Implementation of the MSCR Test and Specification

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- Acknowledgments
  - Federal Highway Administration
    - DTFH61-11-H-00033, “Deployment of Innovative Asphalt Binder and Construction Technologies”
      - Michael Arasteh, AOTR
      - John Bukowski, Tom Harman, Matt Corrigan, Jeff Withee, Tim Aschenbrener, Jason Dietz
  - Member Companies of the Asphalt Institute
    - Technical Advisory Committee

Implementation of the MSCR Test and Specification

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- MSCR Test
  - AASHTO T350
- Performance-Graded (PG) Specification using MSCR
  - AASHTO M332
- Practice for Evaluating the Elastic Behavior of Asphalt Binders Using the MSCR Test
  - Draft practice submitted to AASHTO SOM

Implementation of the MSCR Test and Specification

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- Concerns/Questions/Challenges
  - Inconsistent implementation by specifying agencies
  - Grade names in AASHTO M332
  - Variability of MSCR test
  - Selection of appropriate test temperature
  - Leadership/champion
  - Use of recovery-Jnr curve for evaluating elastic response

- Concerns/Questions/Challenges
  - Use and relevance of Jnr-Diff as a specification requirement
  - Use and criterion for intermediate temperature binder parameter (G*sin δ)
  - Criterion for unmodified asphalt binders (“S” grades)
  - Original DSR criterion
  - Quick QC testing on original binder

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- Use of recovery-Jnr curve for evaluating elastic response
  - Some agencies are using the curve as-is
  - Some agencies are specifying a minimum Rec-3.2 value
    - Kentucky has a requirement of Rec-3.2 ≥ 60% for their PG 76-22 asphalt binders (M320) when tested at 64°C
      - Replaces ER
  - Rec-3.2 is determining factor
  - Is curve even needed?
    - Replacement for PG Plus Tests
    - Maximum phase angle

- Use of recovery-Jnr curve for evaluating elastic response
  - D'Angelo Thesis
    - "A minimum MSCR %Recovery of somewhere between 20% and 40% would be a good indication of an effective polymer network in the binder. This range is based on the large increase in %Recovery seen between 2% SBS blend without cross-linker to 2% SBS blend with cross-linker."
    - "The %Recovery should also be tied to the Jnr value for the binder."
      - "To assure the %Recovery response is primarily from the polymer network and not from just a stiffening of the base binder, the minimum %Recovery should be increased as the Jnr value of the binder decreases."

Implementation of the MSCR Test and Specification

- Use of recovery-Jnr curve for evaluating elastic response
  - D'Angelo Thesis

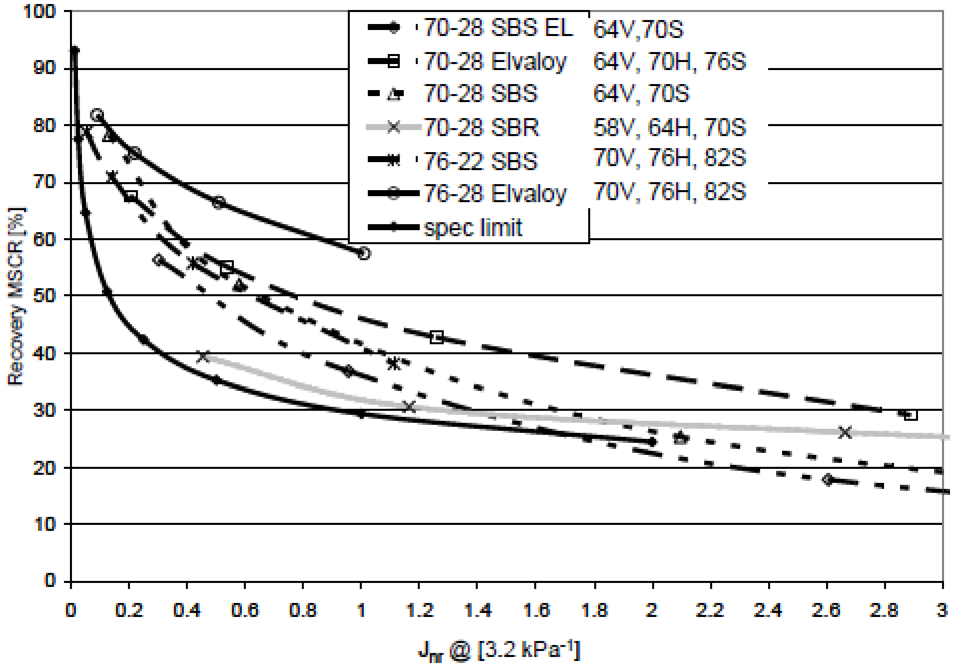
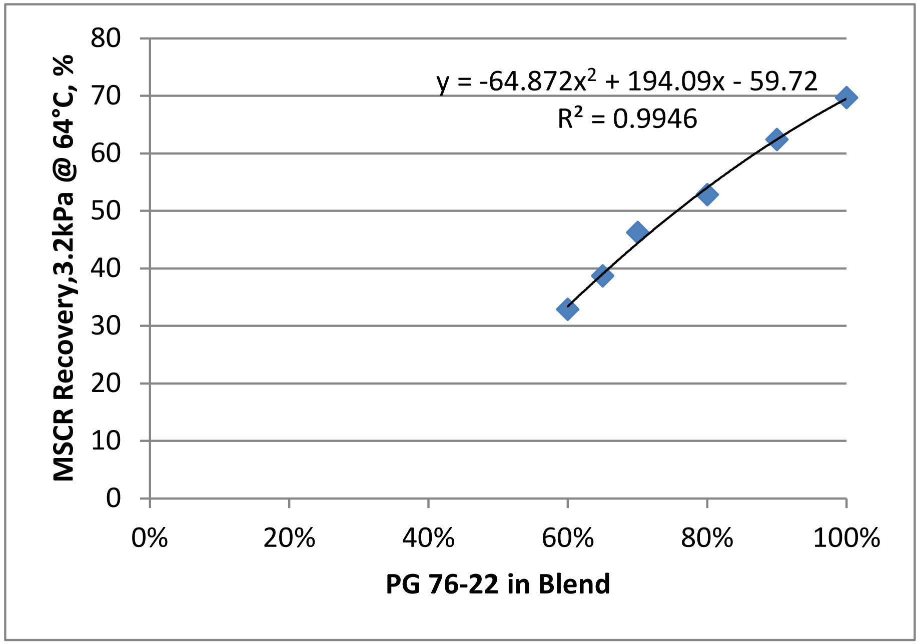
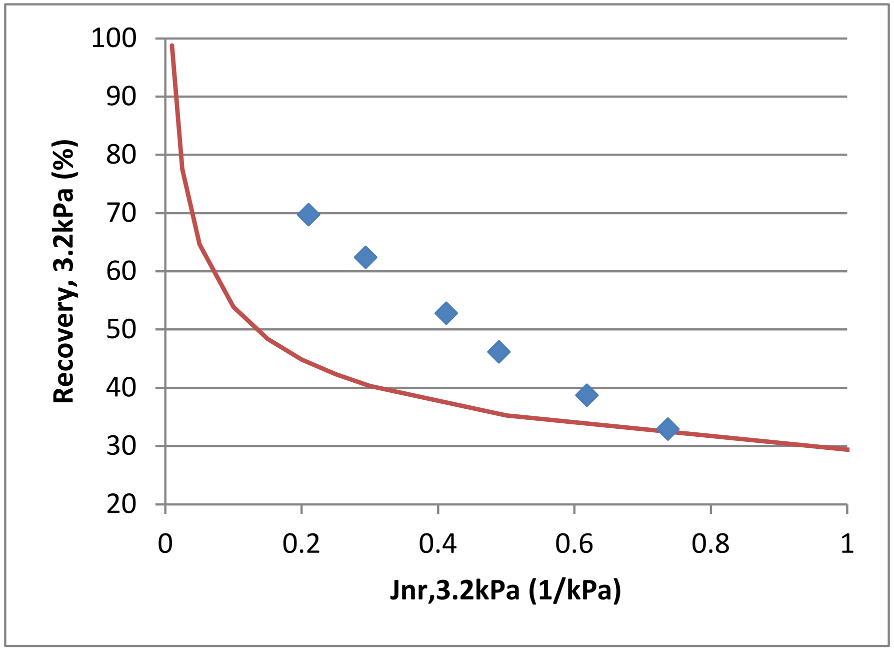


Figure 5.7: Plot of MSCR J_{nr} @ 3.2 kPa^{-1} and MSCR % Recovery for Six Typical Polymer Modified Binders Over Multiple Temperatures From the MTE Polymer Study.

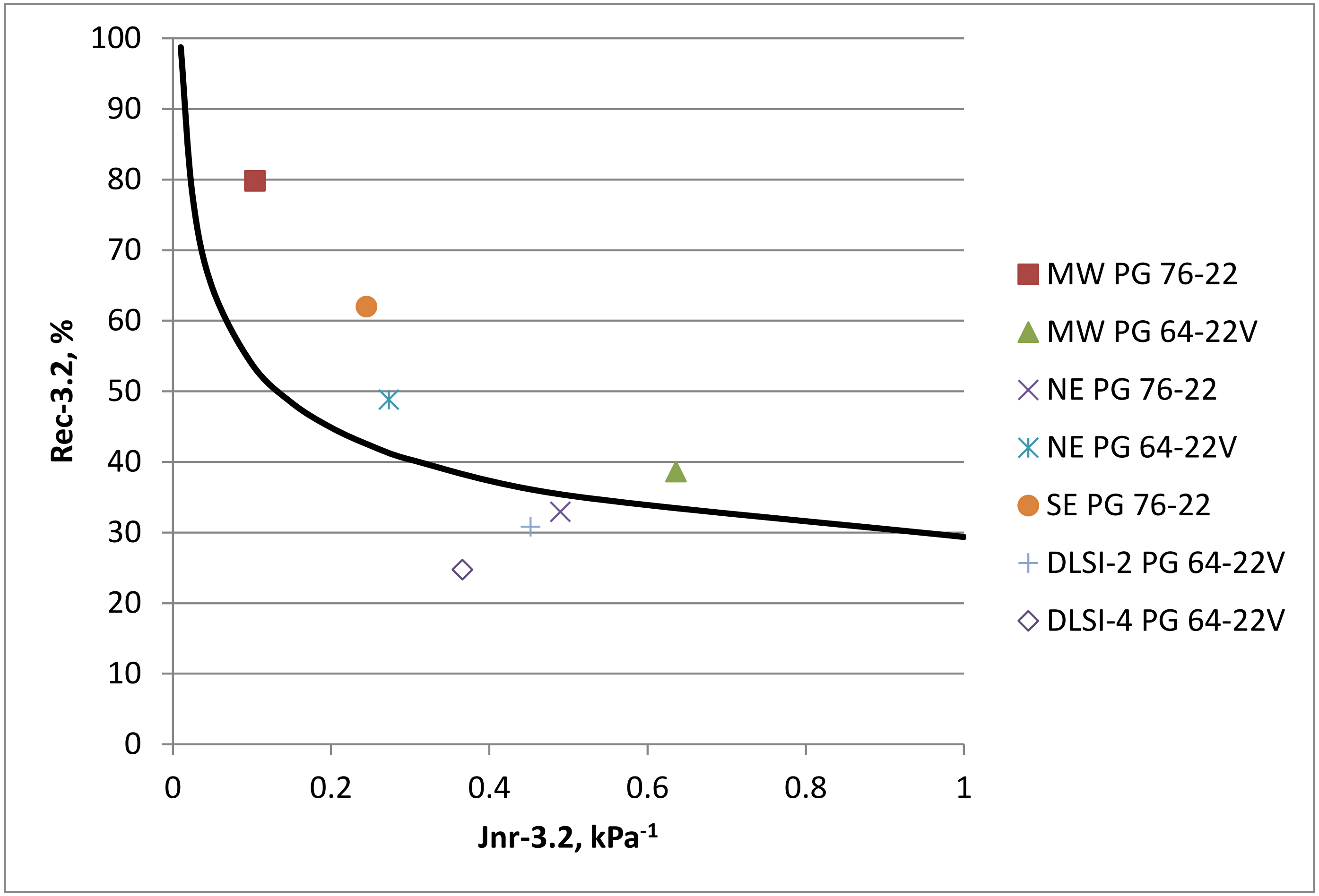
Implementation of the MSCR Test and Specification

- Use of recovery-Jnr curve for evaluating elastic response





- Use of recovery-Jnr curve for evaluating elastic response



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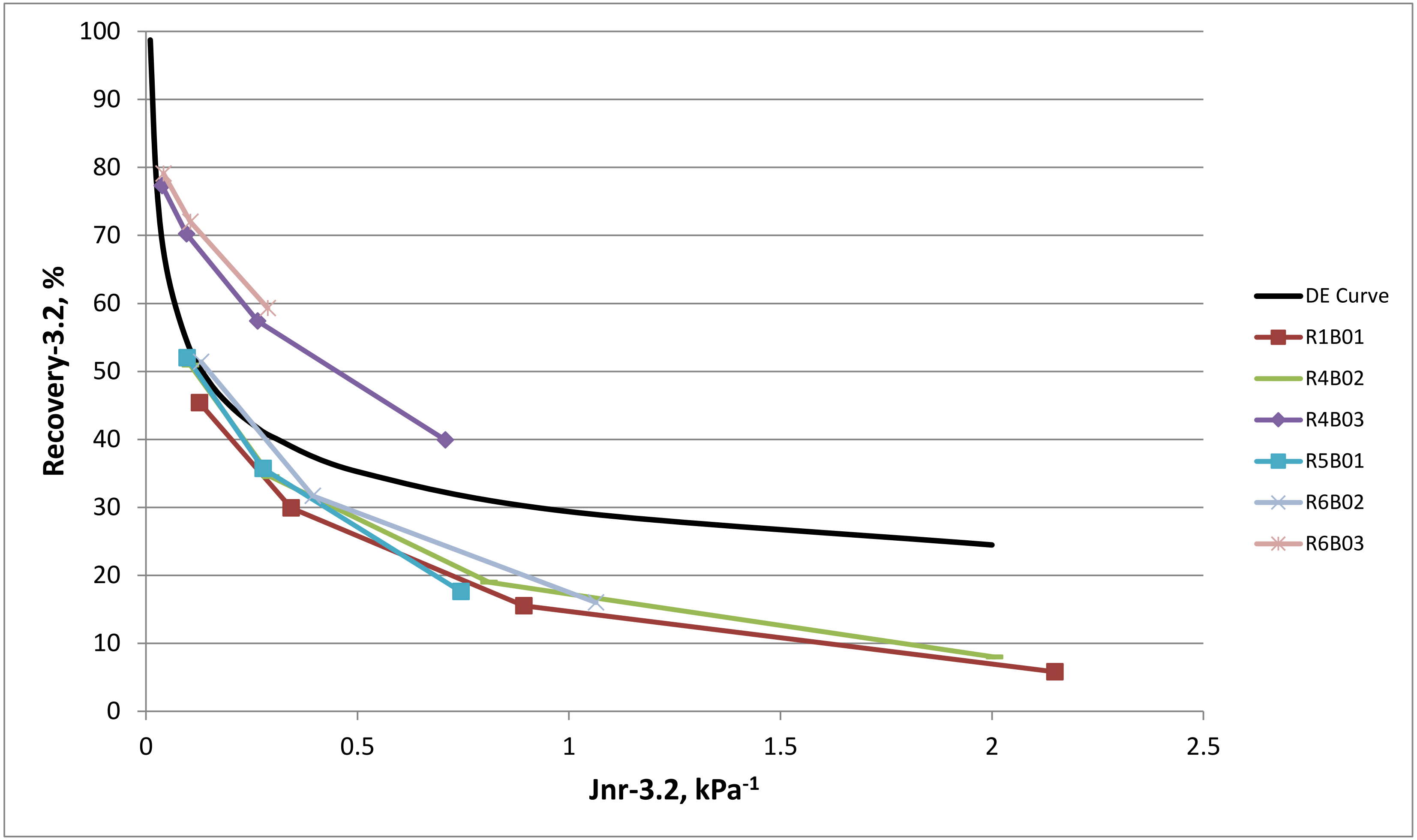
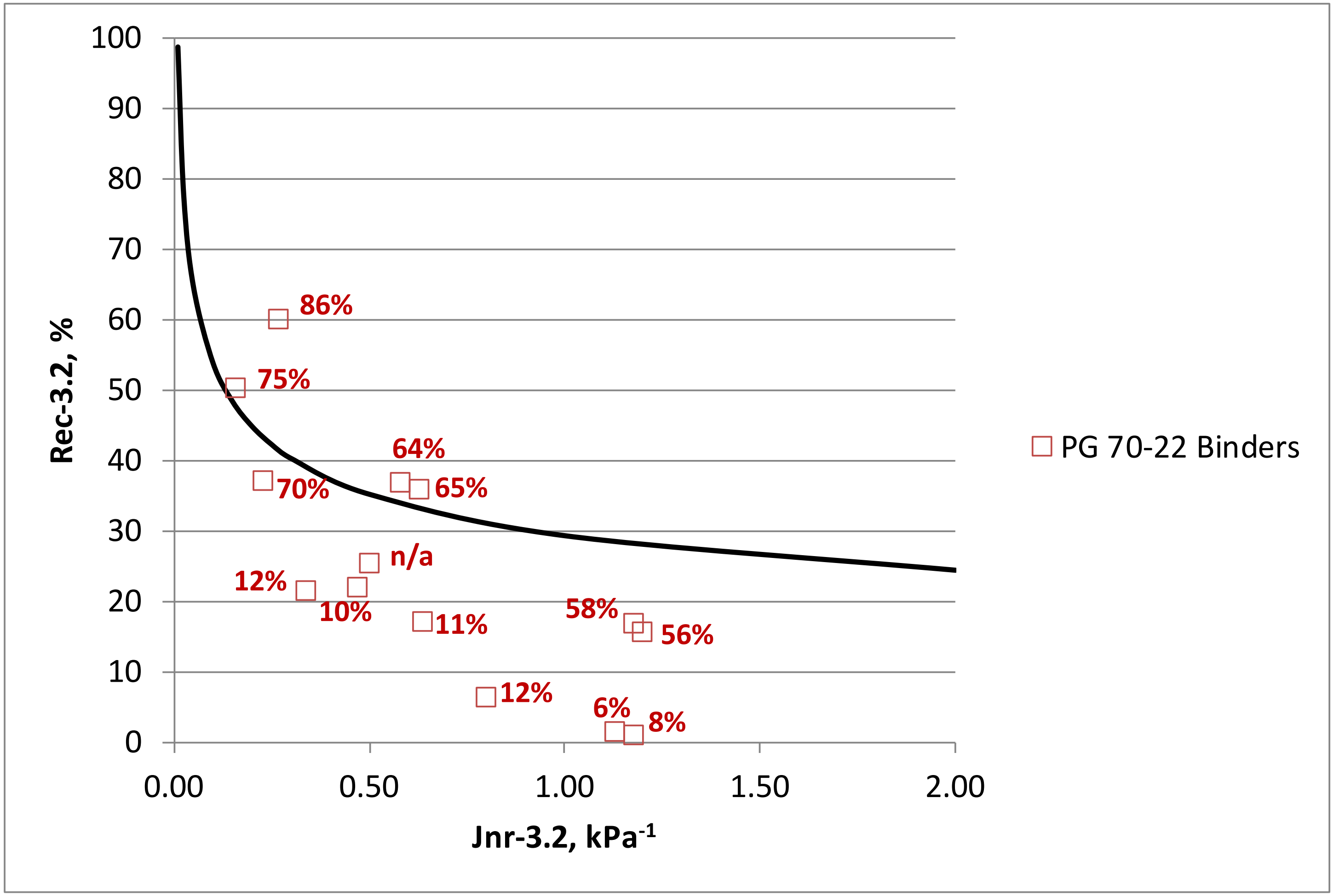


- Use of recovery-Jnr curve for evaluating elastic response



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- Use and relevance of Jnr-Diff as a specification requirement
  - Indicative of stress-sensitive binders
  - Problem for some current formulations
  - Not a problem for the majority of modified binders
  - Is it needed?

- Use and relevance of Jnr-Diff as a specification requirement

ID	Grade	Temp. (°C)	Jnr-3.2 (kPa^{-1})	Rec-3.2 (%)	Jnr-Diff (%)
A	PG 76-28	64	0.748	32.6	1157
B	PG 70-22ER	64	0.311	59.7	20
C	PG 64-28NV	58	0.448	57.2	42
D	PG 64-28PM	58	0.227	73.1	14
E	PG 58-34PM	58	0.532	79.0	38

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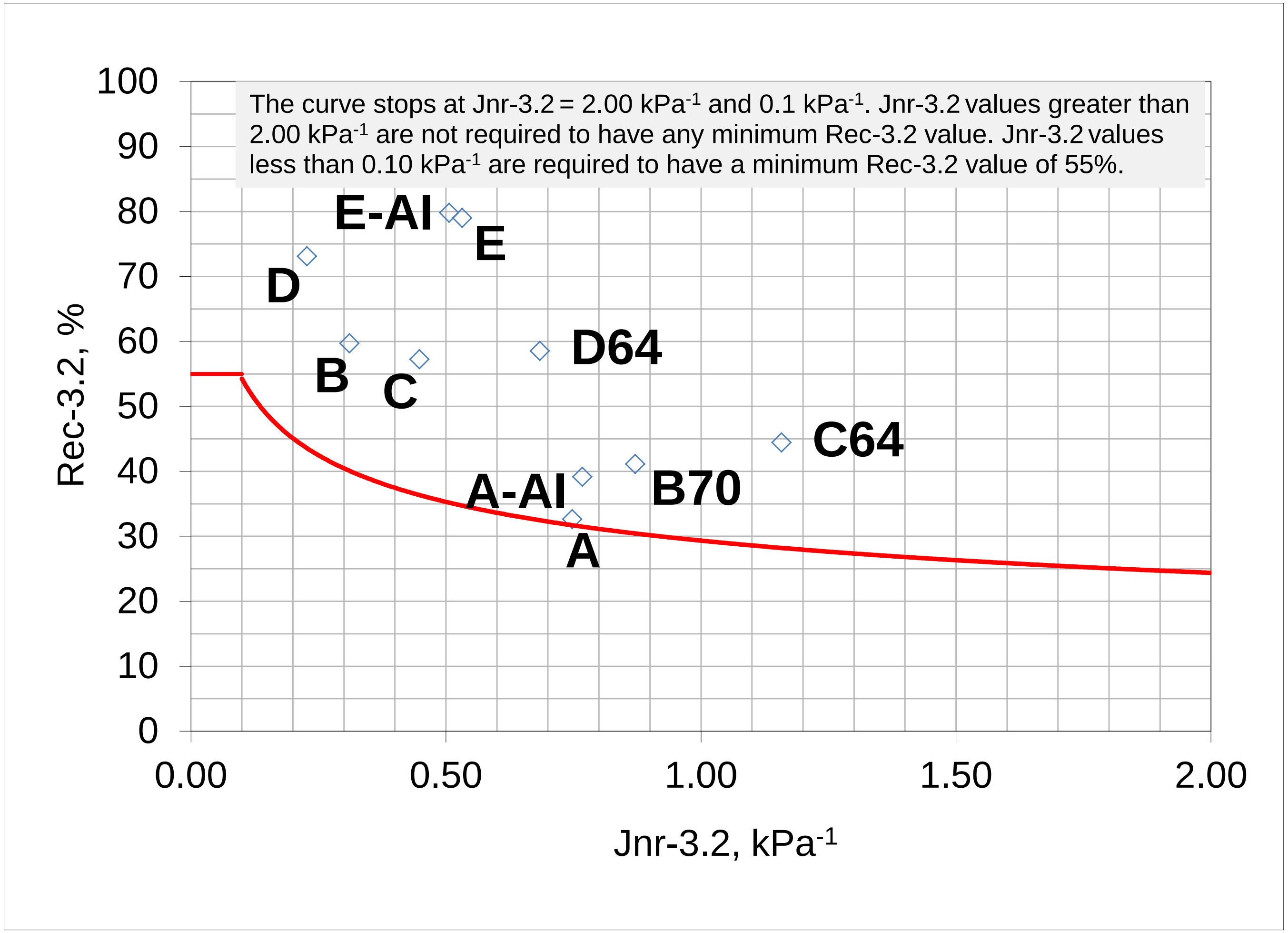
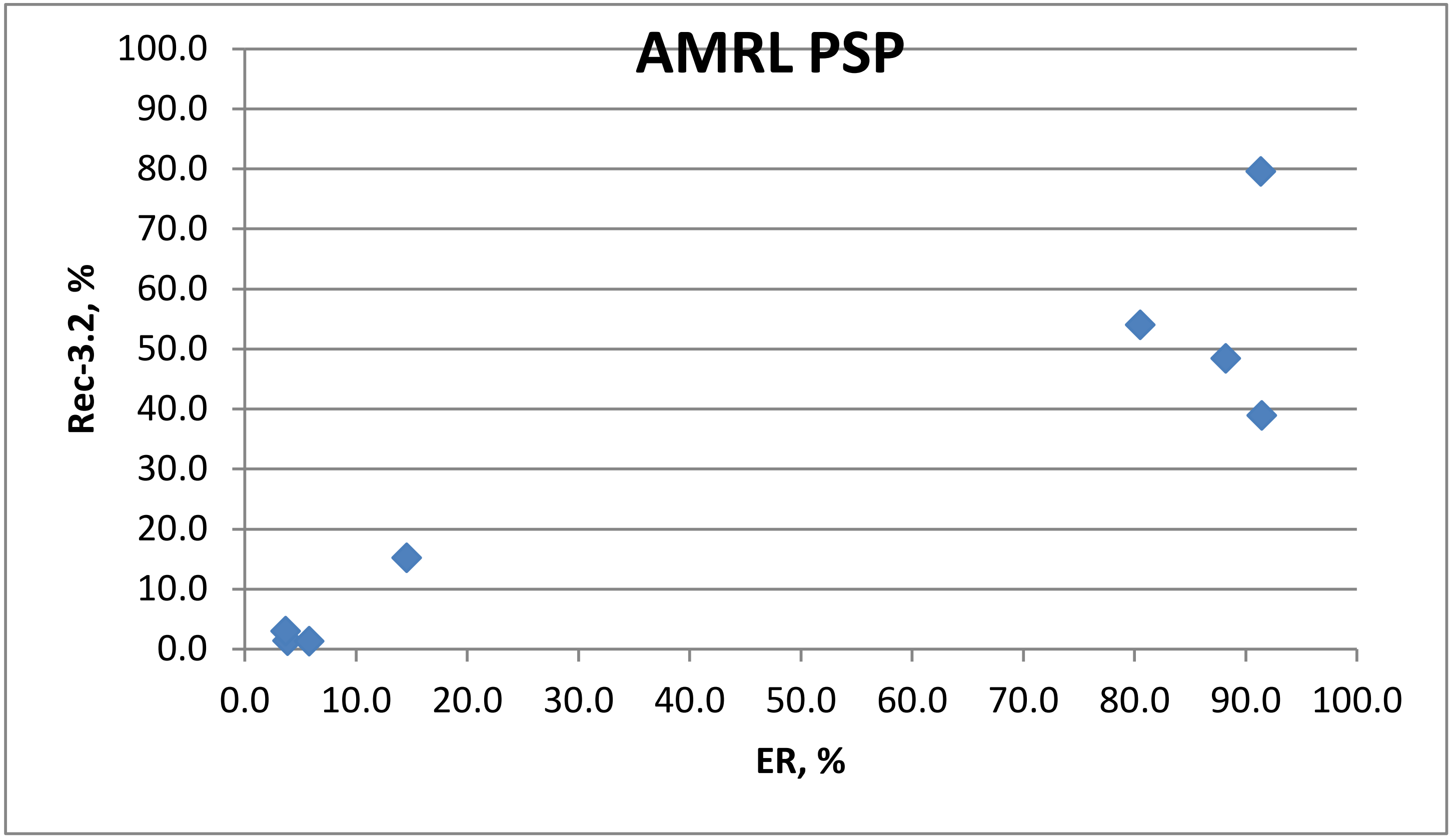
- Use and relevance of Jnr-Diff as a specification requirement



Implementation of the MSCR Test and Specification

- Use and relevance of Jnr-Diff as a specification requirement



Implementation of the MSCR Test and Specification

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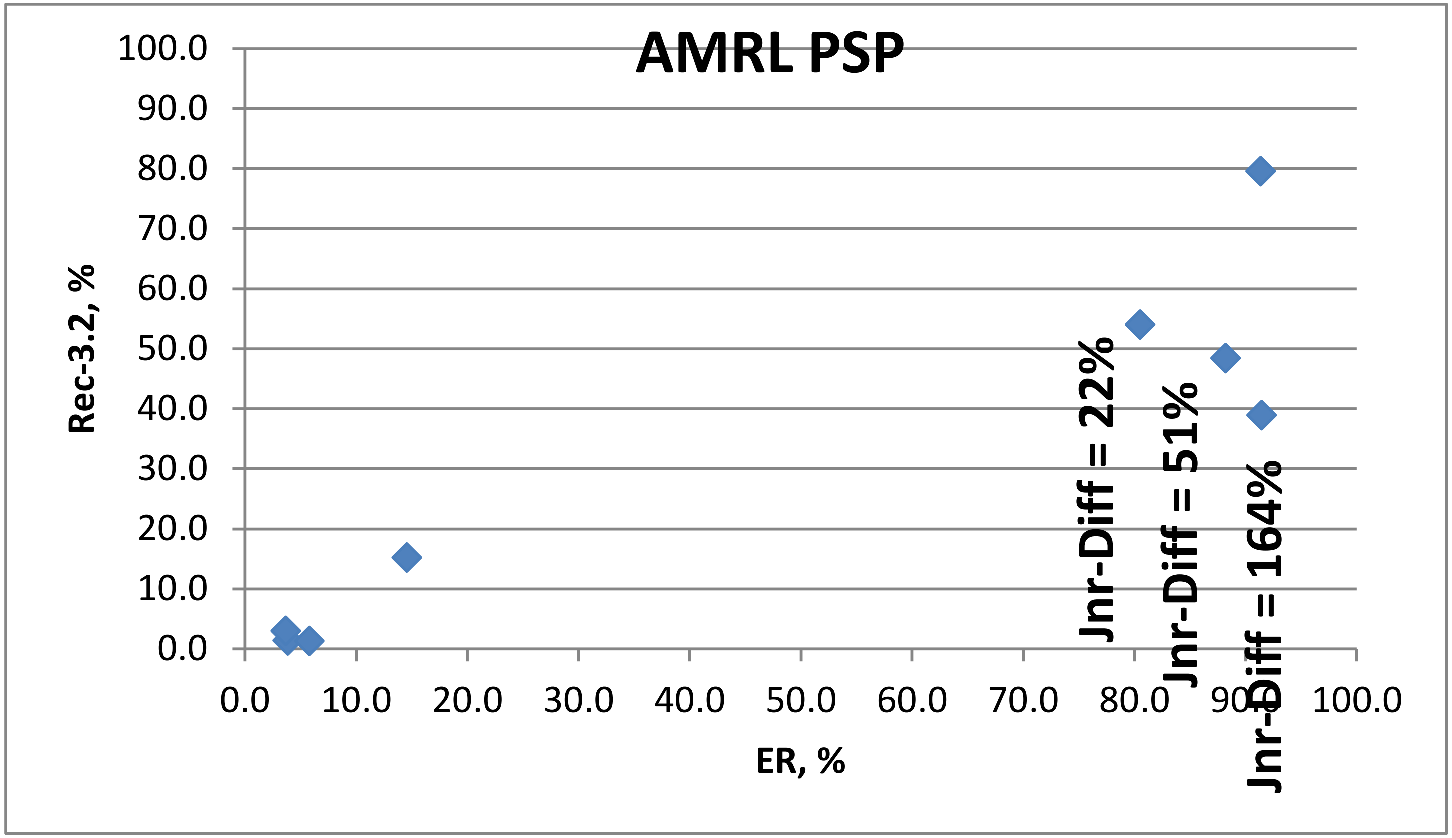
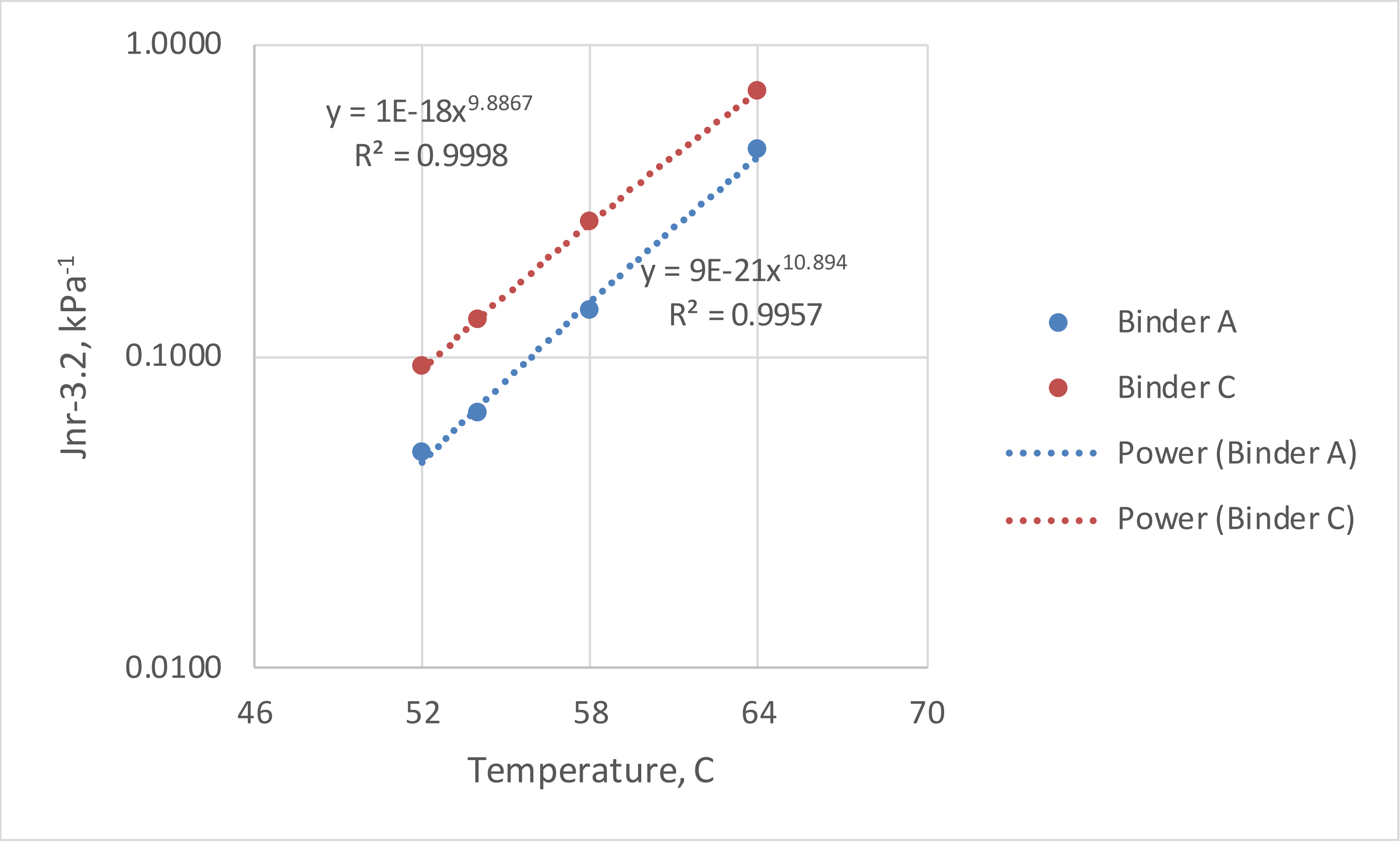


Implementation of the MSCR Test and Specification

- Use and relevance of Jnr-Diff as a specification requirement
  - Experiment using PCCAS ILS Binders
    - Binder A
      - PG 76-28
      - Jnr-3.2 = 0.748 kPa^{-1} at 64°C
      - Rec-3.2 = 32.6% at 64°C
      - Jnr-Diff = 1157% at 64°C
    - Binder C
      - PG 64-28NV
      - Jnr-3.2 = 0.448 kPa^{-1} at 58°C
      - Rec-3.2 = 57.2% at 58°C
      - Jnr-Diff = 42% at 58°C

- Use and relevance of Jnr-Diff as a specification requirement
  - Experiment using PCCAS ILS Binders
    - AI lab standard 9.5mm NMAS mixture
    - 5.4% AC using asphalt binders "A" and "C“
    - Loose mix conditioning for 4 hours at 135°C
    - Compacted using SGC to achieve a final air voids content of 7.0 ± 0.5 percent.
    - Tested using AMPT Flow Number test
      - Temperature of 54 and 58°C
      - Deviator stress of 600kPa
      - Seating load (contact stress) of 30kPa
      - Flow Number reported using a Franken Model fit

- Use and relevance of Jnr-Diff as a specification requirement



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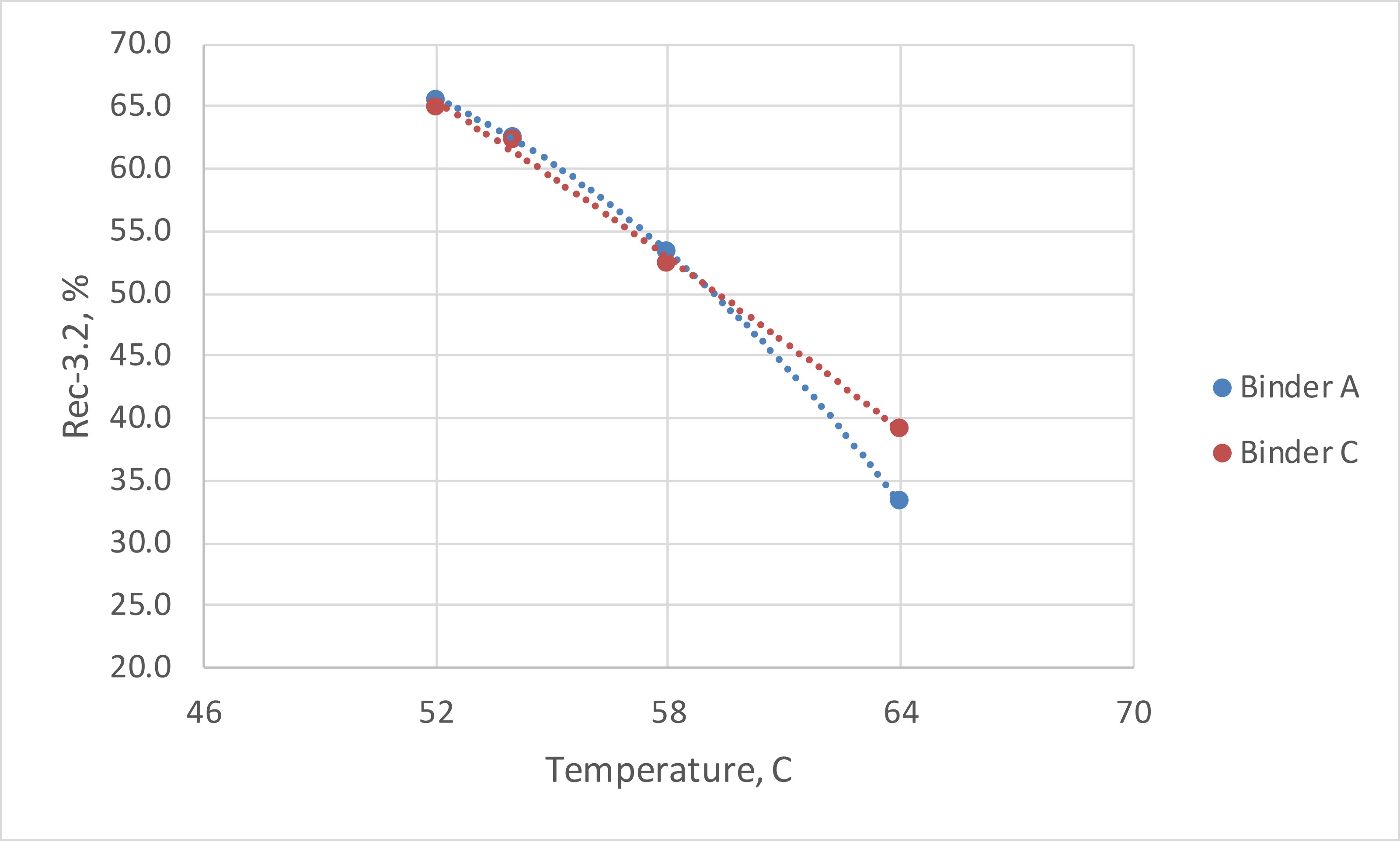

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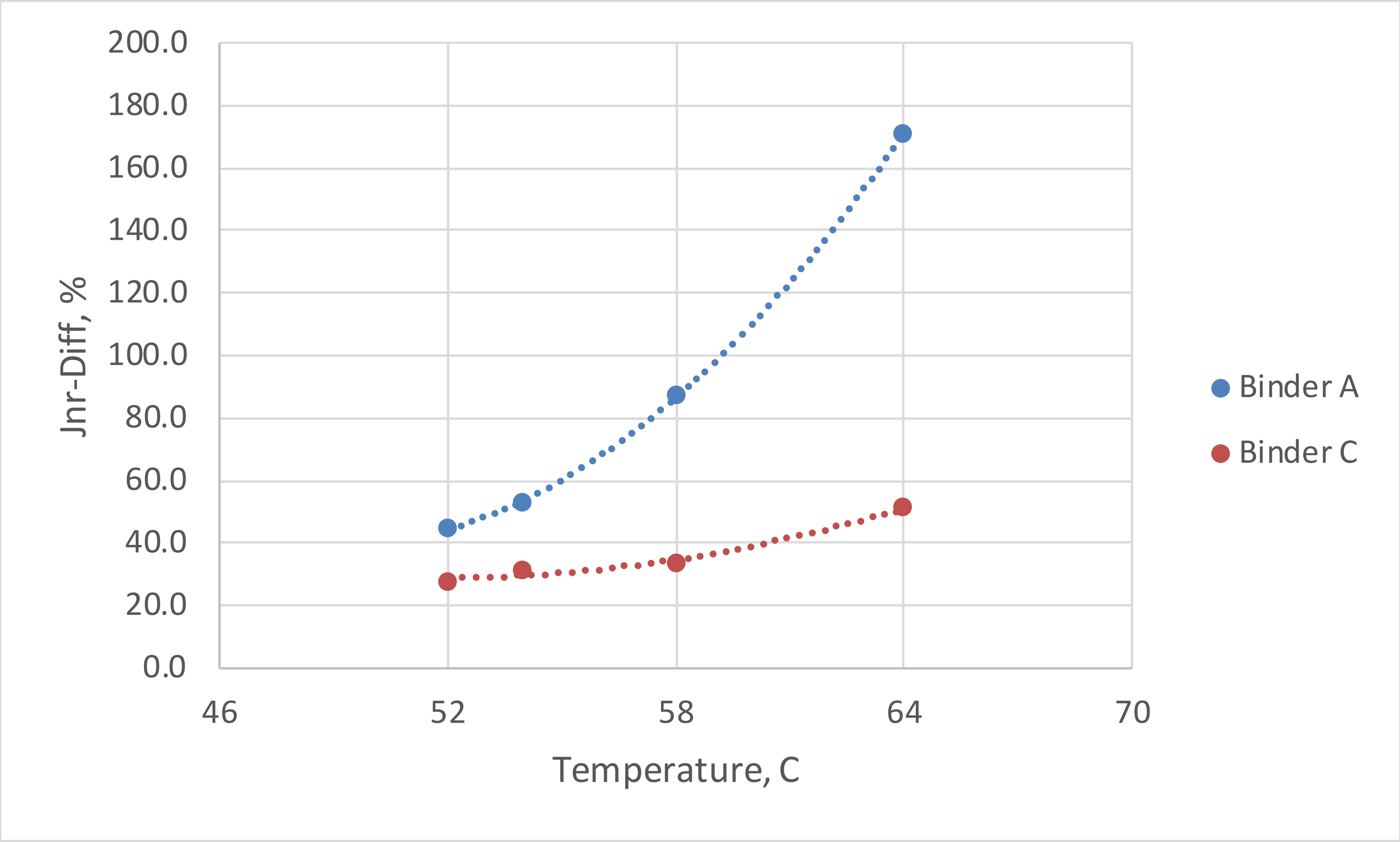

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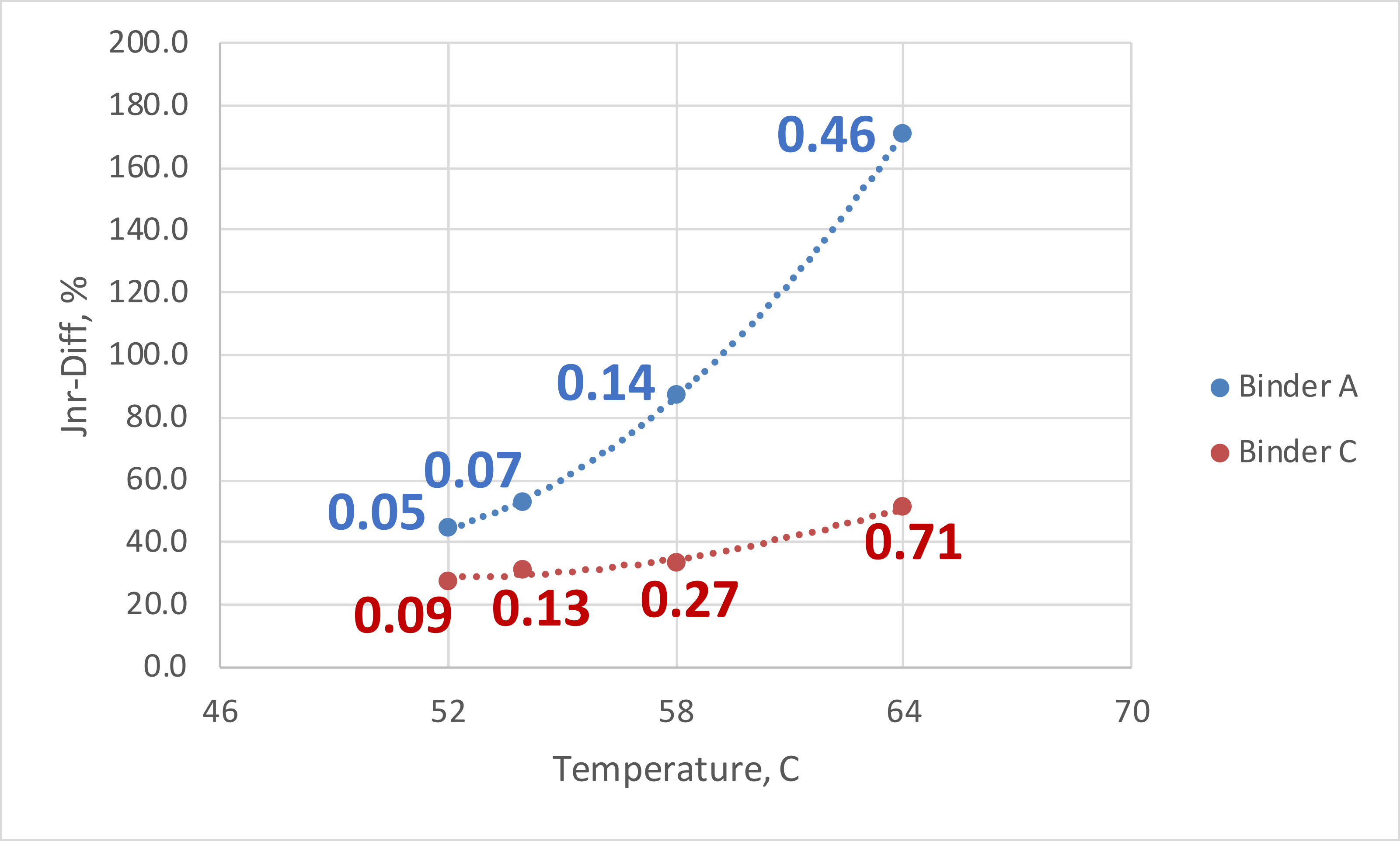

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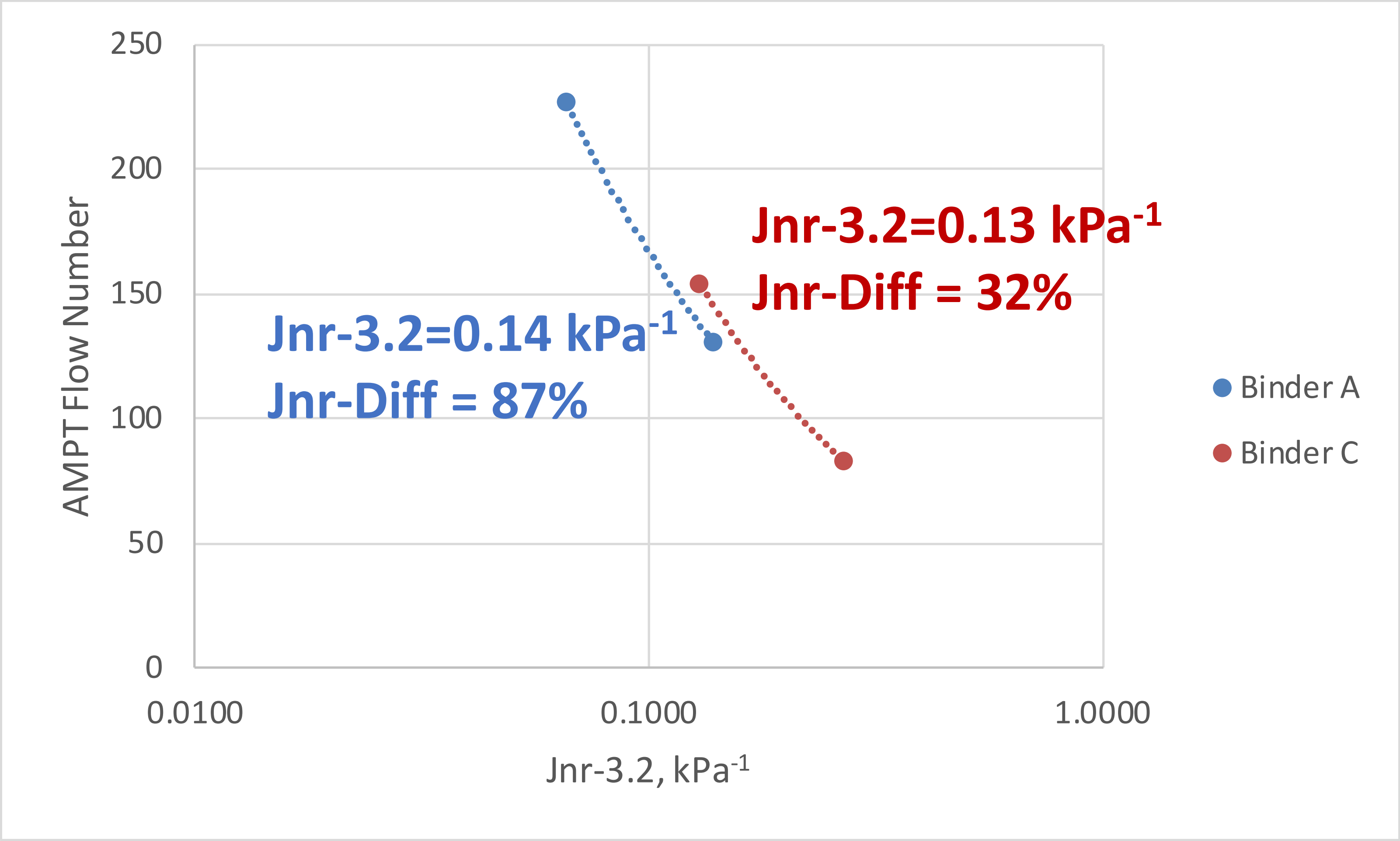

Implementation of the MSCR Test and Specification

- Use and relevance of Jnr-Diff as a specification requirement
  - Proposal to AASHTO SOM Tech Section 2b
    - If Jnr-3.2 ≤ 0.5 kPa^{-1}, then Jnr-Diff requirement is waived

- Use and relevance of Jnr-Diff as a specification requirement

PCCAS MSCR Task Group: Analysis of 2015 Data

				PG			
ID	**Grade**	**Supplier**	**Location**	**Jnr-0.1**	**Jnr-3.2**	**Rec-3.2**	**Jnr-Diff**
23	PG 64-28NV	A	NV	0.699	1.394	46.9	100.5
24	PG 64-28NV	A	NV	0.766	1.592	44.5	108.6
28	PG 64-28PM	B	CA	0.62	1.136	54.6	83
31	PG 70-28ER	C	OR	0.2	0.42	60.6	110.3
32	PG 70-28ER	D	OR	0.71	1.38	43.6	96.6
38	PG 76-22	E	n/a	0.416	0.951	59.7	128.4
39	PG 76-22NV	E	NV	0.34	0.7	68.9	104.8
42	PG 58-34	F	AK	0.04	0.22	91.3	436
43	PG 58-34	G	AK	0.02	0.11	95.9	486
44	PG 58-34	H	WA	0.439	0.812	40.6	94.7
46	PG 52-40	F	AK	0.15	0.53	72	296
47	PG 52-40	G	AK	0.04	0.21	90.8	463

- Use and relevance of Jnr-Diff as a specification requirement

PCCAS MSCR Task Group: Analysis of 2015 Data

				PG-6			
ID	**Grade**	**Supplier**	**Location**	**Jnr-0.1**	**Jnr-3.2**	**Rec-3.2**	**Jnr-Diff**
23	PG 64-28NV	A	NV	0.331	0.494	61.9	49.2
24	PG 64-28NV	A	NV	0.371	0.574	60	54.3
28	PG 64-28PM	B	CA	0.278	0.351	73.8	26.6
31	PG 70-28ER	C	OR	0.09	0.15	74.3	60.6
32	PG 70-28ER	D	OR	0.35	0.52	58.7	53
38	PG 76-22	E	n/a	0.166	0.337	73.8	104.7
39	PG 76-22NV	E	NV	0.13	0.24	80.7	86.3
42	PG 58-34	F	AK	0.02	0.12	92.5	769
43	PG 58-34	G	AK	0.01	0.07	94.1	640
44	PG 58-34	H	WA	0.328	0.514	45.7	75.9
46	PG 52-40	F	AK				
47	PG 52-40	G	AK				

- Use and relevance of Jnr-Diff as a specification requirement

PCCAS MSCR Task Group: Analysis of 2015 Data

				PG-12			
ID	**Grade**	**Supplier**	**Location**	**Jnr-0.1**	**Jnr-3.2**	**Rec-3.2**	**Jnr-Diff**
23	PG 64-28NV	A	NV				
24	PG 64-28NV	A	NV				
28	PG 64-28PM	B	CA	0.131	0.144	80.3	10.4
31	PG 70-28ER	C	OR	0.04	0.06	81	49.5
32	PG 70-28ER	D	OR	0.16	0.21	67.7	36.8
38	PG 76-22	E	n/a	0.031	0.055	86.4	82.2
39	PG 76-22NV	E	NV				
42	PG 58-34	F	AK				
43	PG 58-34	G	AK				
44	PG 58-34	H	WA				
46	PG 52-40	F	AK				
47	PG 52-40	G	AK				

Implementation of the MSCR Test and Specification

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- Variability of MSCR test
  - Continued expressed concerns about variability in Jnr and Rec
  - WCTG Data Set
    - Higher test temperature
    - Higher applied shear stress

- Variability of MSCR test
  - WCTG Data Set

COV Comparison of Superpave PG Plus Tests, 2010-2011 samples				
Test	Maximum	Minimum	Average	Median
Ductility, Unaged	21.8%	6.3%	11.8%	10.8%
Ductility, RTFO	17.4%	8.2%	13.9%	13.9%
Toughness, Unaged	23.6%	4.6%	14.9%	14.9%
Tenacity, Unaged	49.0%	8.9%	21.9%	17.9%
Jnr, 3.2 kPa @ PG Temp.	57.0%	5.2%	27.5%	29.1%
Jnr, 3.2 kPa @ PG - 6 °C Temp.	51.1%	6.9%	24.3%	23.9%
Jnr, 10 kPa @ PG Temp.	878.4%	52.0%	137.1%	78.7%
Jnr, 10 kPa @ PG - 6 °C Temp.	237.3%	54.0%	92.8%	77.6%
% Rec, 3.2 kPa @ PG Temp.	58.4%	2.7%	13.8%	6.7%
% Rec, 3.2 kPa @ PG - 6 °C Temp.	18.8%	0.8%	7.2%	3.9%
% Rec, 10 kPa @ PG Temp.	86.5%	12.1%	39.1%	35.1%
% Rec, 10 kPa @ PG - 6 °C Temp.	55.4%	5.6%	22.1%	20.6%
% Elastic Recovery, 25 °C	5.9%	1.0%	2.5%	2.0%
Maximum	878.4%	54.0%	137.1%	78.7%
Minimum	5.9%	0.8%	2.5%	2.0%

- Variability of MSCR test
  - WCTG Data Set

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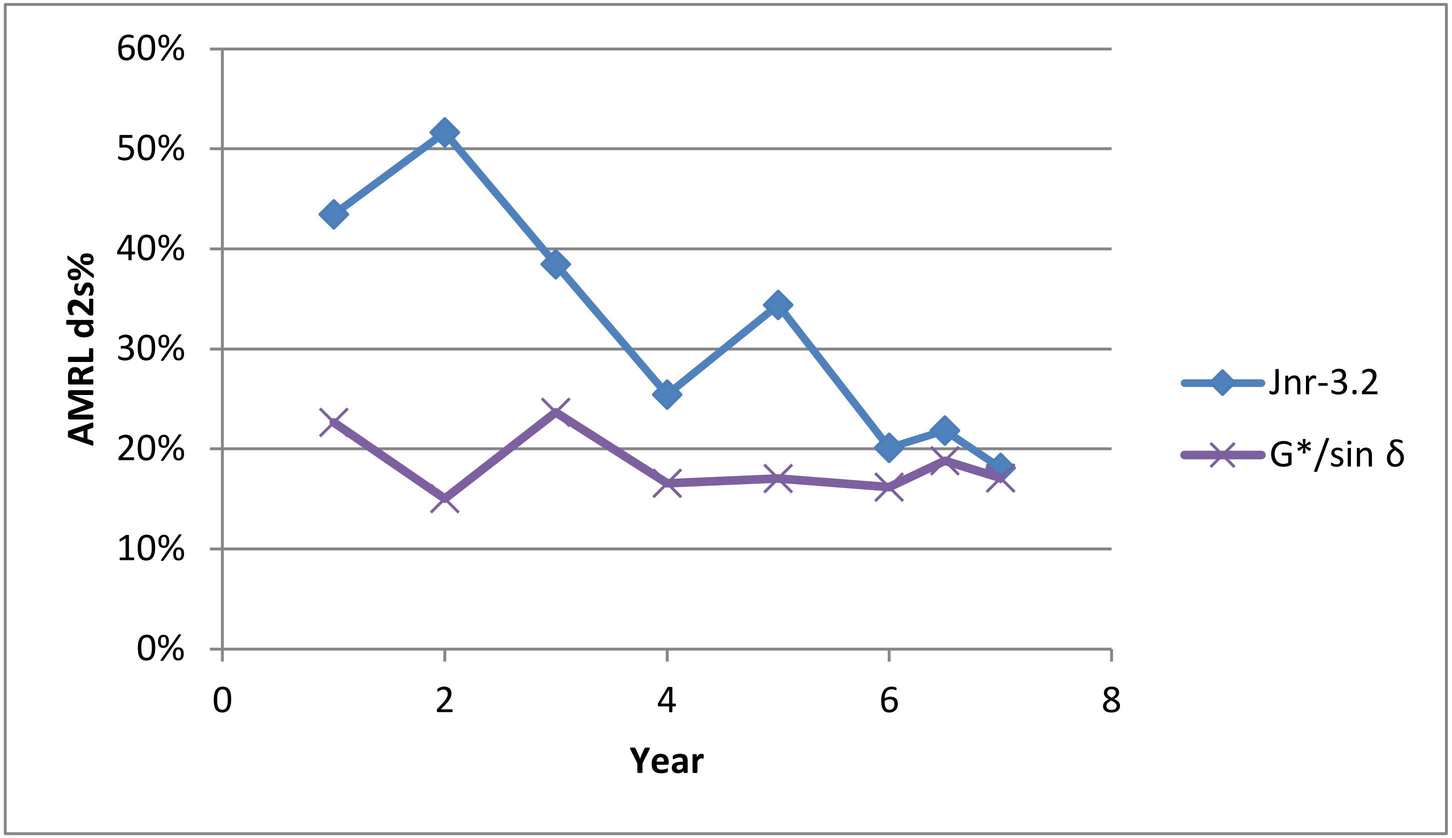
Tenacity, Unaged	49.0%	8.9%	21.9%	17.9%
Jnr, 3.2 kPa @ PG Temp.	57.0%	5.2%	27.5%	29.1%
Jnr, 3.2 kPa @ PG - 6 °C Temp.	51.1%	6.9%	24.3%	23.9%
Jnr, 10 kPa @ PG Temp.	878.4%	52.0%	137.1%	78.7%
Jnr, 10 kPa @ PG - 6 °C Temp.	237.3%	54.0%	92.8%	77.6%
% Rec, 3.2 kPa @ PG Temp.	58.4%	2.7%	13.8%	6.7%
% Rec, 3.2 kPa @ PG - 6 °C Temp.	18.8%	0.8%	7.2%	3.9%
% Rec, 10 kPa @ PG Temp.	86.5%	12.1%	39.1%	35.1%
% Rec, 10 kPa @ PG - 6 °C Temp.	55.4%	5.6%	22.1%	20.6%
% Elastic Recovery, 25 °C	5.9%	1.0%	2.5%	2.0%
Maximum	878.4%	54.0%	137.1%	78.7%
Minimum	5.9%	0.8%	2.5%	2.0%

Implementation of the MSCR Test and Specification

- Variability of MSCR test
  - AI-Coordinated ILS
    - d2s% shown for between lab (reproducibility)

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%

- Variability of MSCR test
  - AMRL PSP



- Variability of MSCR test
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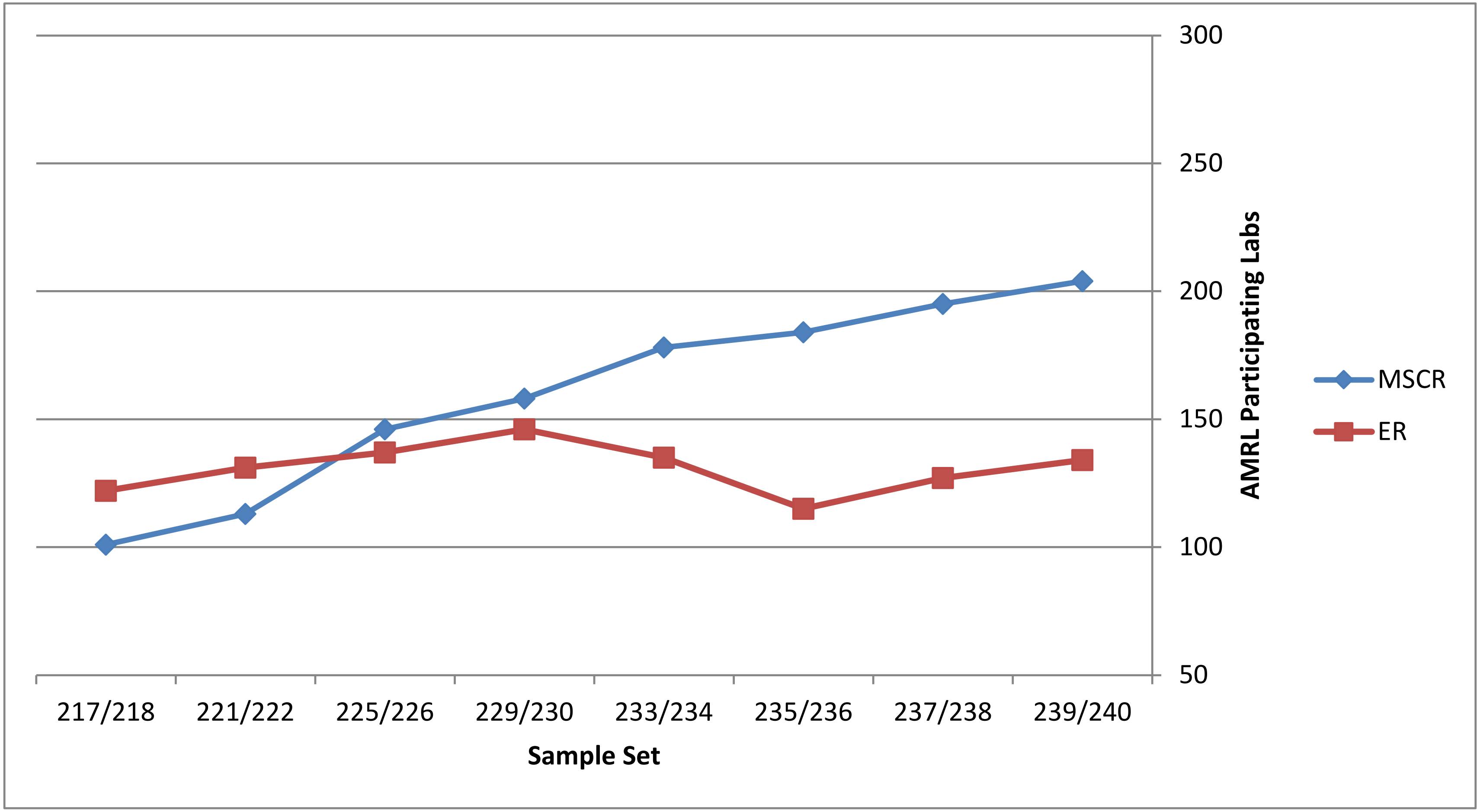

- Variability of MSCR test
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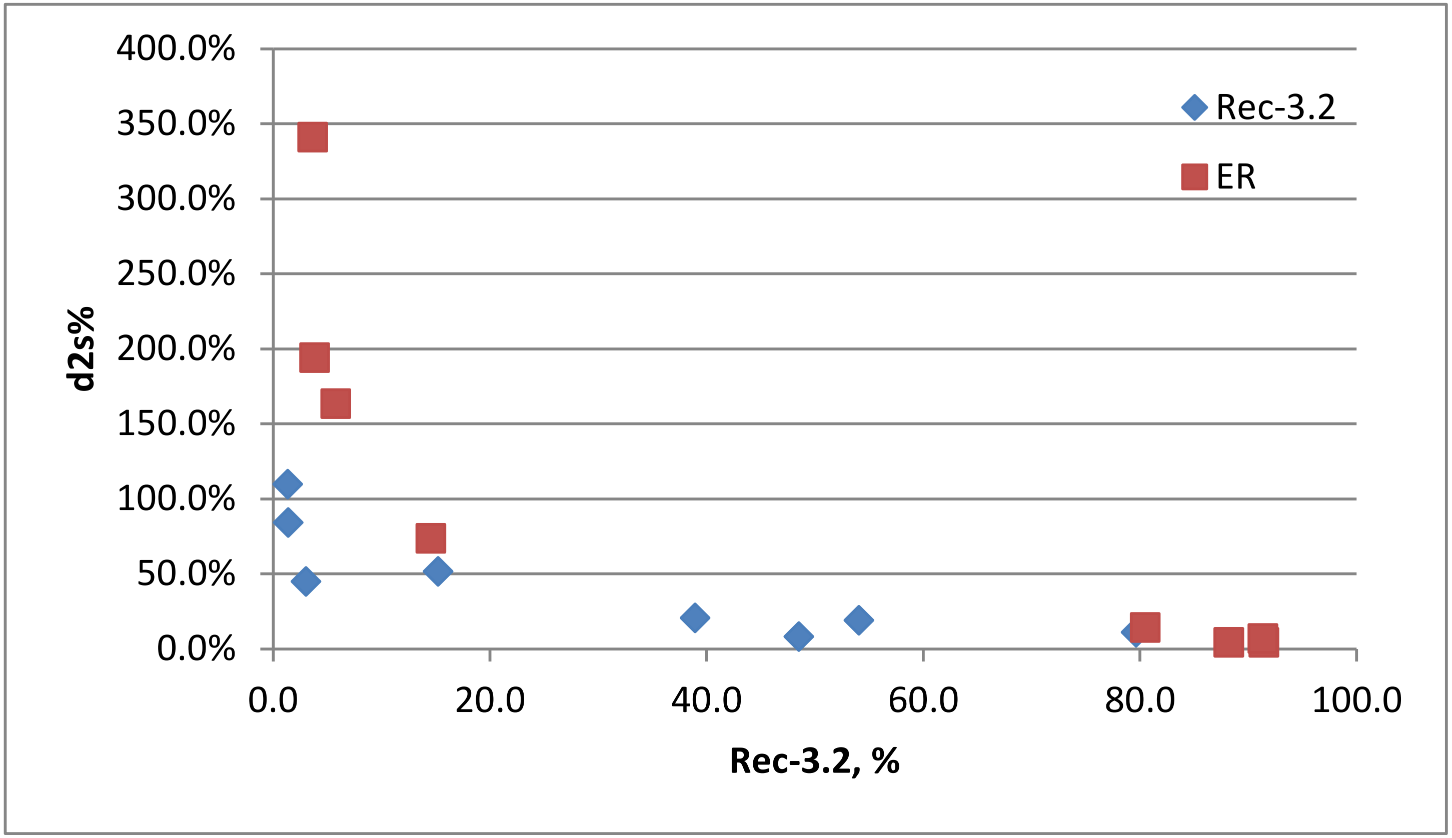


Implementation of the MSCR Test and Specification

- Variability of MSCR test
  - PCCAS ILS (2013)

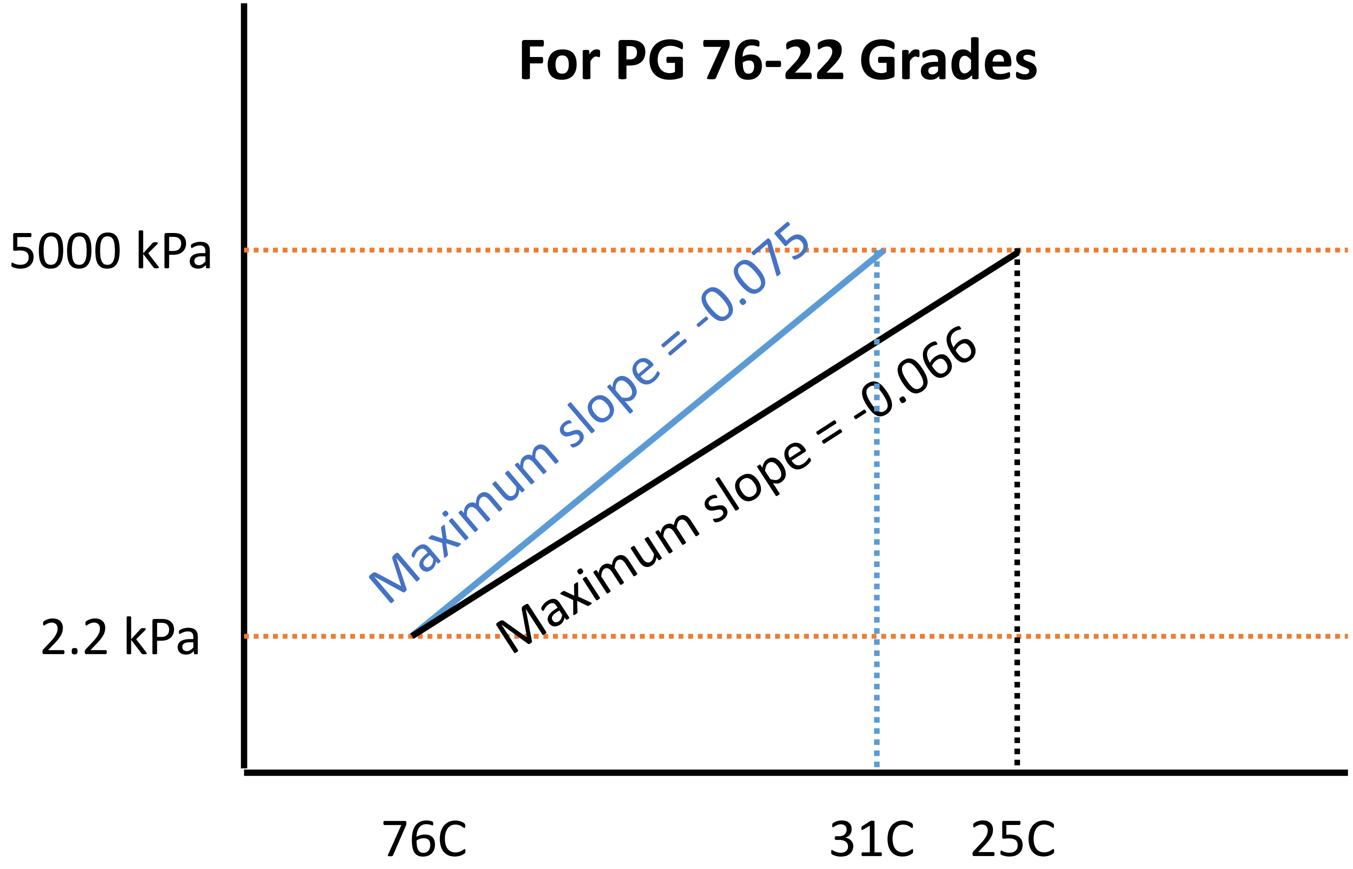
Table 20: Estimated Repeatability and Reproducibility from ILS

	Acceptable Range of Two Test Results (d2s%) 2013 PCCAS ILS	
Test	*Single Operator Precision*	*Multilaboratory Precision*
Elastic Recovery (RTFO) at 25°C	5.6%	9.2%
R&B Softening Point	2.8%	7.7%
Ductility (Original) at 4°C	17.9%	75.0%
Ductility (RTFO) at 4°C	19.5%	95.1%
Toughness at 25°C	15.3%	29.1%
Tenacity at 25°C	17.9%	30.0%
MSCR Rec-3.2	8.0%	17.3%

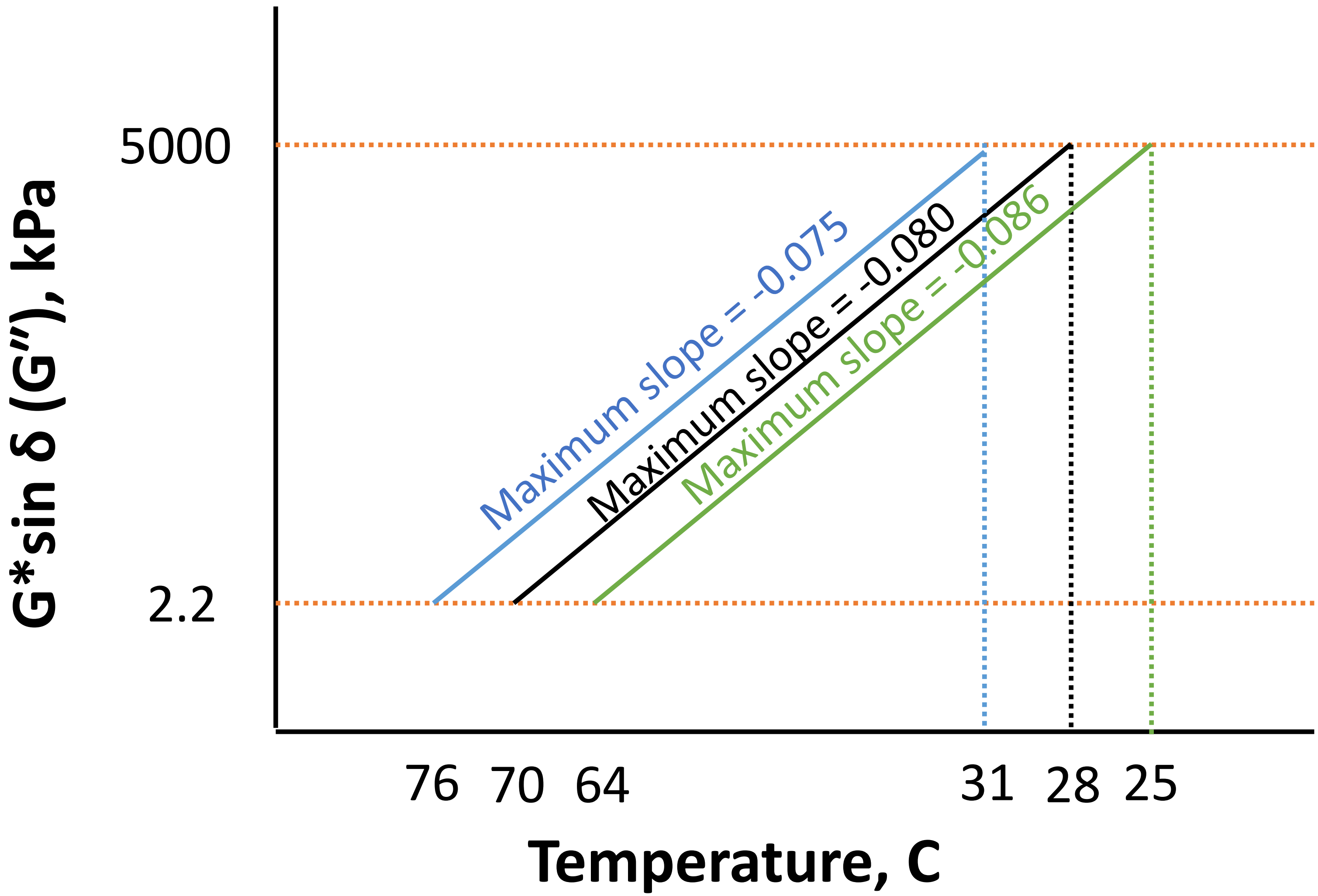
Implementation of the MSCR Test and Specification

- Use and criterion for intermediate temperature binder parameter (G*sin δ)
  - Not specifically a concern with MSCR
    - Use of G*sin δ as intermediate parameter
    - Change to environmental temperature makes matters worse
      - PG 76-22 would be tested at 31°C and G*sin δ would have to be ≤ 5000 kPa
      - PG 64V-22 would be tested at 25°C and G*sin δ would have to be ≤ 6000 kPa
    - Shouldn't criterion change for each grade (H,V, and E)?

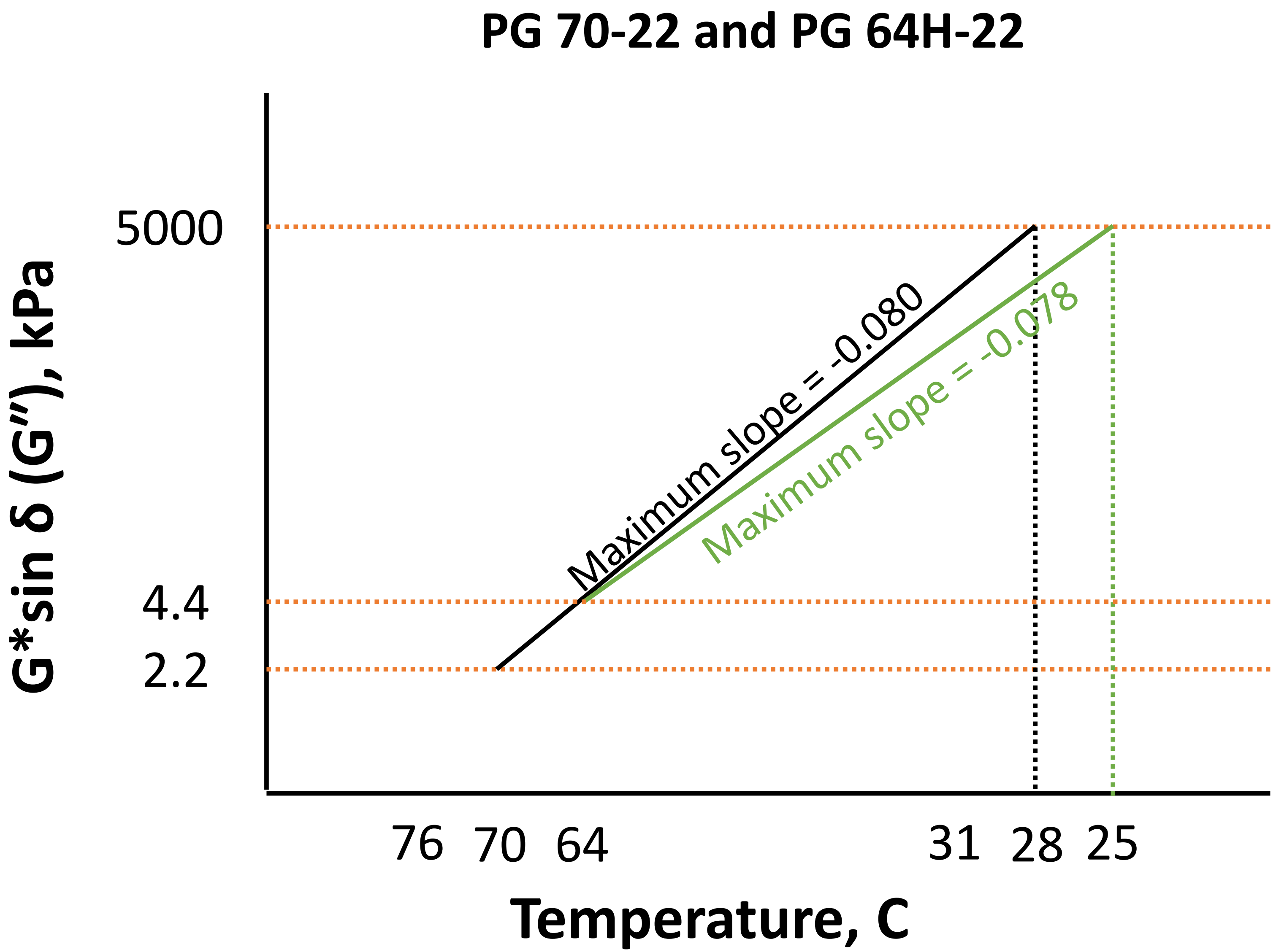
- Use and criterion for intermediate temperature binder parameter (G*sin δ)



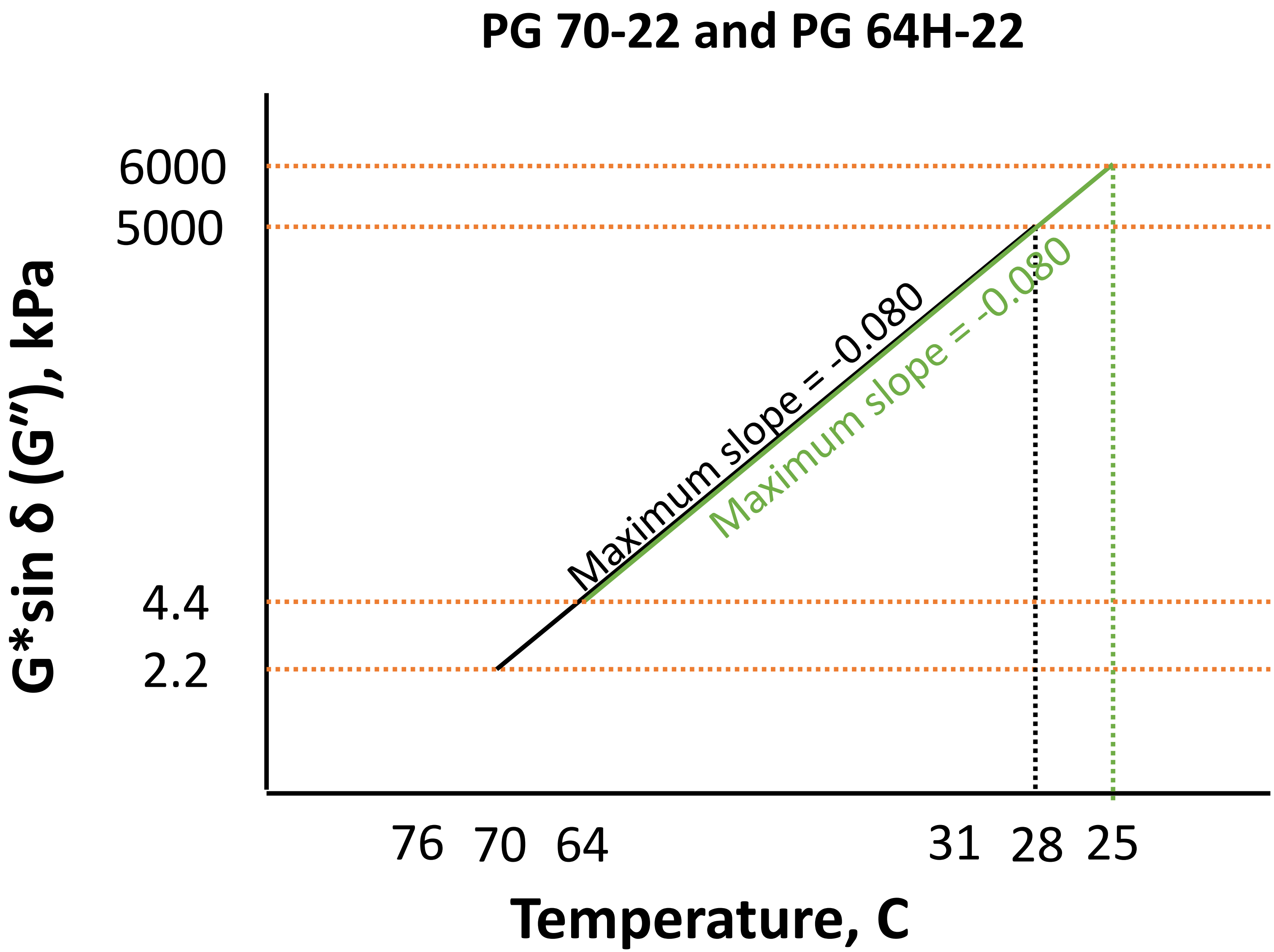
Effect of Intermediate Temperature on Temp. Susceptibility: PG xx-22 Binders



Effect of Intermediate Temperature on Temp. Susceptibility: M320 and M332



Effect of Intermediate Temperature on Temperature Susceptibility



Effect of Intermediate Temperature on Temperature Susceptibility

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M332 Grade	M332 Spec	Equal G-T Slope
S	5000 kPa	5000 kPa
H	6000 kPa	5758 kPa
V	6000 kPa	7136 kPa
E	6000 kPa	9391 kPa

Effect of Intermediate Temperature on Temperature Susceptibility

M332 Grade	Assume δ≈90° at HT	w/ consideration of δ
S	5000 kPa	5000 kPa
H	5758 kPa	5084 kPa
V	7136 kPa	5352 kPa
E	9391 kPa	5510 kPa

Effect of Intermediate Temperature on Temperature Susceptibility

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M332 Grade	Assume δ≈90° at HT	w/ consideration of δ	
S	5000 kPa	5000 kPa	
H	5758 kPa	5084 kPa	**70°**
V	7136 kPa	5352 kPa	**60°**
E	9391 kPa	5510 kPa	**50°**

Implementation of the MSCR Test and Specification

- Use and criterion for intermediate temperature binder parameter (G*sin δ)
  - Not specifically a concern with MSCR
    - Change to environmental temperature makes matters worse
      - PG 76-22 would be tested at 31°C and G*sin δ would have to be ≤ 5000 kPa
      - PG 64V-22 would be tested at 25°C and G*sin δ would have to be ≤ 6000 kPa
    - Shouldn't criterion change for each grade (H,V, and E)?

Current M332 specification appears reasonable. Could still make an argument that a sliding scale is needed…

H=5500 kPa V=6000 kPa E=6500 kPa

Implementation of the MSCR Test and Specification

- Grade names in AASHTO M332
  - Acceptance of letter designation for traffic
  - Need high temperature (environmental) as part of the grade name to know appropriate test temperature
  - PG designation is still appropriate
    - Still a Performance Graded asphalt binder
      - Even more so since Jnr is better correlated to rutting distress than $G^*/\sin\delta$ for both modified and unmodified binders
  - Education for Designers, truck drivers
  - Confusion of E and V (similar sounds) when ordering
    - Consider “X” instead of “E”?

Implementation of the MSCR Test and Specification

- Inconsistent implementation by specifying agencies
  - We don’t have a rutting problem so why do we need a better high temperature parameter?
  - Every M320 grade may not equate to a distinct M332 grade
    - the current polymer loading in a PG 70-22 and PG 76-22 may be high enough that both grade to a PG 64V-22

- MTE Rutting Study: Hamburg WI E10 Fine Mix

PG GRADE (M320)	PG GRADE (MP19)	Test Temp, C	Jnr-3.2 at Test Temp, kPa^{-1}	Rec-3.2, %	HWT Rut Depth at 10,000 Passes, mm
70-22	n/a	75	5.74	0.5	13.2
64-22	64-22S	64	3.40	3.4	7.1
70-22	70-22S	70	2.92	1.5	5.1
70-22	64-22H	64	1.35	4.4	3.6
76-22	64-22E	64	0.24	55.8	1.7
82-22	64-22E	64	0.08	78.5	1.6

Implementation of the MSCR Test and Specification

- Leadership/champion
  - Implementation belongs to everyone
    - PG system had leaders in all areas
      - Researchers
        - Dr. Tom Kennedy, A-001 Research Program Leader
      - Users
        - FHWA (implementation funding and technology transfer)
        - Lead States
      - Industry
        - Expert Task Group
        - Suppliers
    - Need leaders in user agencies, industry

Implementation of the MSCR Test and Specification

- Suggestions for Path Forward
  - Need to repackage message
    - What should have been done as PG system was implemented was to change high temperature criterion as grade was bumped (due to traffic)
    - Need to change criterion rather than test temperature
    - Recognize that this is a major specification change instead of just focusing on MSCR as a new test
      - Truer to concept of a performance-based specification
      - Next step in evolution of specification

Thanks!