represent a technical advancement over the current performance-graded (PG) asphalt binder specification, AASHTO M320, which will allow for better characterization of the high temperature performance-related properties of an asphalt binder.

Although the implementation of the revised performance-graded asphalt binder specification (which uses J_{nr} from the MSCR test instead of RTFO G*/sin δ) is still the ultimate goal, the Asphalt Institute Technical Advisory Committee (AI-TAC) recognizes that many user agencies would simply prefer to use the MSCR test in conjunction with the AASHTO M320 specification rather than transitioning to a system that uses different grade names. In this case, the AI-TAC would recommend the following procedures for user agencies to consider:

- Use the MSCR test (AASHTO TP70) as a replacement PG-Plus test for modified asphalt binders that currently require an "elasticity evaluation" Plus test such as Elastic Recovery. Testing can also be conducted on standard, unmodified asphalt binders if desired.
- Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO TP70. To have useful information, testing must be conducted on RTFO-aged material at the appropriate climate grade. Recommended test temperatures are shown in TABLE 1 below. Although TABLE 1 provides likely test temperatures, the 98% reliability high PG from LTPPBind 3.1 provides the most accurate representation of the climatic conditions and should be used if the agency is in doubt about the proper test temperature. A 98% reliability high PG map is shown in FIGURE 1 as a reference.
- Following AASHTO TP70, determine the J_{nr} values at 0.1 and 3.2 kPa shear stress and the corresponding MSCR Recovery values at the same stress levels.
- Using the data from the 3.2 kPa shear stress portion of the test, plot the MSCR Recovery as a function of J_{nr} and compare to FIGURE 2 below. Data points above the curve are considered to have sufficient delayed elastic response for an elastomeric-modified asphalt binder.
- Calculate the stress sensitivity parameter, $J_{nr,diff}$, by using the equation $J_{nr,diff} = (J_{nr,3.2kPa} - J_{nr,0.1kPa}) \div J_{nr,0.1kPa}$. If the ratio is greater than 0.75 then the asphalt binder is considered stress sensitive. In AASHTO MP19, a maximum ratio of 0.75 is permitted. If using the MSCR with AASHTO M320, it is suggested that the $J_{nr,diff}$ value be reported and noted if the criterion is not met.

As stated in the Implementation of the Multiple Stress Creep Recovery Test and Specification, AI recommends that if the MSCR Recovery is used to evaluate the delayed elastic response of the asphalt binder, then other PG-Plus tests with a similar purpose – such as Elastic Recovery, Force Ductility, and Toughness and Tenacity tests – should be eliminated. This saves testing time for both the user and supplier. If the current PG-Plus tests are not eliminated, then the time savings is lost. In this instance, the MSCR Recovery test should not be added.

Comparison testing between the MSCR Recovery value and the values of the current PG-Plus tests will no doubt be conducted. However, technologists should be cautioned not to expect a strong correlation because of the different test conditions that are used. AI has conducted some limited comparison testing between the MSCR Recovery and other PG-Plus tests and may be able to provide guidance on appropriate values to consider.

Please contact Mike Anderson of the Asphalt Institute (manderson@asphaltinstitute.org) with any specific questions or comments regarding this guidance.

Asphalt Institute Technical Advisory Committee
2 December 2010

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MSCR Guidance

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Use the MSCR test (AASHTO TP70) as a replacement PG-Plus test for modified asphalt binders that currently require an "elasticity evaluation" Plus test such as Elastic Recovery.

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO TP70.
        - » Some guidance on temperature provided

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO TP70.
        - » Some guidance on temperature provided

- Informational Documents
  - "Guidance on the Use of the MSCR Test with the AASHTO M320 Specification"
    - Recommendations
      - Conduct the MSCR test on the RTFO-aged asphalt binder following the procedures in AASHTO TP70.
        - » "…the 98% reliability high PG from LTPPBind 3.1 provides the most accurate representation of the climatic conditions and should be used if the agency is in doubt about the proper test temperature."

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - Determine J_{nr} and Recovery at 0.1 and 3.2 kPa stress
      - Plot Rec-3.2 versus Jnr-3.2 and determine if data point plots above the curve. Data points above the curve are considered to have sufficient delayed elastic response for an elastomeric-modified asphalt binder.

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - Calculate the stress sensitivity parameter and determine if the ratio is less than 75%.

MSCR Guidance

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - if the MSCR Recovery is used to evaluate the elastic response of the asphalt binder, then other PG-Plus tests with a similar purpose – such as Elastic Recovery, Force Ductility, and Toughness and Tenacity tests – should be eliminated.

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”
    - Recommendations
      - Comparison testing between the MSCR Recovery value and the values of the current PG-Plus tests will no doubt be conducted.
      - Technologists are cautioned not to expect a strong correlation because of the different test conditions that are used.

- Informational Documents
  - “Guidance on the Use of the MSCR Test with the AASHTO M320 Specification”

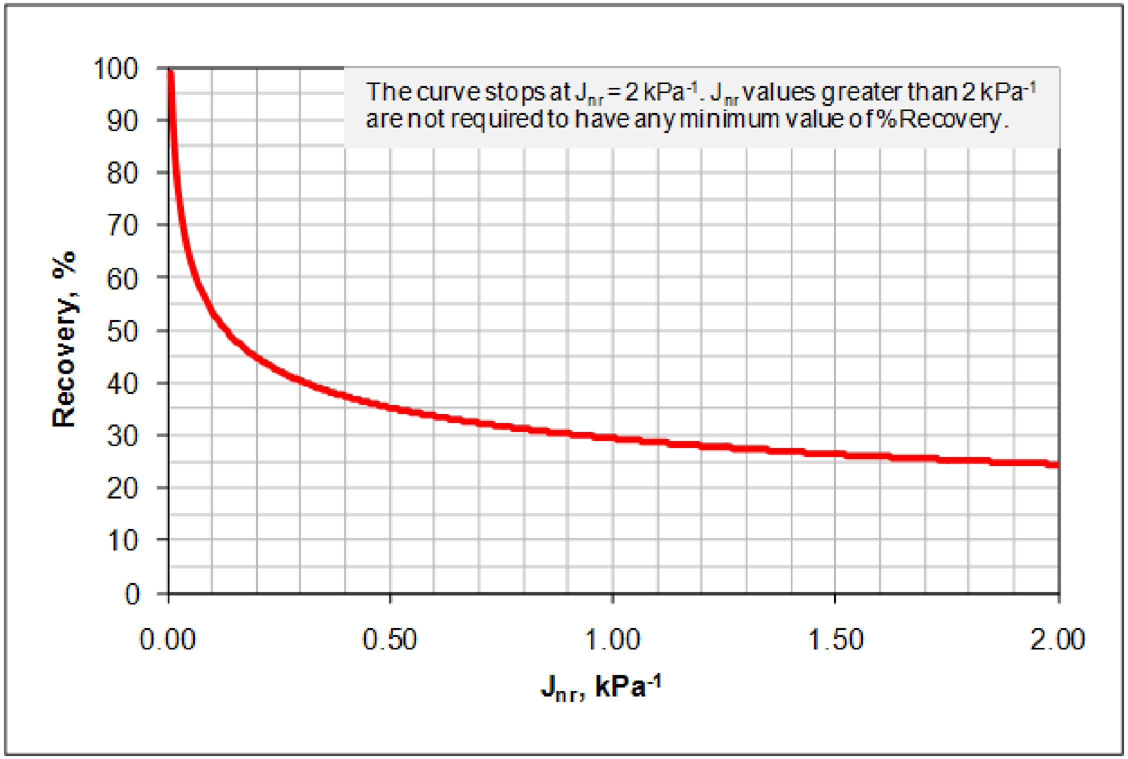


FIGURE 2: Comparison of MSCR J_{nr} and Recovery to Assess Delayed-Elastic Response

- Informational Documents
  - "The Multiple Stress Creep Recovery (MSCR) Procedure"
    - April 2011
    - FHWA
    - Provide an overview of the intent of the Superpave MSCR procedure to evaluate asphalt binder and its relation to asphalt pavement performance

- Informational Documents
  - “The Multiple Stress Creep Recovery (MSCR) Procedure”
  - FHWA-HIF-11-038

TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, Industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Pavement Technology

FHWA-HIF-11-038

April 2011

THE MULTIPLE STRESS CREEP RECOVERY (MSCR) PROCEDURE

This Technical Brief provides an overview of the intent of the Superpave MSCR procedure to evaluate asphalt binder and its relation to asphalt pavement performance.

Rationale for MSCR Procedure

The Multiple Stress Creep Recovery (MSCR) test is the latest improvement to the Superpave Performance Graded (PG) Asphalt Binder specification. This new test and specification – listed as AASHTO TP70 and AASHTO MP19 – provide the user with a new high temperature binder specification that more accurately indicates the rutting performance of the asphalt binder and is blind to modification. A major benefit of the new MSCR test is that it eliminates the need to run tests such as elastic recovery, toughness and tenacity, and force ductility, procedures designed specifically to indicate polymer modification of asphalt binders. A single MSCR test can provide information on both performance and formulation of the asphalt binder.

Overview

So what exactly is the MSCR test? The MSCR test uses the well-established creep and recovery test concept to evaluate the binder's potential for permanent deformation. Using the Dynamic Shear Rheometer (DSR), the same piece of equipment used today in the existing PG specification, a one-second creep load is applied to the asphalt binder sample. After the 1-second load is removed, the sample is allowed to recover for 9 seconds. Figure 1 shows typical data for a polymer modified binder. The test is started with the application of a low stress (0.1 kPa) for 10 creep/recovery cycles then the stress in increased to 3.2 kPa and repeated for an additional 10 cycles.

The material response in the MSCR test is significantly different than the response in the existing PG tests. In the PG system, the high

- Informational Documents
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"
    - April 2012
    - AI TAC
    - Provide specifics on how the MSCR should be performed (64°C) and offer possible criterion based on AI testing.

- Informational Documents
  - “Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group”

Use of MSCR Recovery to Replace PG Plus Tests
In the Southeast Asphalt User-Producer Group

To ensure polymer modification in premium asphalt binders, many user agencies require that one or more "PG Plus" tests be performed as supplemental tests to the requirements of the current performance-graded (PG) asphalt binder specification, AASHTO M320. In the SEAUPG, for premium asphalt binders (i.e., PG 70-28, PG 76-22, and PG 76-28) many user agencies require that the asphalt binder either meet a minimum elastic recovery value (usually performed on RTFO-aged binder) or maximum DSR phase angle (usually performed on unaged binder).

There are two major advantages to using the MSCR Recovery versus the current PG-Plus tests. First, while it is similar to Elastic Recovery in that it indicates the presence of an elastomeric modifier, testing has indicated that the MSCR Recovery may be more discriminating in assessing how the polymer network is performing within the asphalt binder. Second, the MSCR test is much quicker, requiring no additional equipment, less preparation time, and less effort than running a separate sample for Elastic Recovery by either AASHTO T 301 or ASTM D 6084, while losing none of the reliability. Although the DSR phase angle determination does not require any additional time (since the value is determined as a normal part of the AASHTO T315 procedure), the Elastic Recovery procedure (either AASHTO T301 or ASTM D6084) can take several hours to complete.

To use the MSCR Recovery value as a replacement PG-Plus test for premium asphalt binders in the SEAUPG, the following procedure is recommended:

1. Perform the MSCR test (AASHTO TP70) on RTFO-aged asphalt binder at 64°C.
2. Use the average MSCR Recovery value calculated from the test at 3.2kPa shear stress (MSCR Rec-3.2).
3. Compare the MSCR Rec-3.2 value to the suggested criterion below.

Data from the Asphalt Institute's research suggests the following:

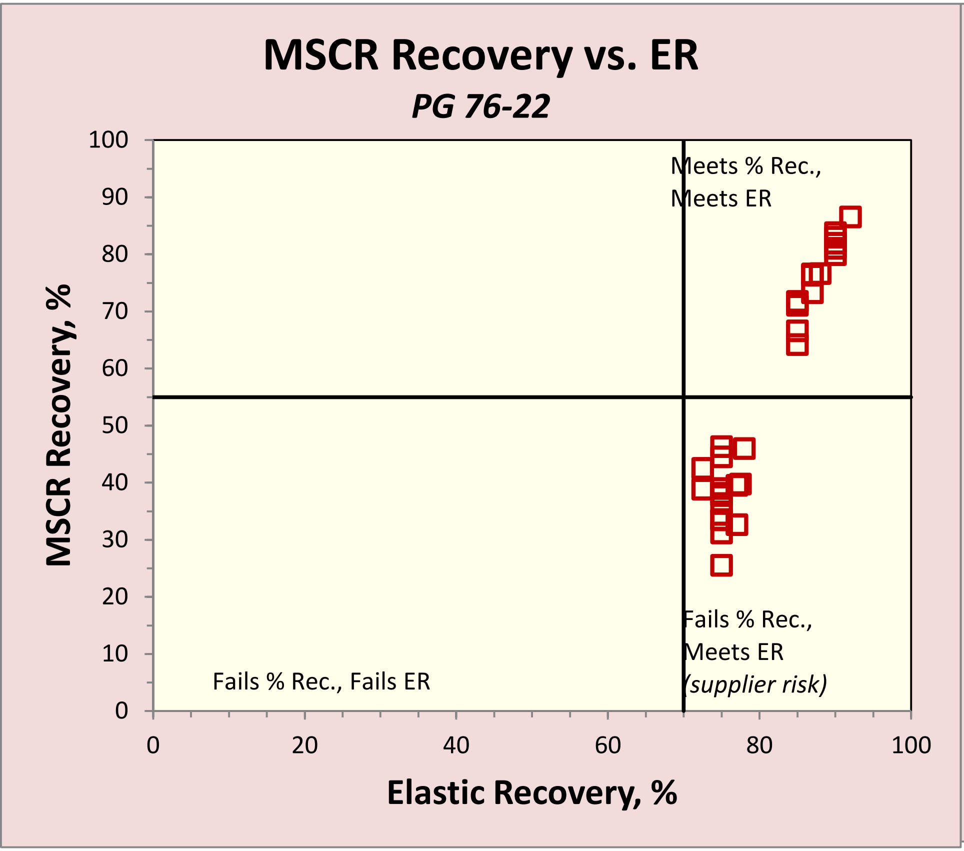
- If using the Elastic Recovery (AASHTO T301) value at 25°C, an appropriate MSCR Rec-3.2 criterion at 64°C is 15 percentage points less than the current Elastic Recovery criterion. For example, a user agency that has a minimum requirement of 75% for Elastic Recovery would instead require a minimum MSCR Rec-3.2 value of 60%.
  - If the Elastic Recovery value is based on testing performed at 10°C, a limited analysis by AI suggests that an appropriate MSCR Rec-3.2 criterion at 64°C is 5% less than the current Elastic Recovery criterion.
- If using DSR Phase Angle (AASHTO T315) of the *Original (unaged)* asphalt binder, with a requirement that the phase angle be a maximum of 75 degrees, an appropriate minimum MSCR Rec-3.2 value at 64°C is 55%.

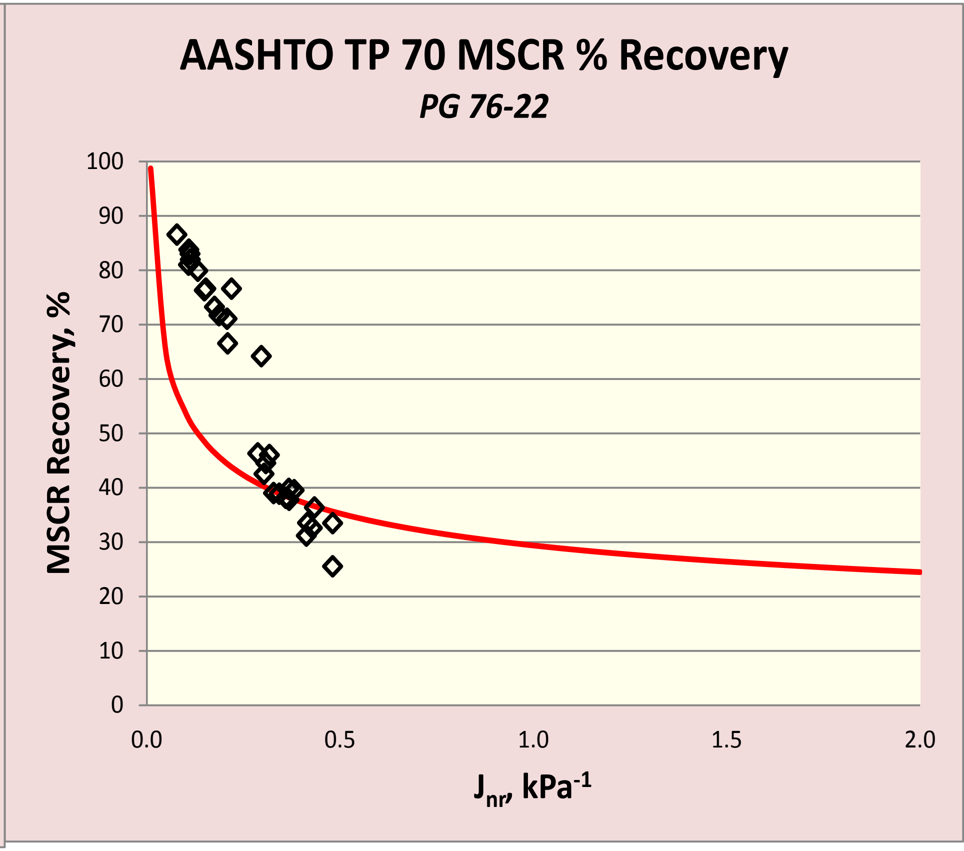
The Asphalt Institute also suggests that the average MSCR Creep Compliance (J_{nr}) value calculated from the test at 3.2kPa shear stress (termed MSCR Jnr-3.2) be determined and used with the MSCR Rec-3.2 value to generate a data point on the Recovery-J_{nr} curve in AASHTO TP70 (shown in Figure 1 below). This point provides an indication of the delayed elastic response of the modified asphalt binder and should be above the curve.

- Informational Documents
  - “Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group”
    - Recommendations
      - Perform the MSCR test (AASHTO TP70) on RTFO-aged asphalt binder at 64°C.
      - Use the average MSCR Recovery value calculated from the test at 3.2kPa shear stress (MSCR Rec-3.2).

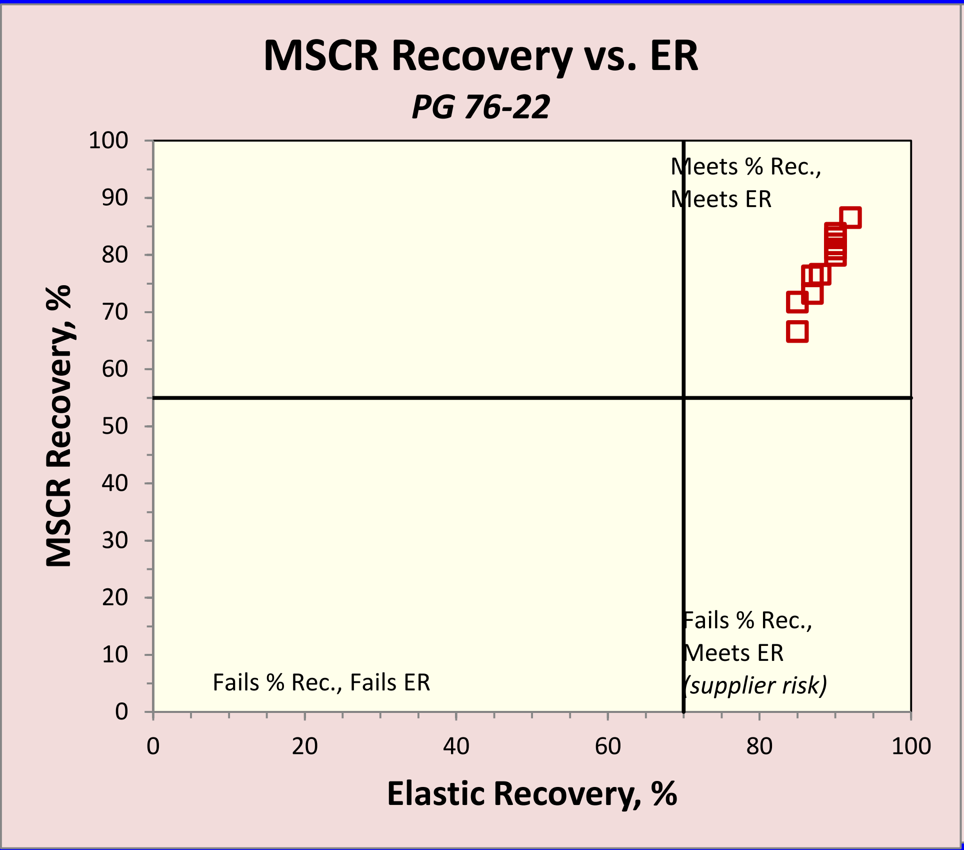
- Informational Documents
  - "Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group"
    - Recommendations
      - Compare the MSCR Rec-3.2 value to the suggested criterion

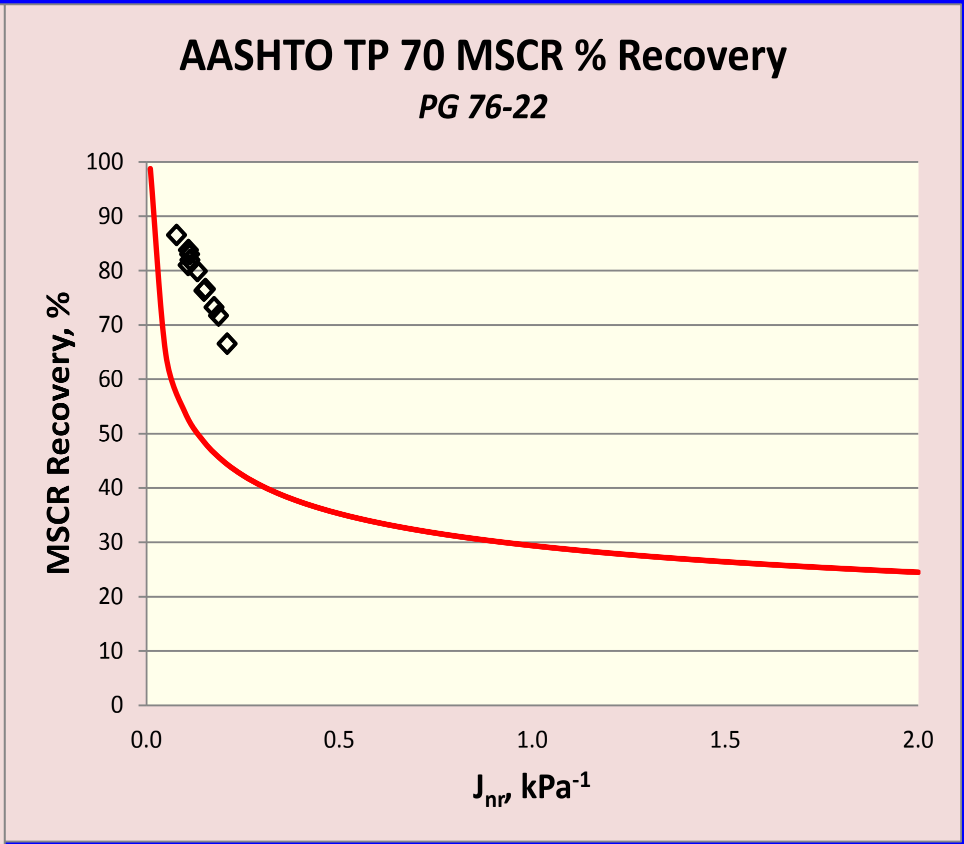
- Informational Documents
  - “Use of MSCR Recovery to Replace PG Plus Tests in the Southeast Asphalt User-Producer Group”
    - Recommendations
      - For states using ER at 25°C, set criterion for MSCR Rec-3.2 at 15% less than the ER criterion
        - » Based on analysis of modified binders from 2007-2011
        - » GTR-modified binders not included (suggested values may not be appropriate)


MSCR Recovery vs. ER
PG 76-22
Meets % Rec., Meets ER
Fails % Rec., Meets ER (supplier risk)
Fails % Rec., Fails ER
MSCR Recovery, %
Elastic Recovery, %
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100

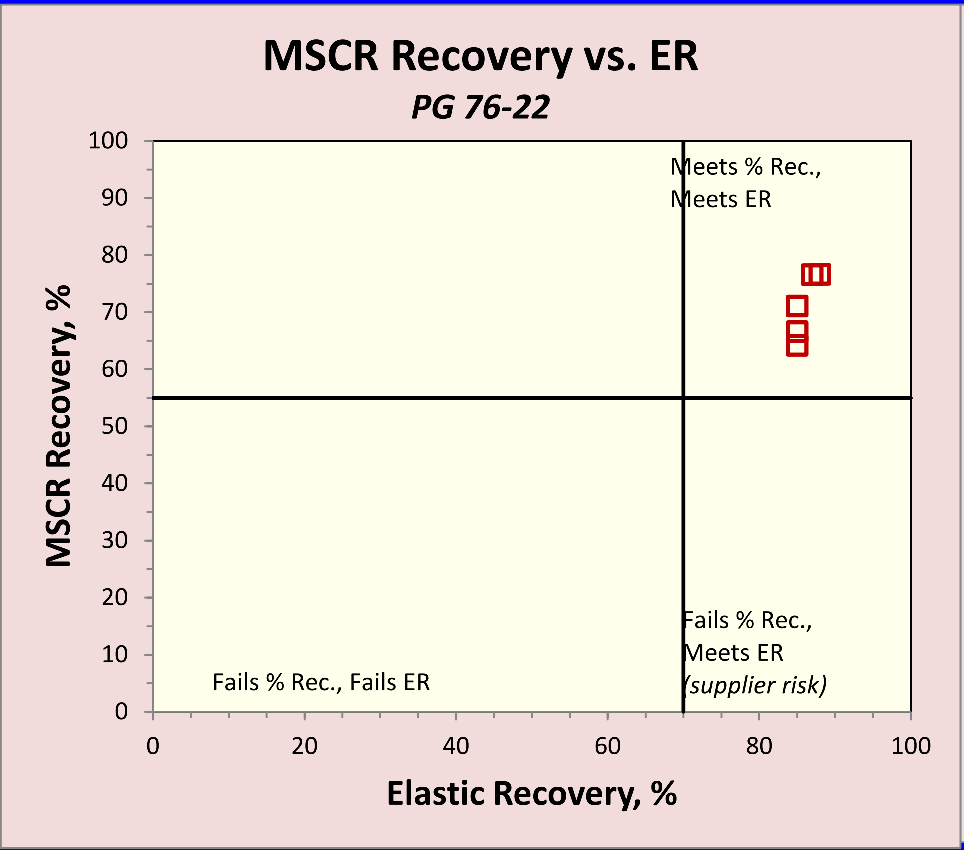

AASHTO TP 70 MSCR % Recovery
PG 76-22
MSCR Recovery, %
J_{nr}, kPa^{-1}
0
10
20
30
40
50
60
70
80
90
100
0.0
0.5
1.0
1.5
2.0

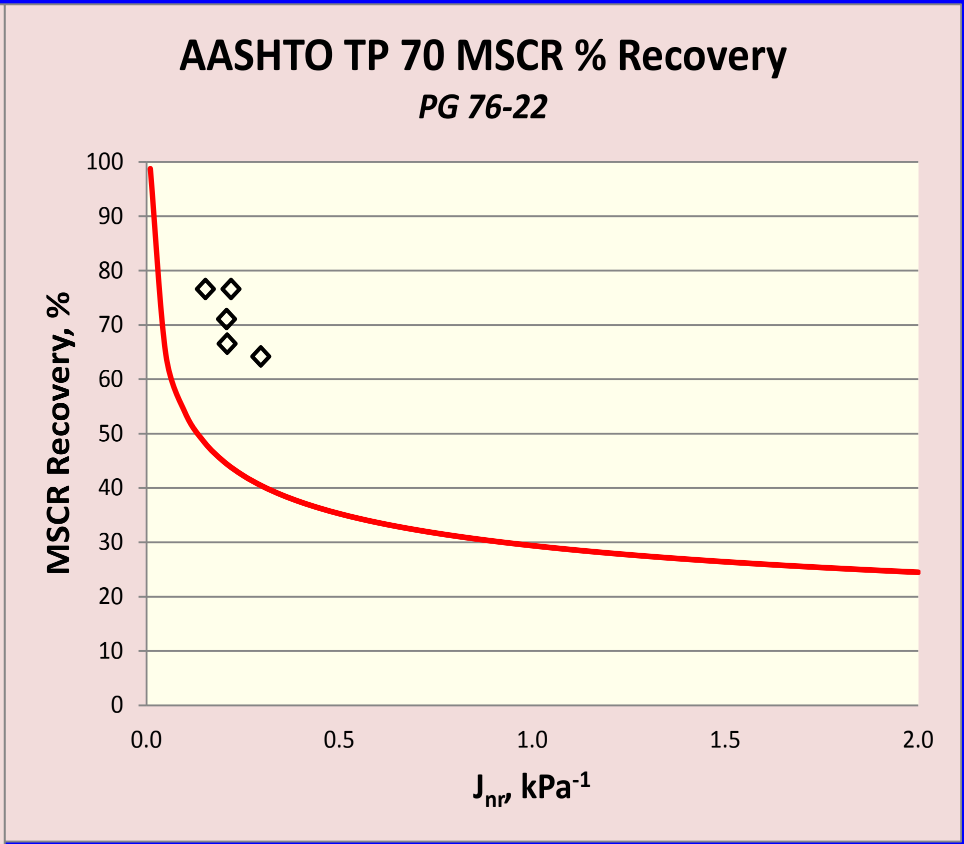
User 1 Source 1



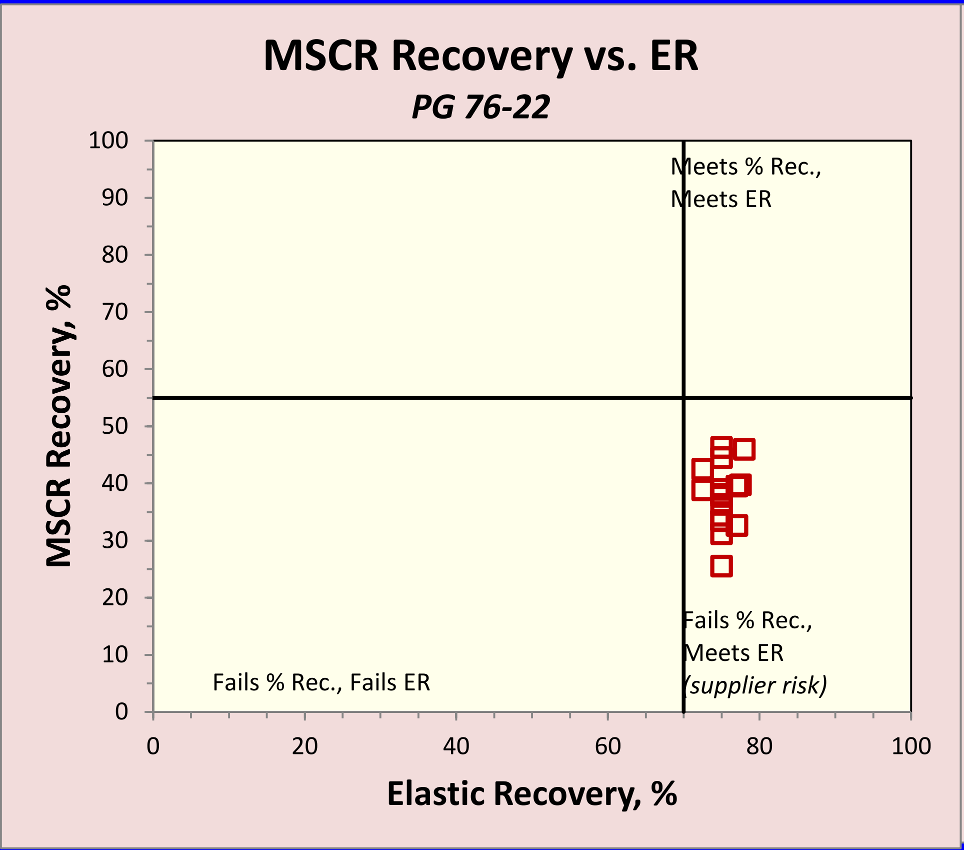


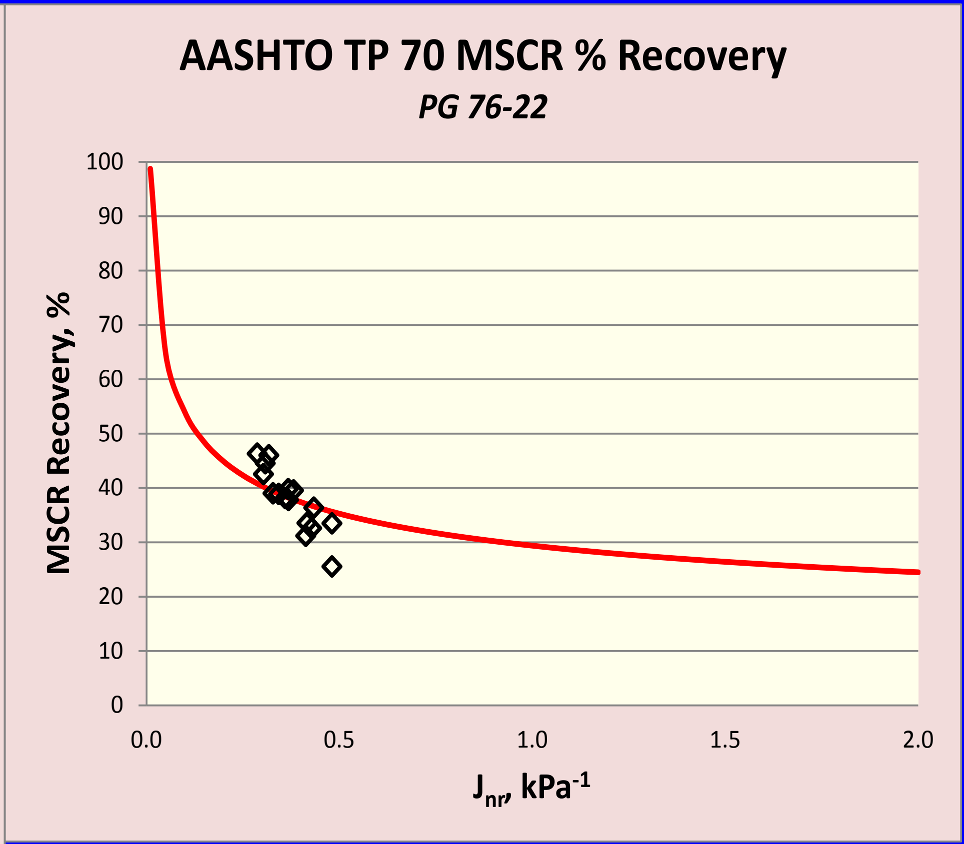
User 1 Source 2





User 1 Source 3





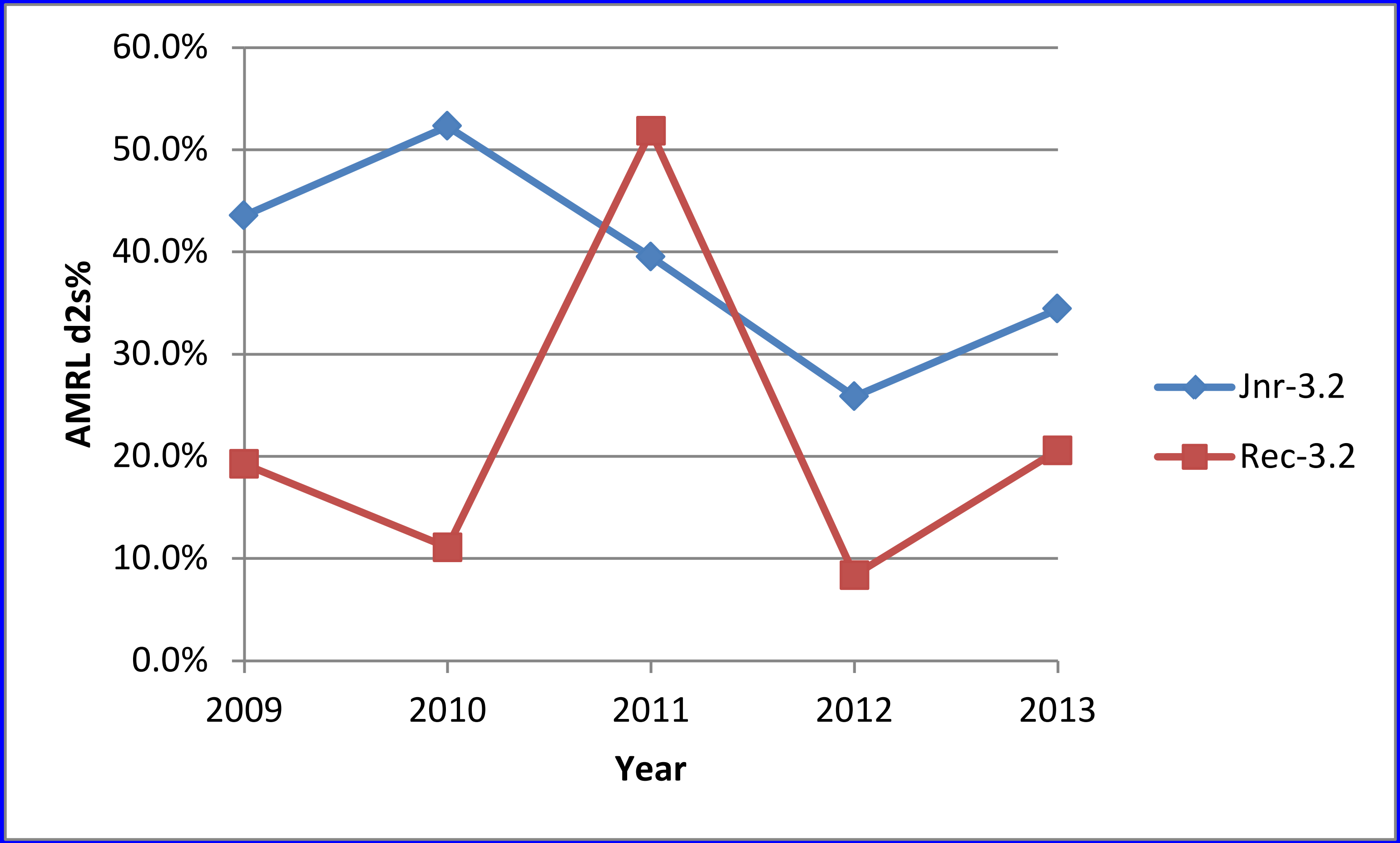
MSCR Implementation

- Interlaboratory Studies
  - NEAUPG
    - 2010
    - 2012
  - SEAUPG
    - 2011
  - PCCAS
    - 2013

Multi-Lab Precision Estimates from AI ILS Studies

ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	13.8%	36.8%

AMRL PSP Analysis



Multi-Lab Precision Estimates from AI ILS Studies (with AMRL PSP)

ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	13.8%	36.8%
AMRL PSP (2009-2011) (2012-2013)	 27.4% 14.5%	 45.1% 30.1%

MSCR Fatigue Study

- Asphalt Binders
  - PG 76-22
    - Midwest (Force Ductility)
    - Southeast (Phase Angle)
    - Northeast (Elastic Recovery)
  - PG 64-22V
    - Midwest
    - Northeast
  - DLSI Lab Binders
    - 4% SBS
    - 2.5% SBS cross-linked

MSCR Fatigue Study

- Asphalt Mixture Testing
  - Single asphalt mixture
    - STOA
      - 4 hours at 135°C
  - Flexural Beam Fatigue
    - 20°C
    - 450, 600, 800, and 1000 microstrain
    - Cycles to failure (Stiffness*Cycles)
  - DC(t)
    - Low temperature

MSCR Fatigue Study

- Asphalt Binder Testing
  - MSCR
    - 64°C, RTFO-aged material
    - AASHTO TP70
  - Elastic Recovery
    - 25°C, RTFO-aged material
    - AASHTO T301
  - Force Ductility
    - 4°C, original material
    - AASHTO T300
  - Linear Amplitude Sweep
    - 20°C, RTFO-aged material

Fatigue Study: Asphalt Binders

	Jnr-3.2	Rec-3.2	FD Ratio	ER	δ
737	0.104	79.8	0.55	83	64.3
748	0.636	38.6	0.37	73	74.5
736	0.490	32.9	0.33	65	73.6
735	0.273	48.8	0.41	70	70.5
732	0.245	62.0	0.52	77	66.9
734	0.452	30.8	0.34	68	72.3
733	0.366	24.7	0.29	65	75.1

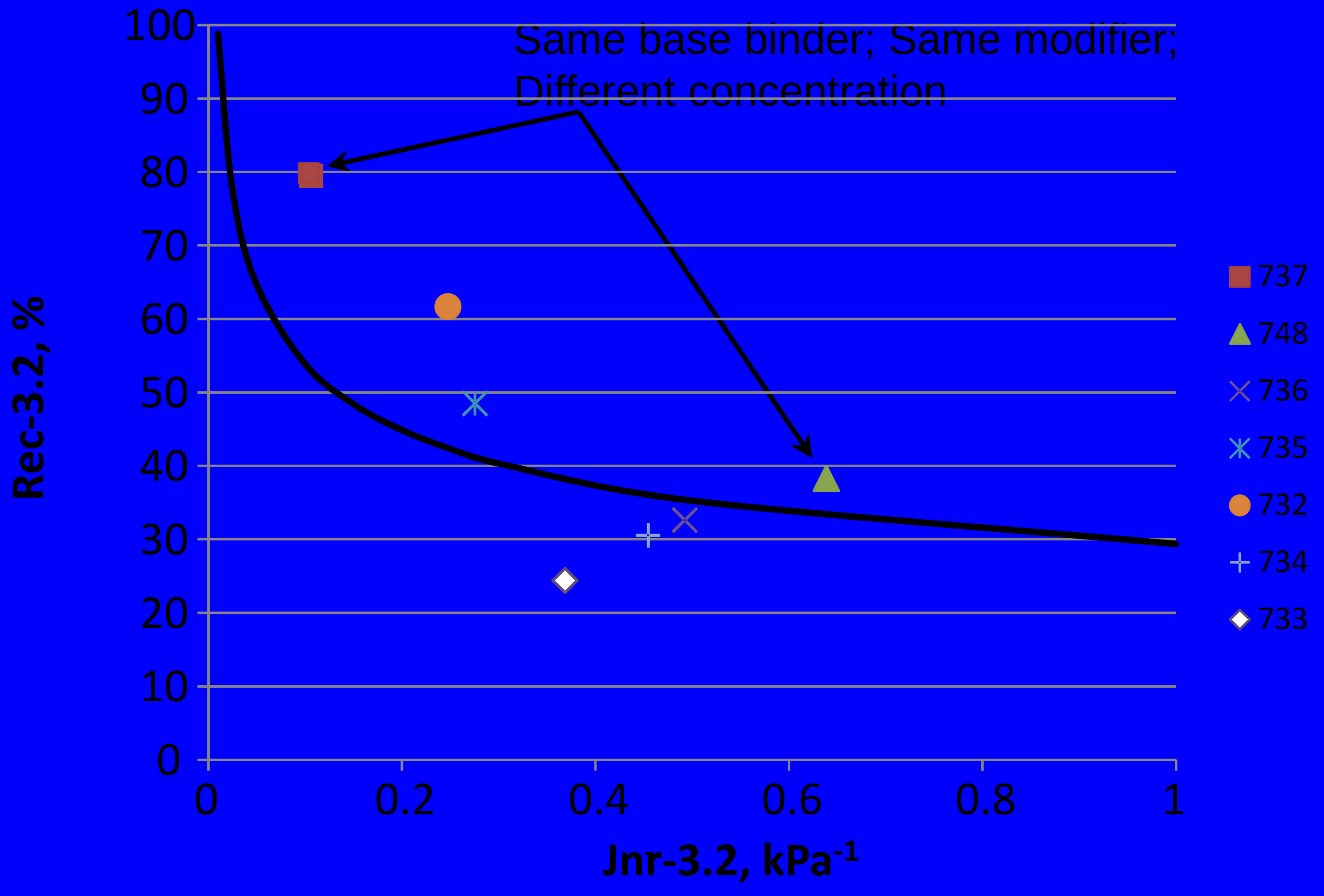
Fatigue Study: Asphalt Binders

	Jnr-3.2	Rec-3.2	FD Ratio	ER	δ
737	0.104	79.8	0.55	83	64.3
748	0.636	38.6	0.37	73	74.5

Same Base Binder
Same Modifier
Different Concentration

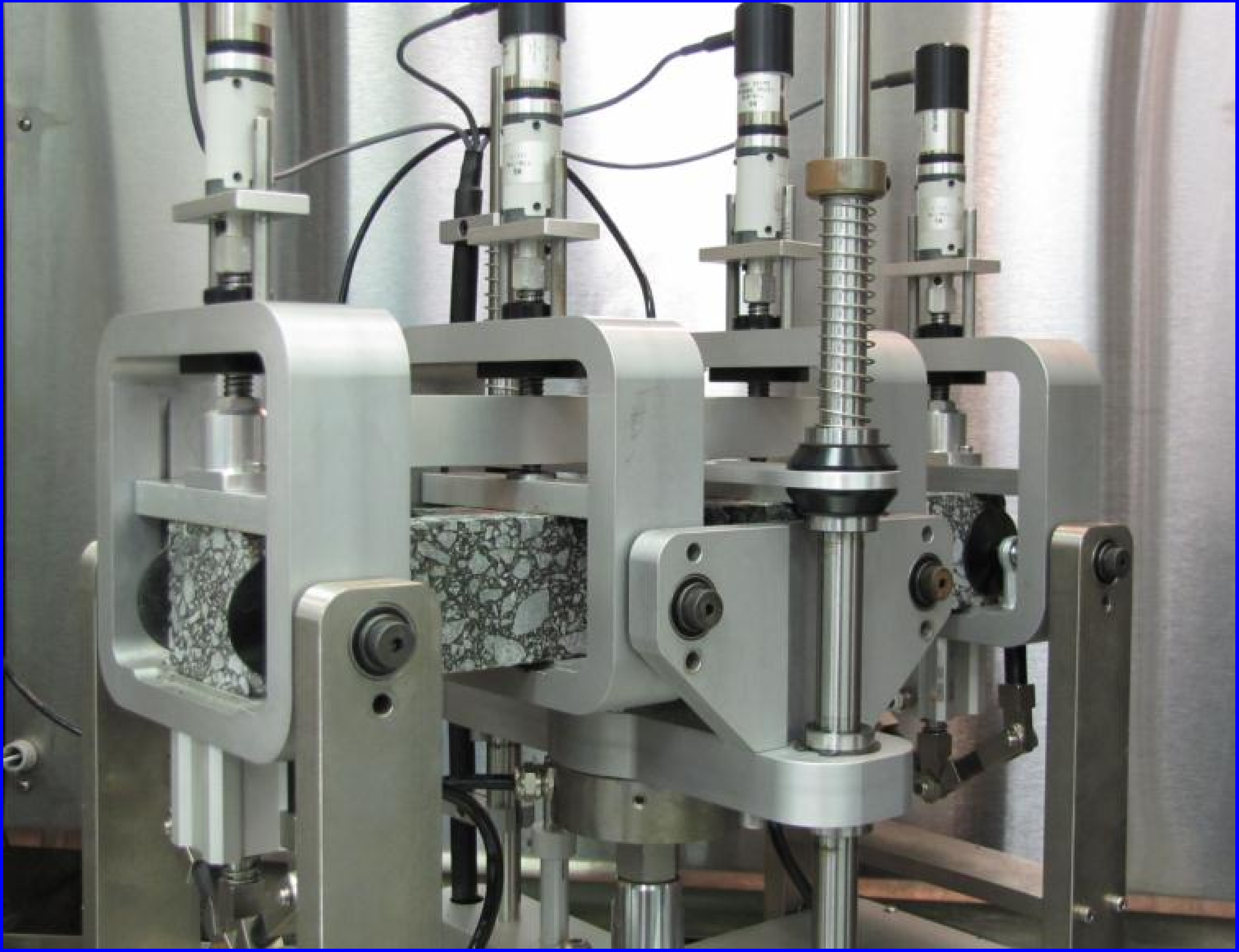
30% less polymer

Fatigue Study: Asphalt Binders

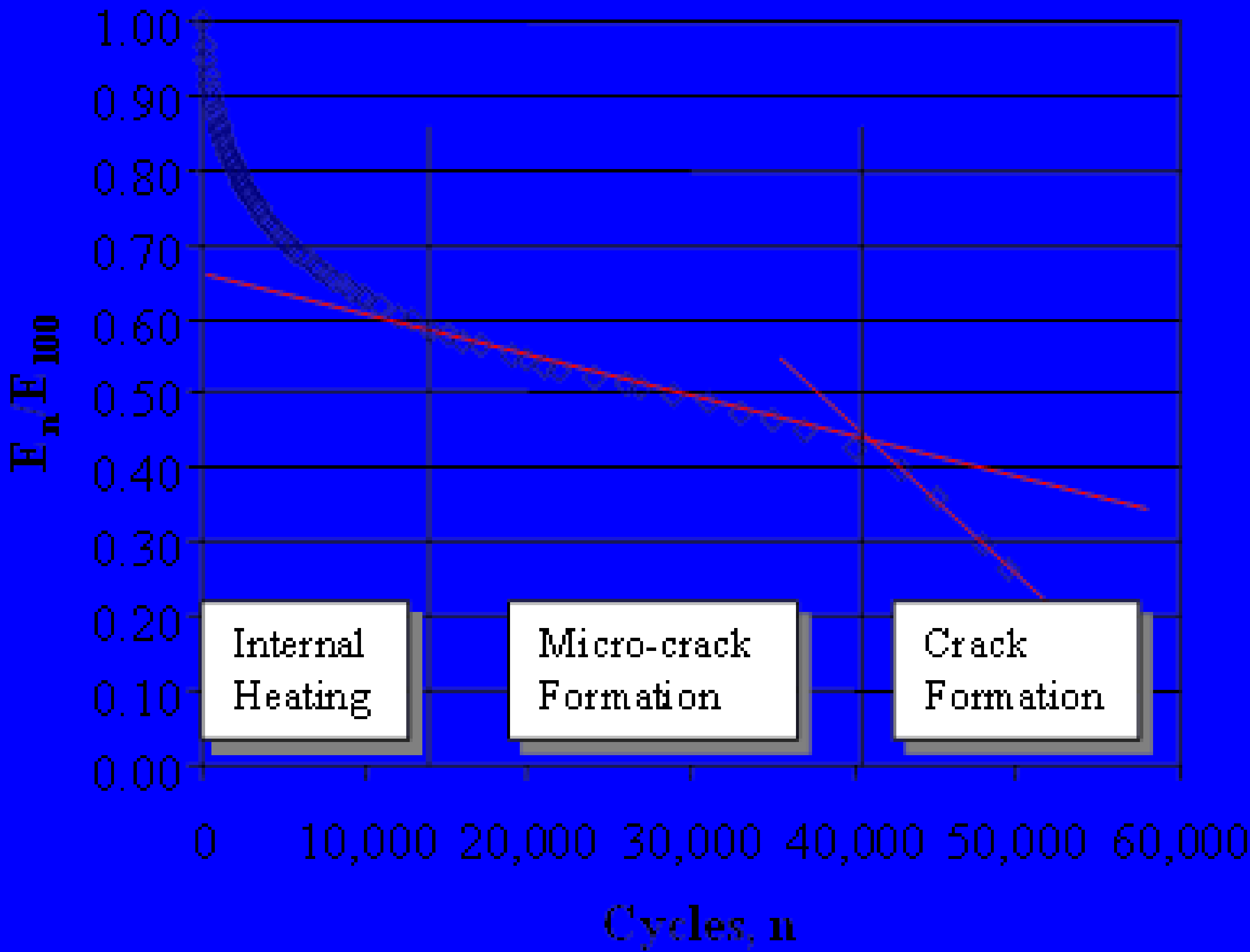


Flexural Beam Fatigue (IPC)

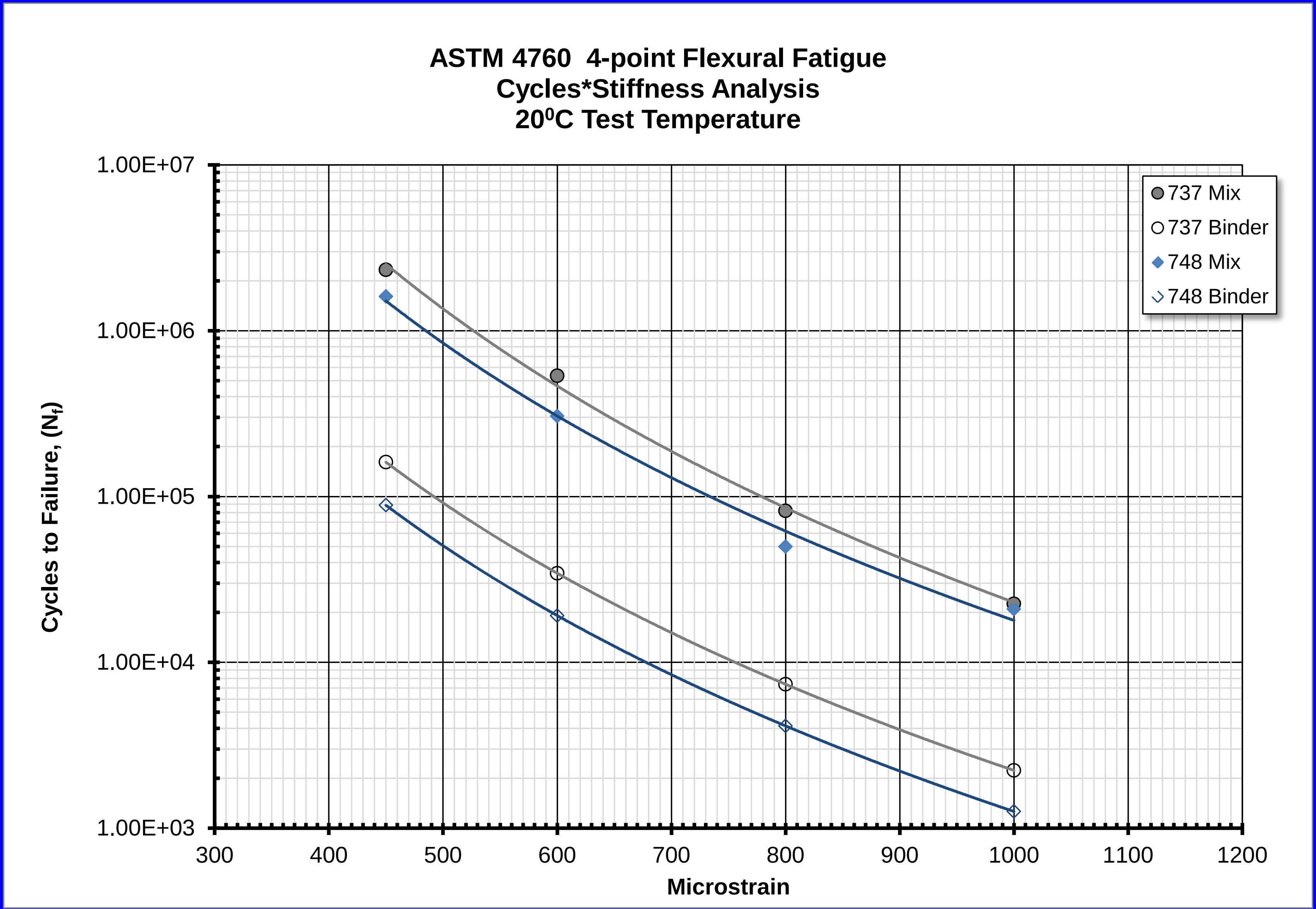
Flexural Beam Fatigue Fixture



Flexural Beam Fatigue Test



Fatigue Study: Effect of Modifier Concentration

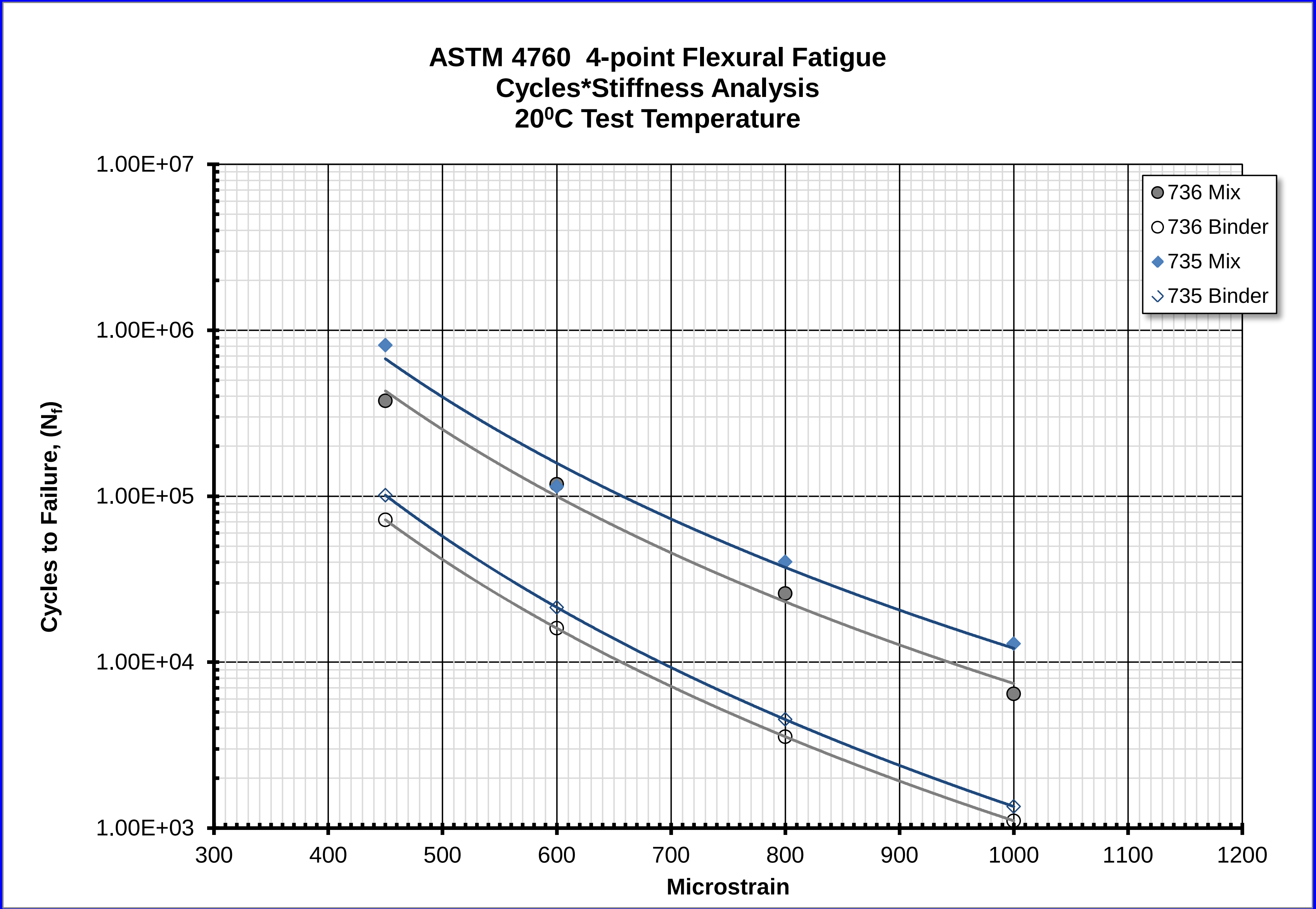


Fatigue Study: Effect of Modifier Concentration

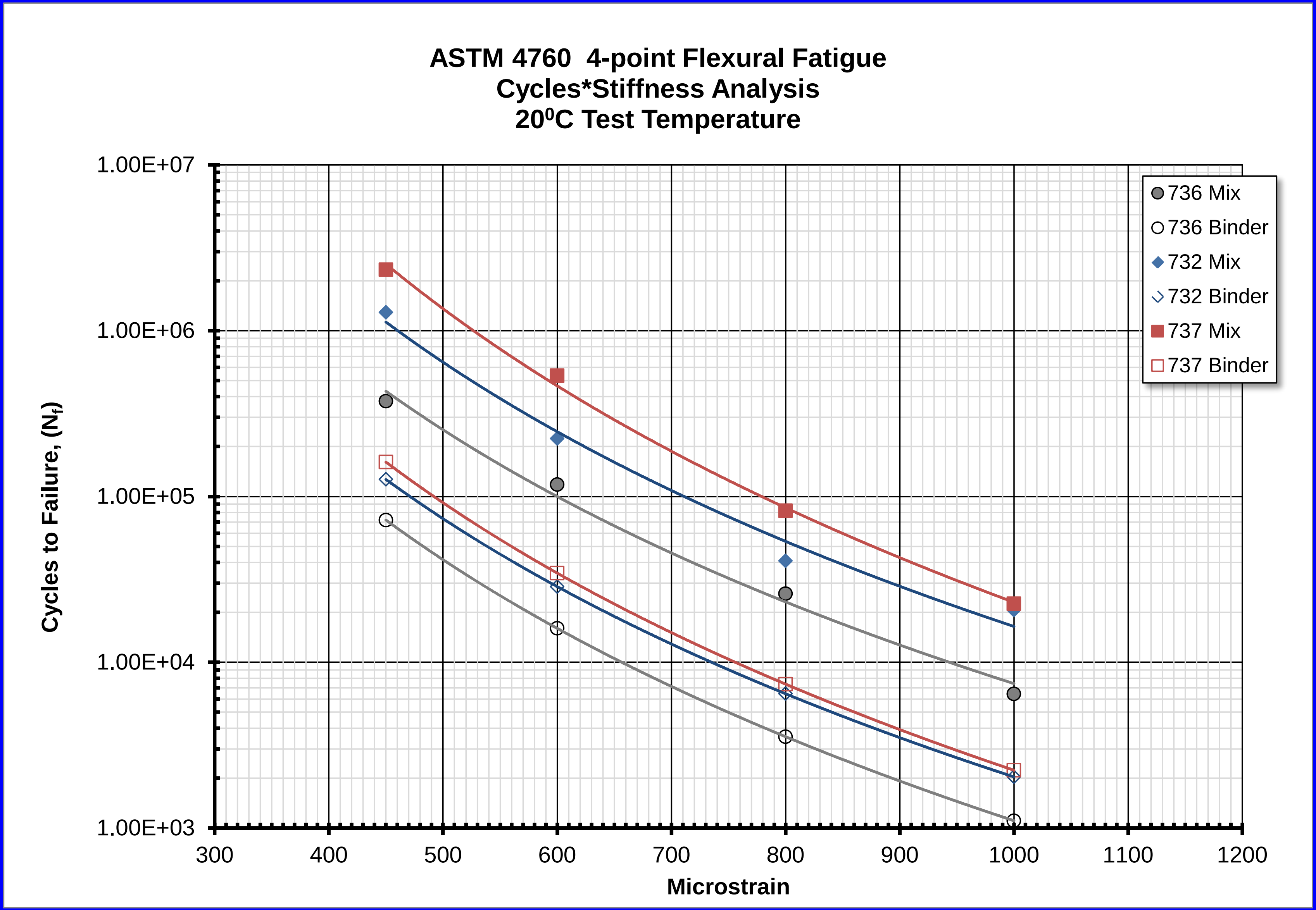
	N_f			
	Binder Strain (E-06)			
Binder	22,500	30,000	40,000	50,000
737	1.61E+05	3.45E+04	7.37E+03	2.23E+03
748	8.86E+04	1.91E+04	4.13E+03	1.26E+03
Ratio 748/737	55%	56%	56%	57%

	N_f			
	Mix Strain (E-06)			
Mixture	450	600	800	1000
737	2.33E+06	5.35E+05	8.19E+04	2.25E+04
748	1.61E+06	3.05E+05	4.98E+04	2.09E+04
Ratio 748/737	69%	57%	61%	93%

Fatigue Study: Effect of Modifier Type/Concentration



Fatigue Study: Effect of PG Plus Formulation



Fatigue Study: Effect of Modifier Concentration

- Caveats
  - Lab fatigue testing only
  - Single mixture
  - Single modifier/binder combination
- Reinforces the need for mixture performance testing

Laboratory Mixing and Compaction Temperatures

- Summary of Findings from Experiment
  - Mixing Temperature appears to have some effect on the high temperature stiffness of the asphalt binder
    - Lower Jnr-3.2 associated with higher mixing temperature, more aging
    - Increase in stiffness may not be practically significant

Laboratory Mixing and Compaction Temperatures

- Summary of Findings from Experiment
  - Mixing Temperature appears to have no effect on the number of cycles to failure from the LAS test
    - At a given temperature, aging has an effect on the slope of the Nf-strain curve (steeper slope associated with more aging.

Laboratory Mixing and Compaction Temperatures

- Summary of Findings from Experiment
  - Mixing Temperature appears to have no consistent effect on the continuous temperature determined at intermediate (PAV DSR) and low temperature (BBR S and m)
    - PAV aging may overwhelm any initial effects.
- Important caveats to the experiment
  - Recovered asphalt binder from mix
  - Single test results

Laboratory Mixing and Compaction Temperatures

- Implication of Findings from Experiment
  - The relative insensitivity of binder and mixture properties to the mixing temperature over a range of 20°C suggests that it is not necessary to have a procedure that is too rigorous, but rather one that provides a reasonable estimate for routine laboratory use.

Association of Asphalt Paving Technologists

- AAPT Annual Meeting
  - March 16-19, 2014
  - Atlanta, GA
    - Hyatt Regency Atlanta
  - www.asphalttechnology.org
- Leading Edge Workshop

Association of Asphalt Paving Technologists

- AAPT Leading Edge Workshop
  - Sunday March 16, 2014 (2:10-5:00PM)
  - “Asphalt Modification”
    - A look at the history of asphalt binder modification in the USA and the current state of the practice. Industry and academic leaders have been asked to present:
      - An overview on the use of asphalt modification,
      - Summary of tests and relationships that can be used to describe performance,
      - How we can effectively evaluate performance,
      - Gaps in the research necessary for implementation.

Association of Asphalt Paving Technologists

- AAPT Leading Edge Workshop
  - Sunday March 16, 2014 (2:10-5:00PM)
  - Asphalt Modification
    - “A History of Asphalt Modification in the USA (John D’Angelo, Consultant)
    - Design of Modified Asphalt Binders (Gaylon Baumgardner, Paragon Technical Services)
    - Recombination of Asphalt with Bio-asphalt: Binder formulation and asphalt mixes application (Joana Peralta, ISU)
    - Evaluation of modification via laboratory performance tests (Louay Mohammad, LSU)
    - Performance assessment of SBS-modified binder systems via paving trials and test sections (Robert Kluttz, Kraton)
    - Control and specification of modified asphalt binders – A DOT perspective (Tanya Nash, Florida DOT)

Thanks!

Global, International, Regular, Associate and Canadian members

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