Implementation of the MSCR Test and Specification:
Questions, Clarifications, and Emphasis

Mike Anderson, Asphalt Institute

PCCAS Meeting
May 10-11, 2016 Seattle, WA

- 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

- 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

- 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

Implementation of the MSCR Test and Specification

- 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."

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

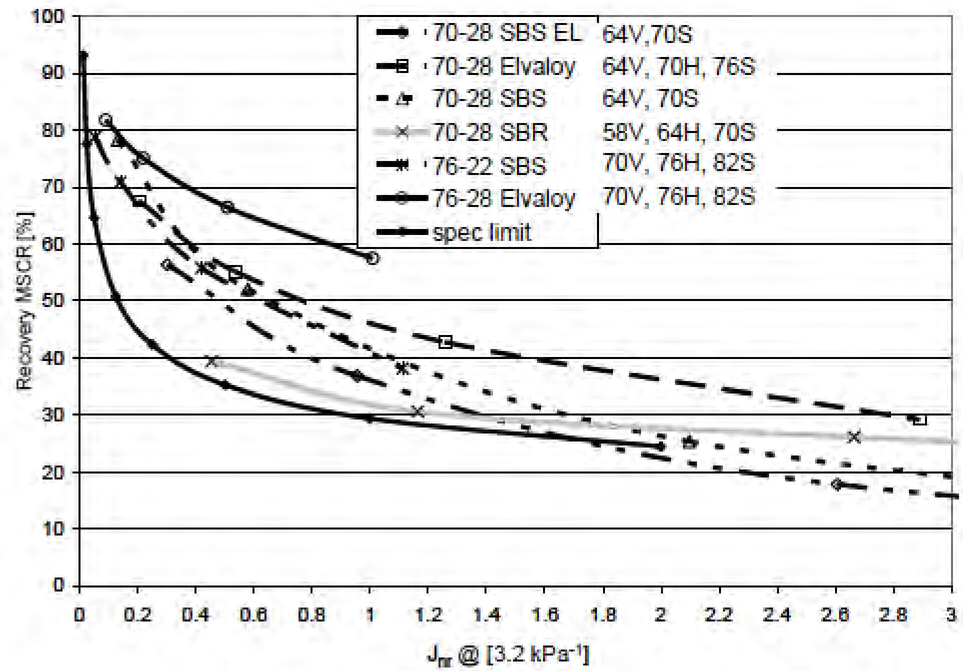

Figure 5.7: Plot of MSCR J_{nr} @ 3.2 kPa^{-1} and MSCR % Recovery for Six Typical Polymer Modified Binders Over Multiple Temperatures From the MTE Polymer Study.

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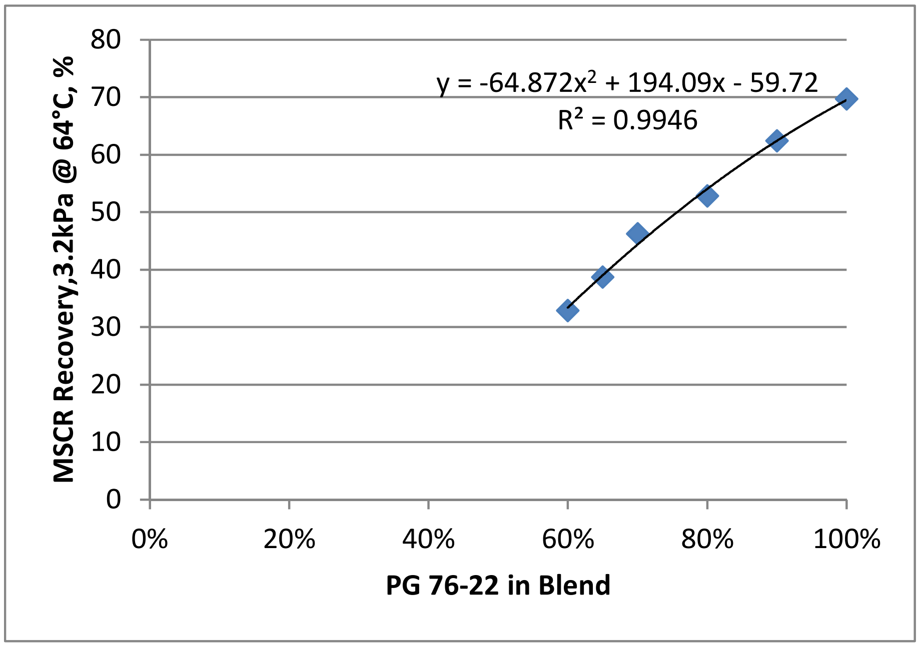
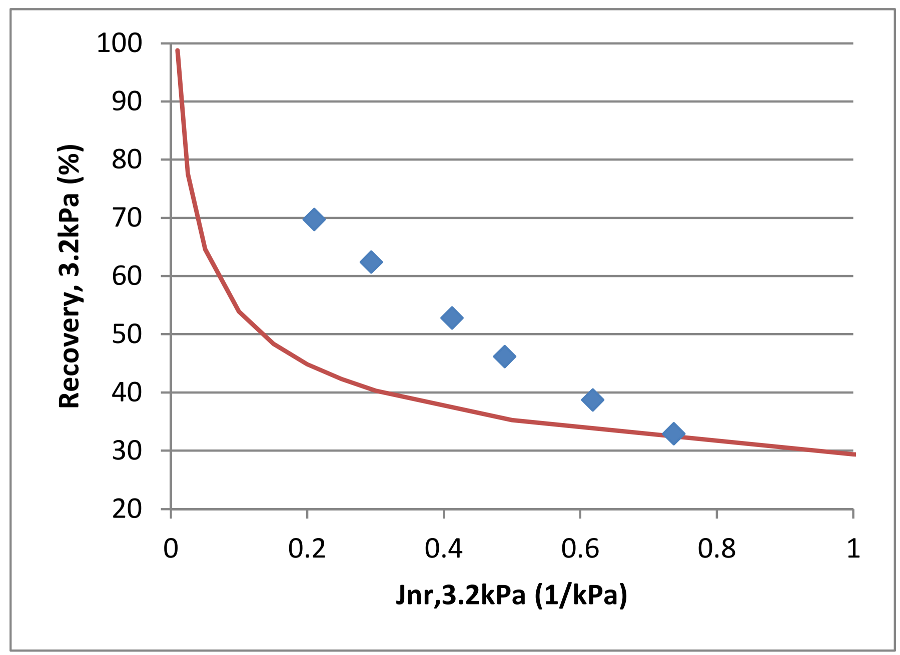
- Use of recovery-Jnr curve for evaluating elastic response





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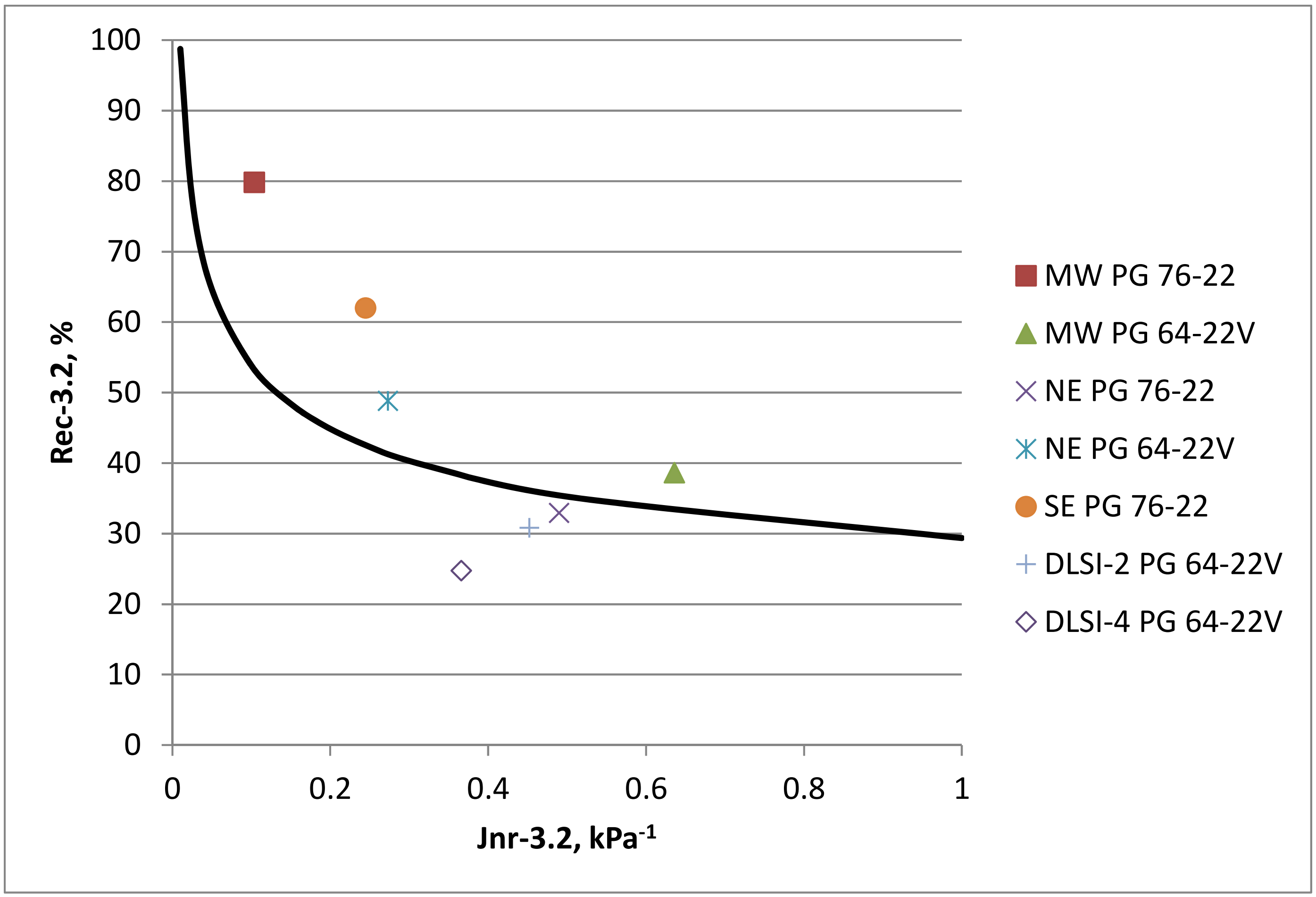

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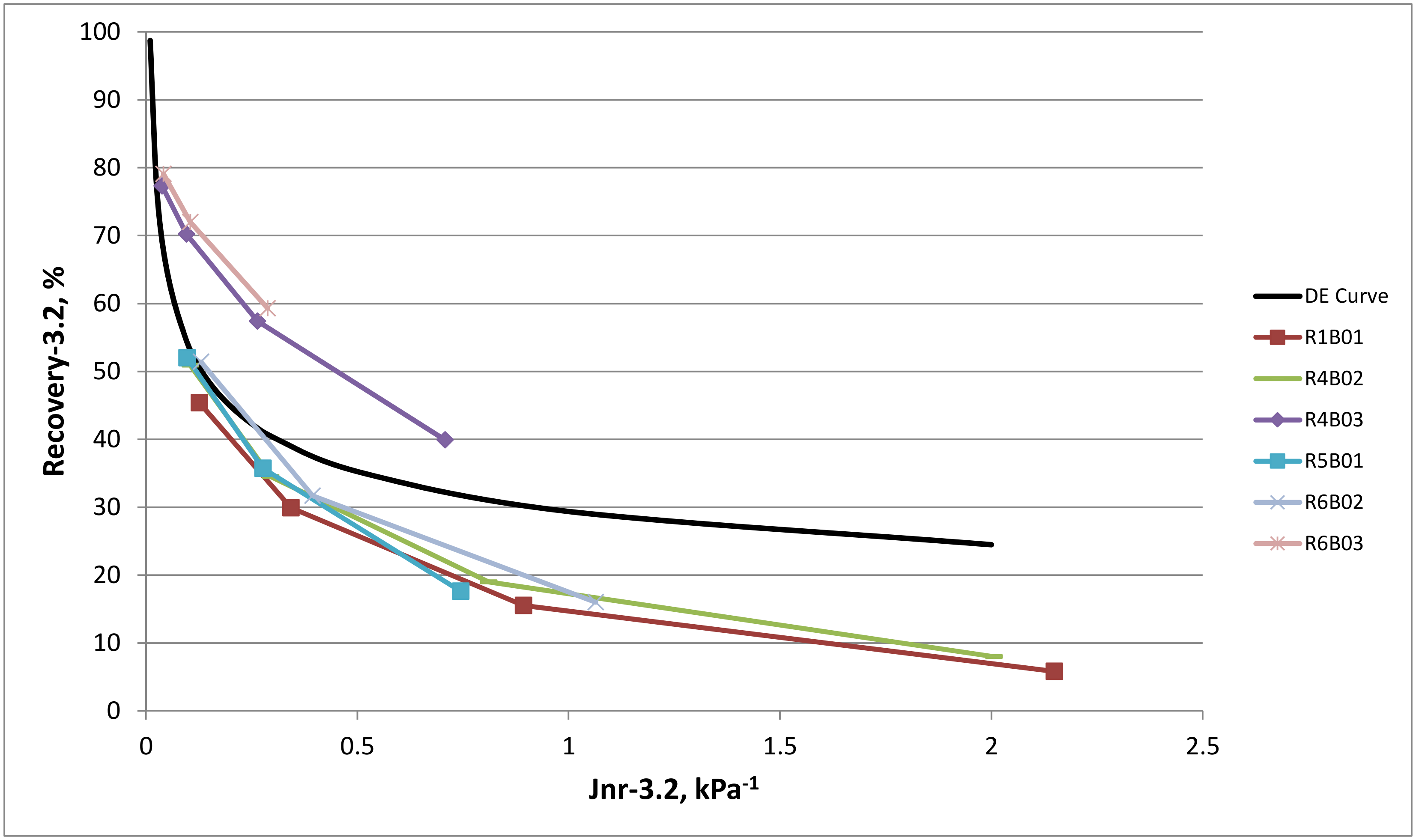
- Use of recovery-Jnr curve for evaluating elastic response



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- Selection of appropriate test temperature
  - “Standard” environmental temperature
    - Selection of environmental temperature based on LTPPBind 3.1
    - Guidance on the appropriate assumptions needed
      - Similar to AMPT Flow Number
    - Locations that choose “standard” temperature that is different than environmental temperature
      - e.g., choosing 64°C when LTPPBind would suggest that the climate is 58°C
    - Southeastern states that use 67°C as standard temperature

Implementation of the MSCR Test and Specification

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- Selection of appropriate test temperature
  - Standard environmental temperature with grade bumping (higher traffic)

  - Standard environmental temperature with grade dumping (RAP and RAS use)
    - Use of a softer grade due to RAP and/or RAS use
    - What temperature for testing?
      - i.e., PG 58-28 is used in a RAP-RAS mix in a 64°C climate
      - Test the PG 58-28 at environmental temperature (64°C)? If so what grade would this be ("R"?) Or test as PG 58S-28 (at 58°C)?

- Original DSR Criterion
  - Testing at environmental temperature with no change in criterion
  - H, V, and E grades will easily meet criterion at environmental grade
    - $G^*/\sin\delta \geq 1.00$ kPa

Implementation of the MSCR Test and Specification

- Criterion for unmodified asphalt binders ("S" grades)
  - Original criterion was J_{nr} at 3.2 kPa shear stress (Jnr-3.2) ≤ 4.0 kPa^{-1}
  - Changed to ≤ 4.5 kPa^{-1} based on recommendation from Asphalt Binder ETG
    - Asphalt Institute report dated 26 April 2013
    - Presentation at Asphalt Binder ETG Meeting in May 2013 (Raleigh, NC)
  - Concern that change still allows some currently acceptable unmodified asphalt binders (M320) to fail M332.

Implementation of the MSCR Test and Specification

- Criterion for unmodified asphalt binders ("S" grades)

Table 15: Calculated Values of Jnr-3.2 at AASHTO T315 T_c and $G^*/\sin\delta$ at AASHTO TP70 T_c

	Figure 1 (Source A, PG 64-22)	Figure 2 (AI Miscellaneous)	Figure 4 (SHRP MRL)	Figure 31 (SHRP MRL, Multiple Labs)
Jnr-3.2 at AASHTO T315 T_c (where $G^*/\sin\delta$ = 2.20 kPa)	4.70 kPa^{-1}	4.65 kPa^{-1}	4.52 kPa^{-1}	4.65 kPa^{-1}
$G^*/\sin\delta$ at AASHTO TP70 T_c (where Jnr-3.2 = 4.00 kPa^{-1})	2.53 kPa	2.52 kPa	2.46 kPa	2.52 kPa

$G^*/\sin\delta$ at T350 T_c (where Jnr-3.2 = 4.50 kPa^{-1})	2.285 kPa	2.267 kPa	2.209 kPa	2.267 kPa

2.257 kPa

Implementation of the MSCR Test and Specification

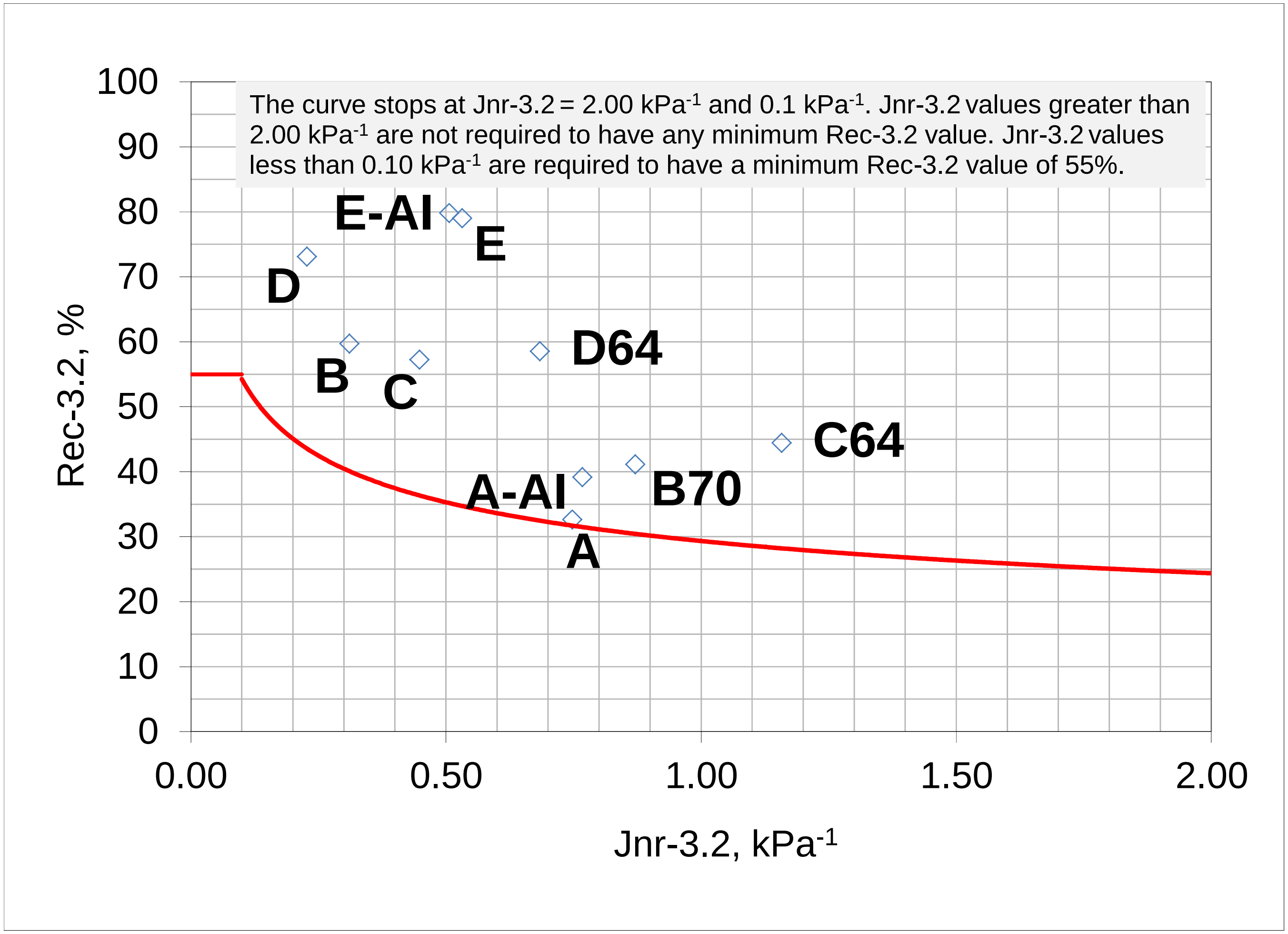
- Use and relevance of Jnr-Diff as a specification requirement
  - Indicative of stress-sensitive binders
  - Problem for some current formulations
  - Not a problem for the majority of modified binders
  - Is it needed?

- 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

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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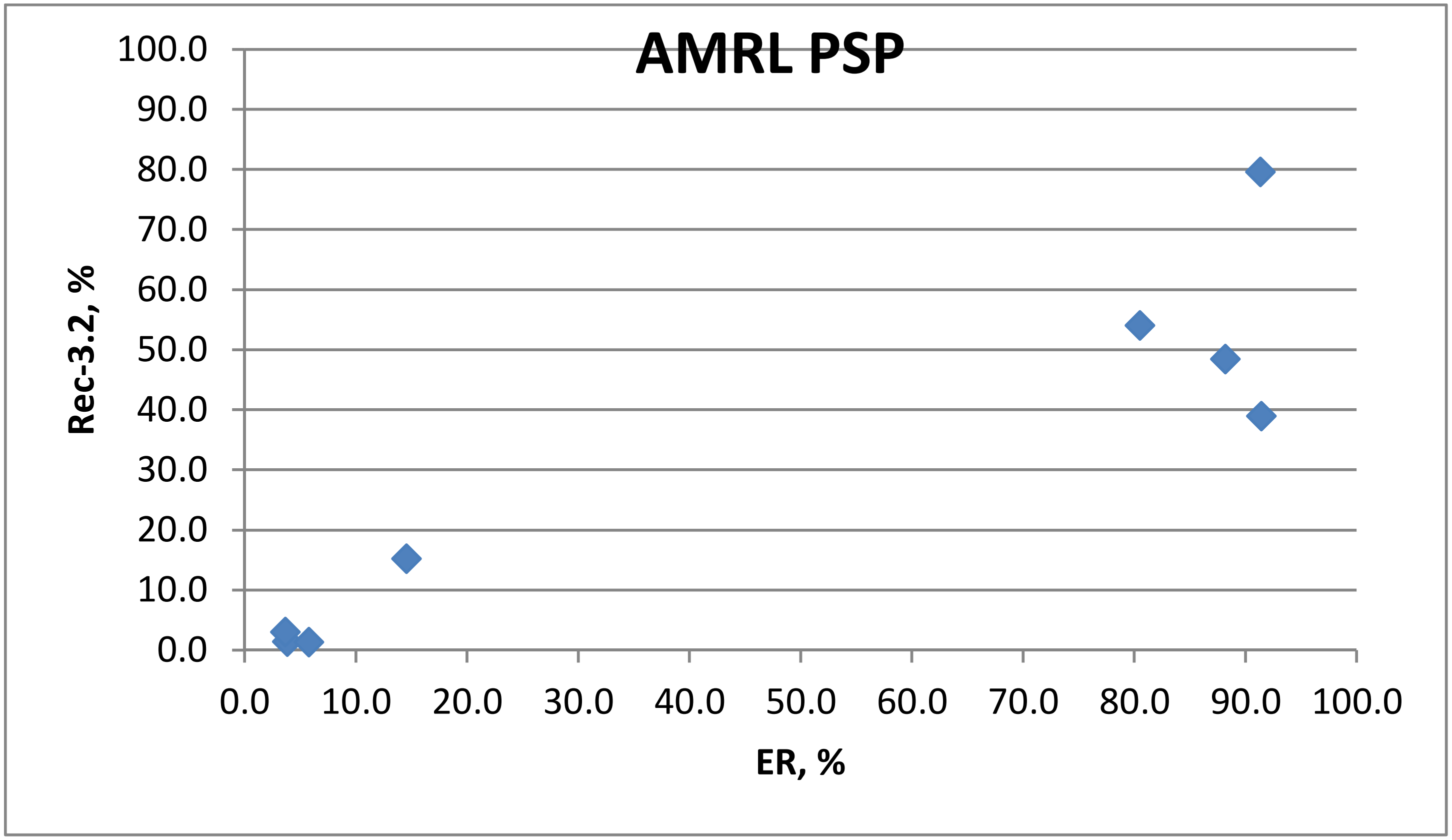

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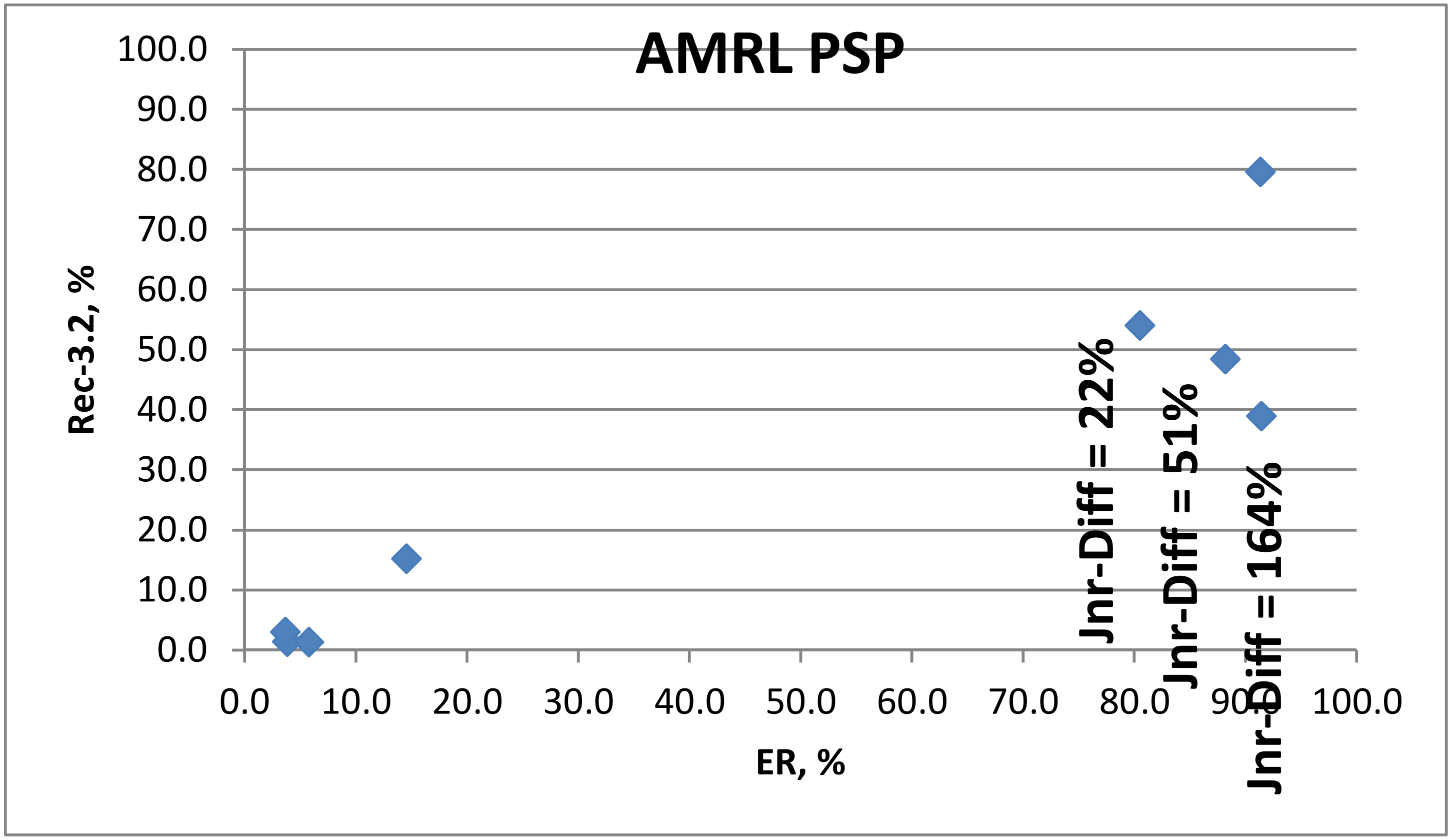

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- Use and relevance of Jnr-Diff as a specification requirement
  - Experiment using PCCAS ILS Binders
    - Binder A
      - PG 76-28
      - Jnr-3.2 = 0.748 kPa^{-1} at 64°C
      - Rec-3.2 = 32.6% at 64°C
      - Jnr-Diff = 1157% at 64°C
    - Binder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

Implementation of the MSCR Test and Specification

- 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

Implementation of the MSCR Test and Specification

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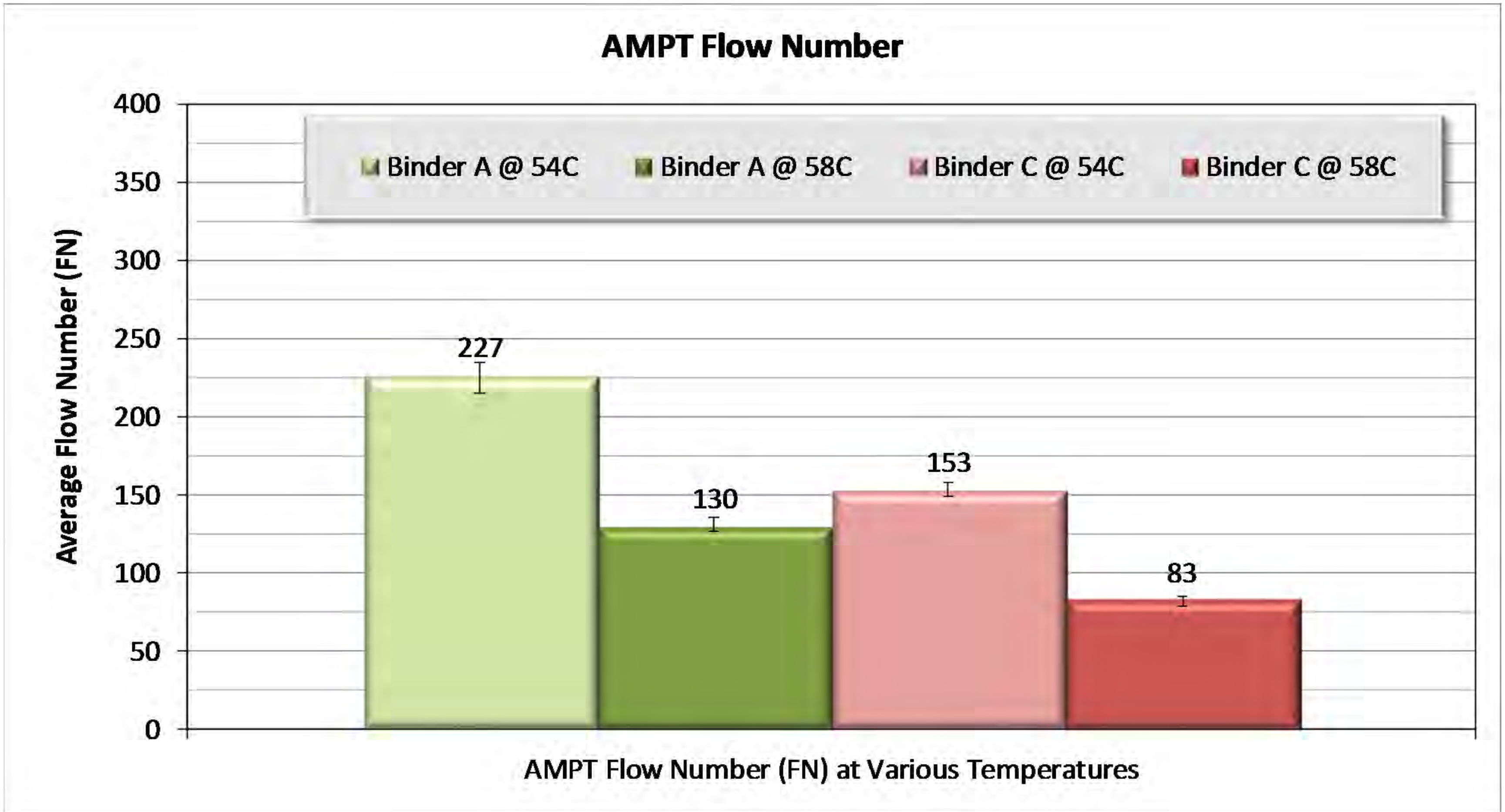
- Use and relevance of Jnr-Diff as a specification requirement



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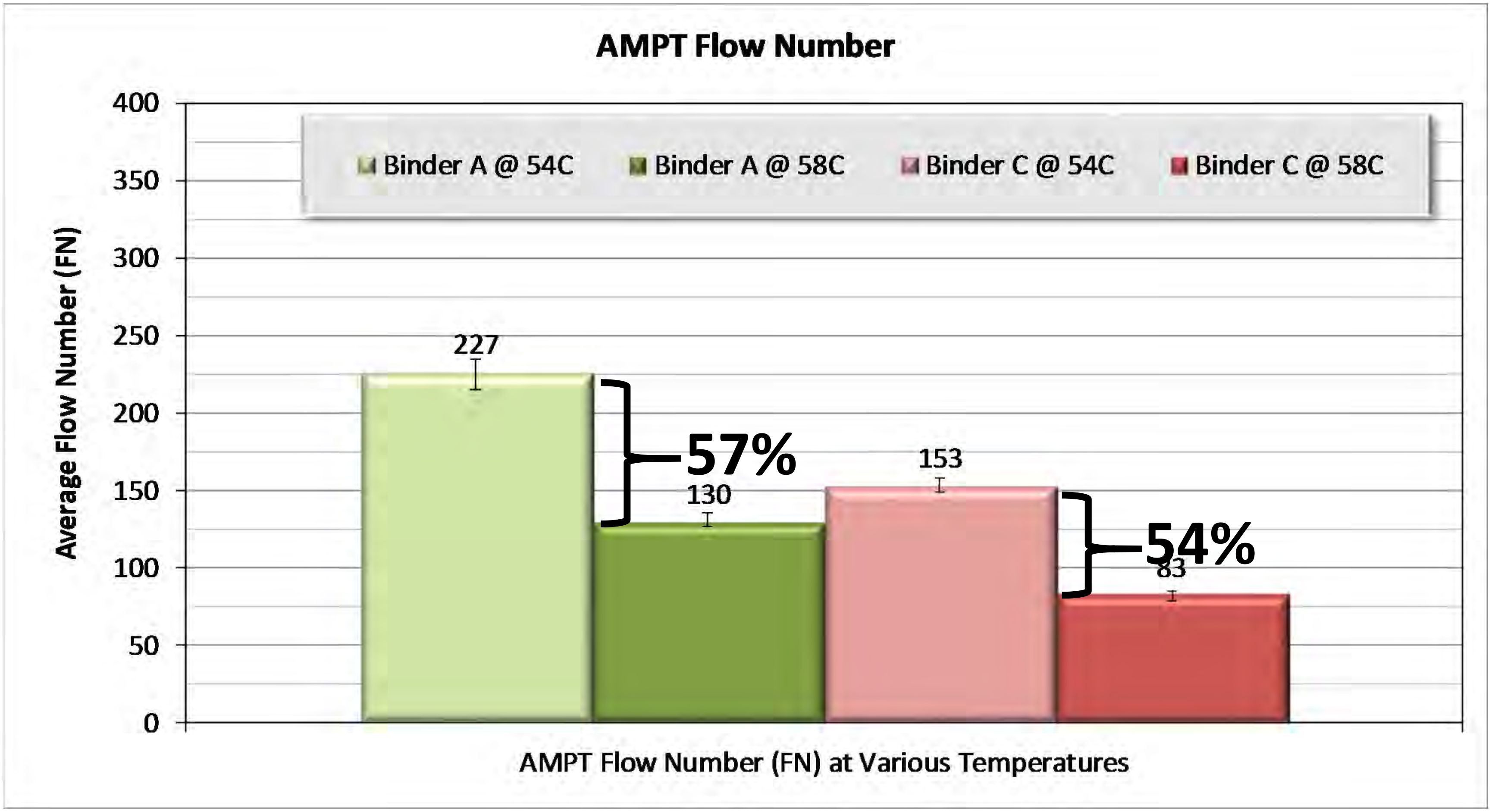

Implementation of the MSCR Test and Specification

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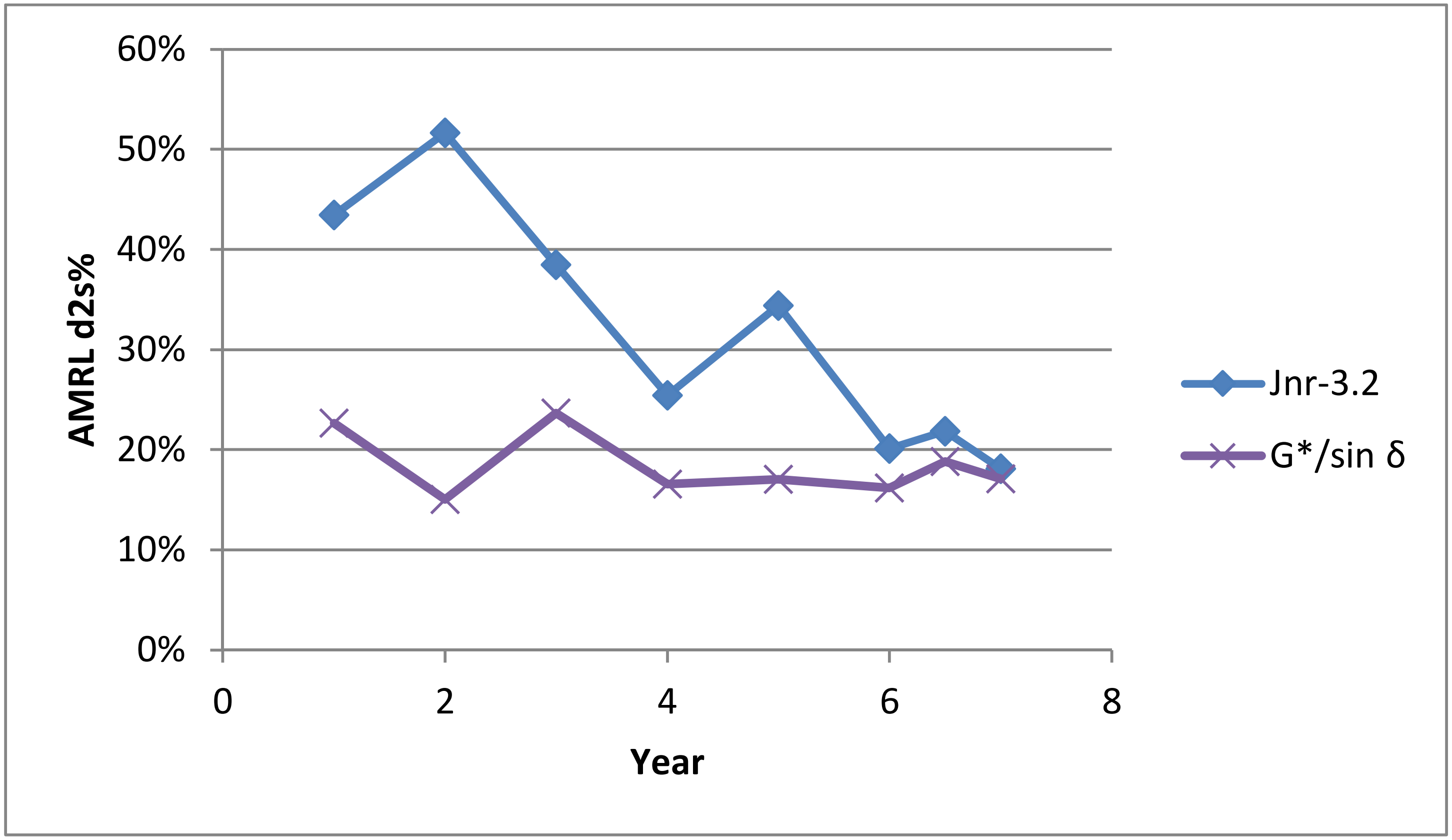
- Variability of MSCR test
  - AI-Coordinated ILS
    - d2s% shown for between lab (reproducibility)

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%

Implementation of the MSCR Test and Specification

- Variability of MSCR test
  - AMRL PSP



- Variability of MSCR test
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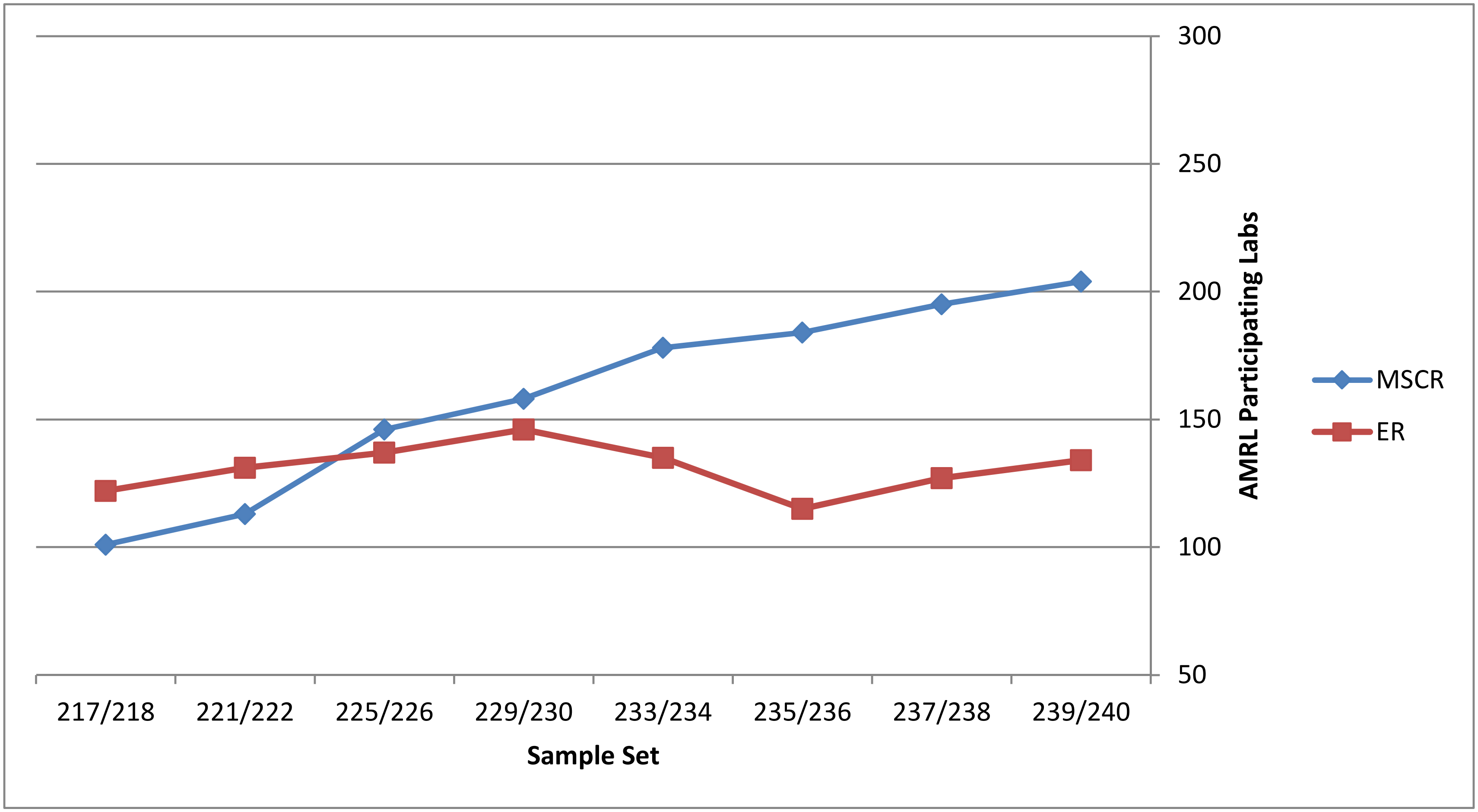

- Variability of MSCR test
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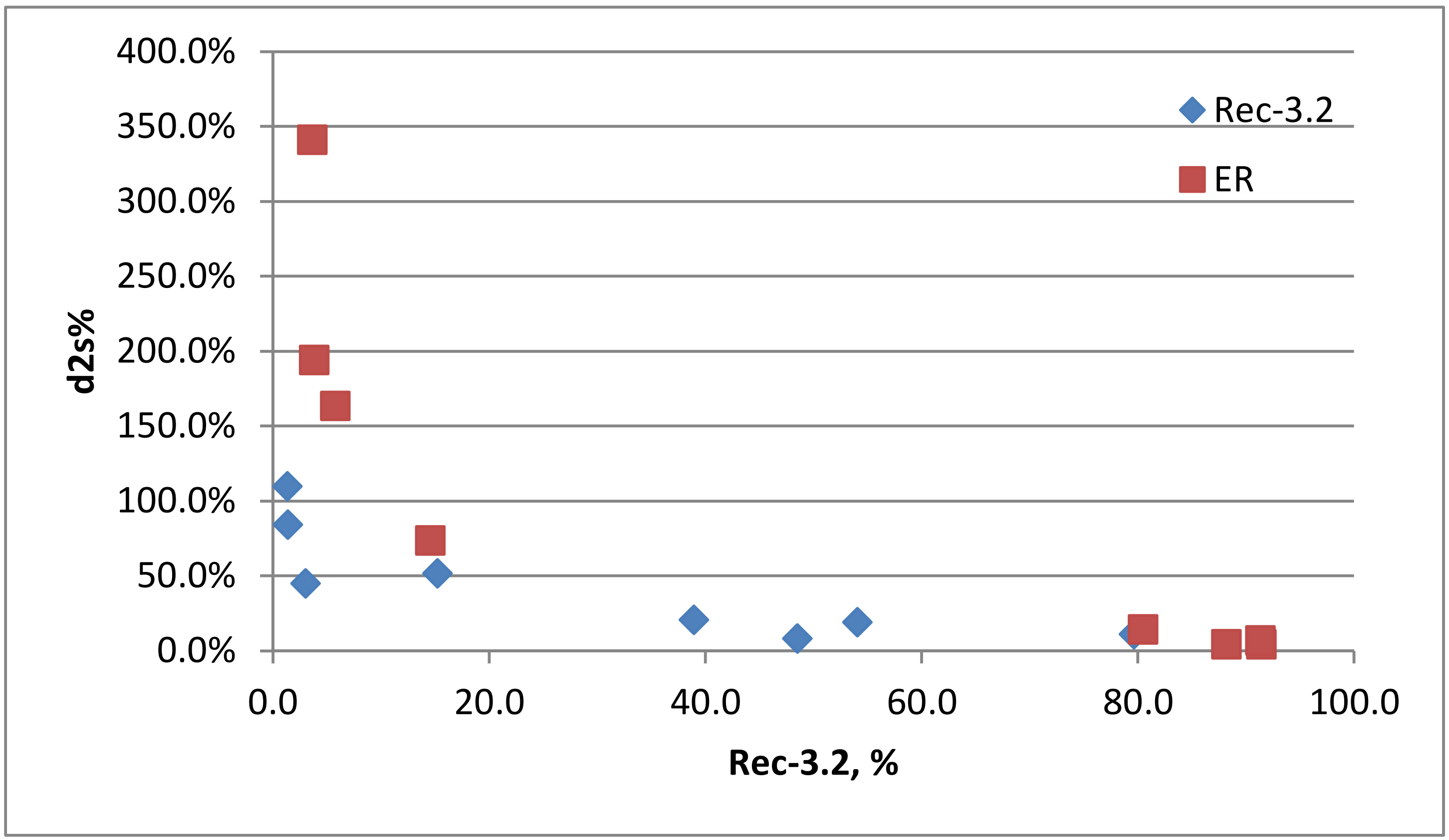


Implementation of the MSCR Test and Specification

- Variability of MSCR test
  - PCCAS ILS (2013)

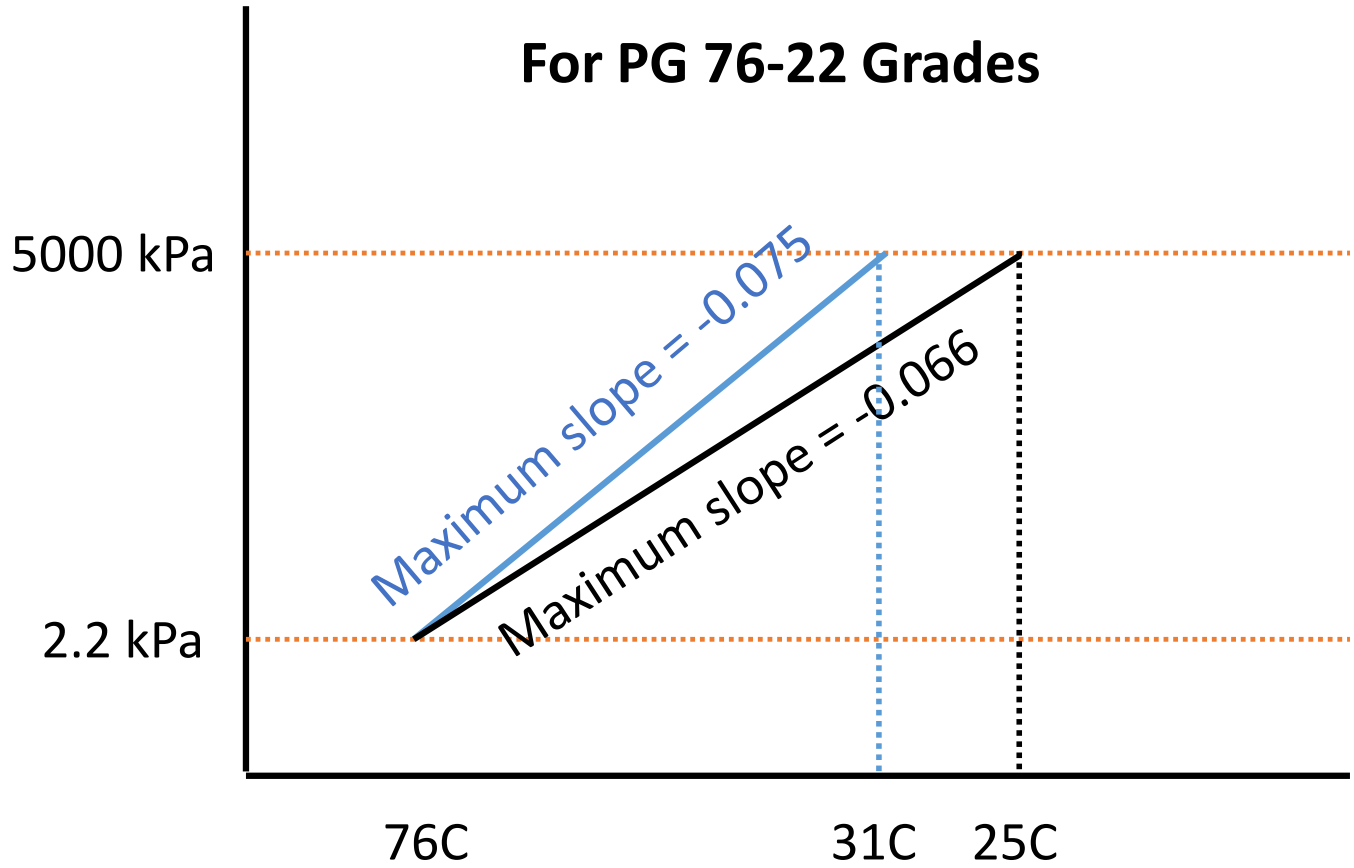
Table 20: Estimated Repeatability and Reproducibility from ILS

Test	*Acceptable Range of Two Test Results (d2s%) 2013 PCCAS ILS* 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

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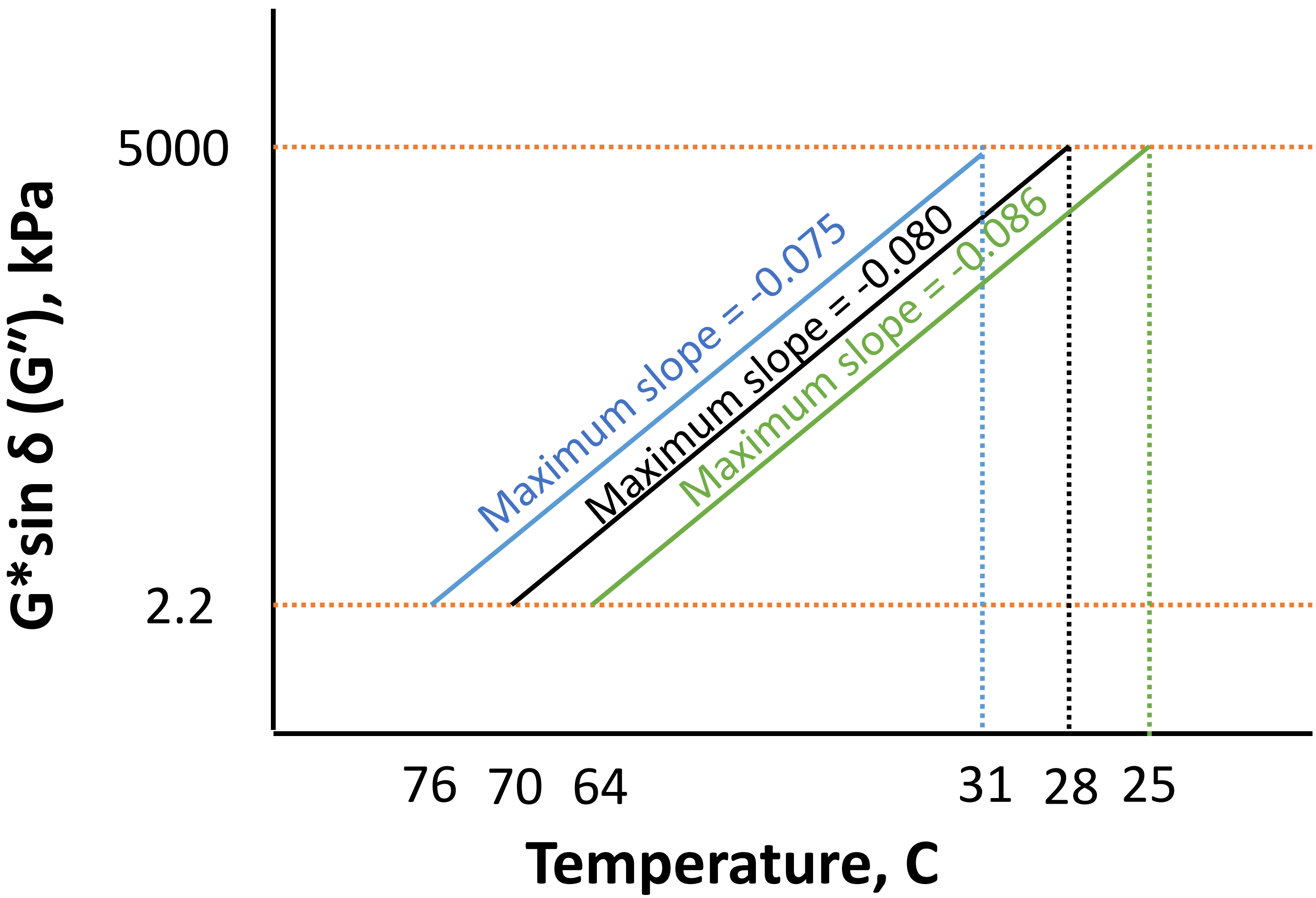

Effect of Intermediate Temperature on Temp. Susceptibility: M320 and M332

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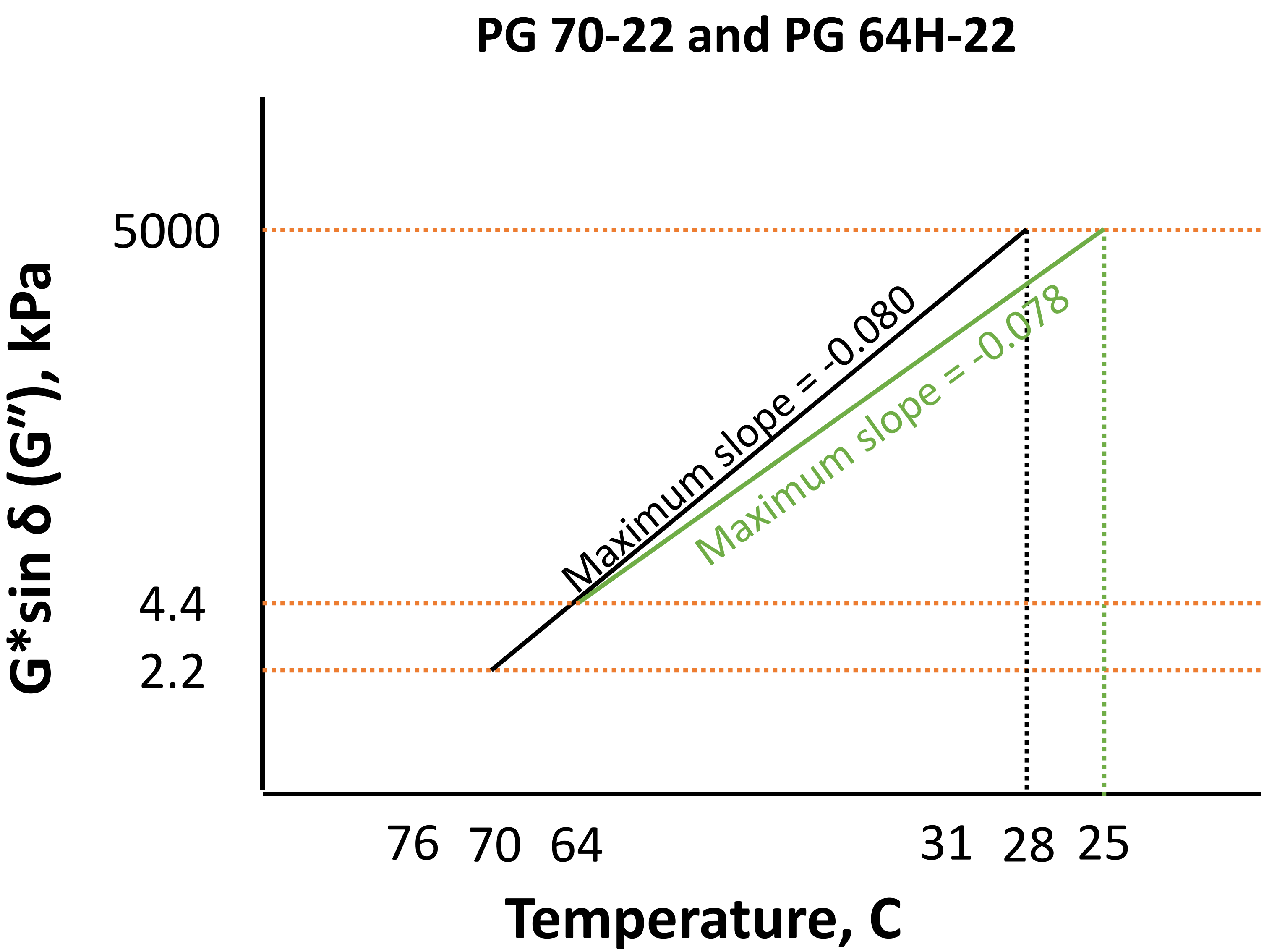

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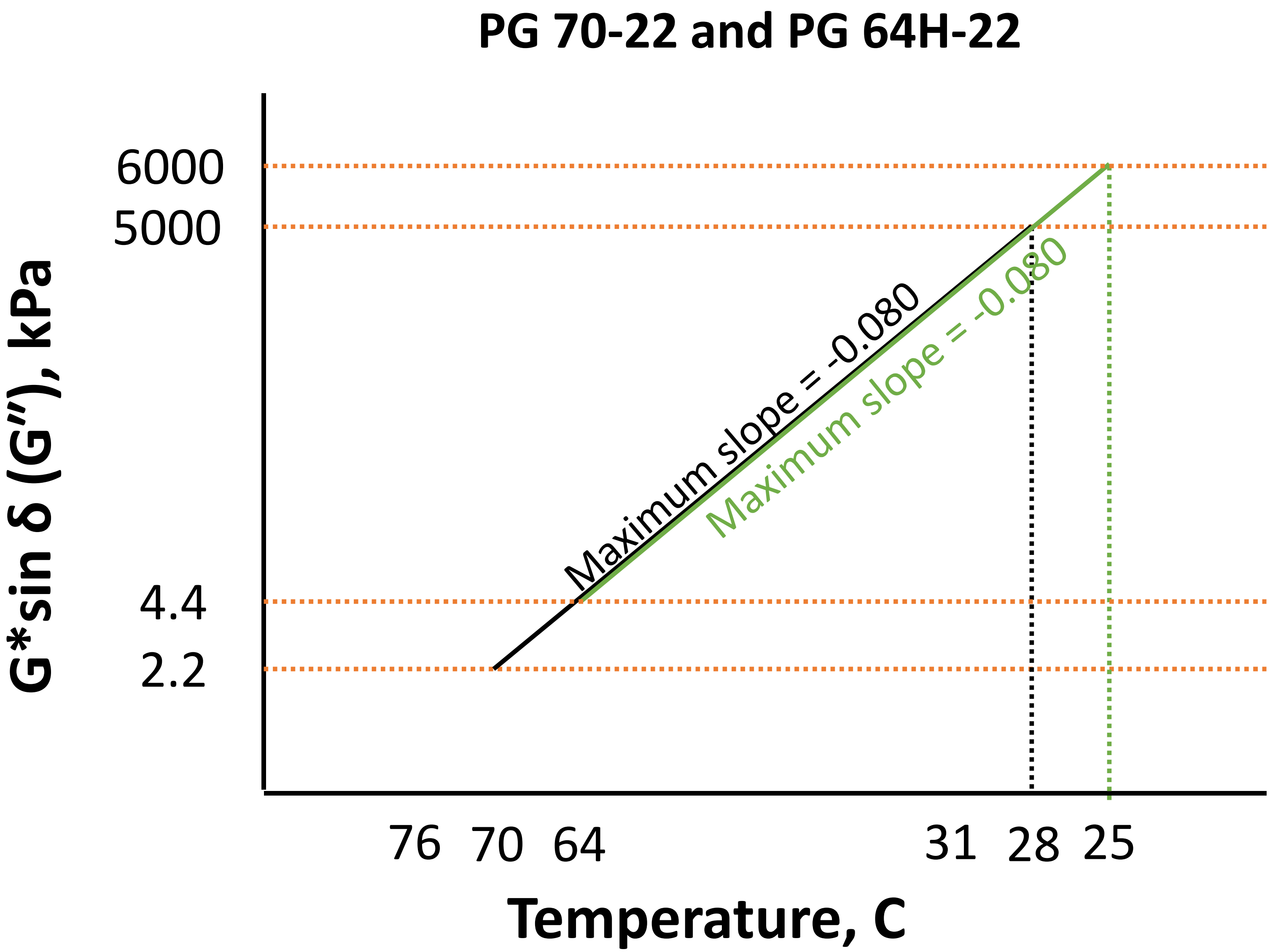

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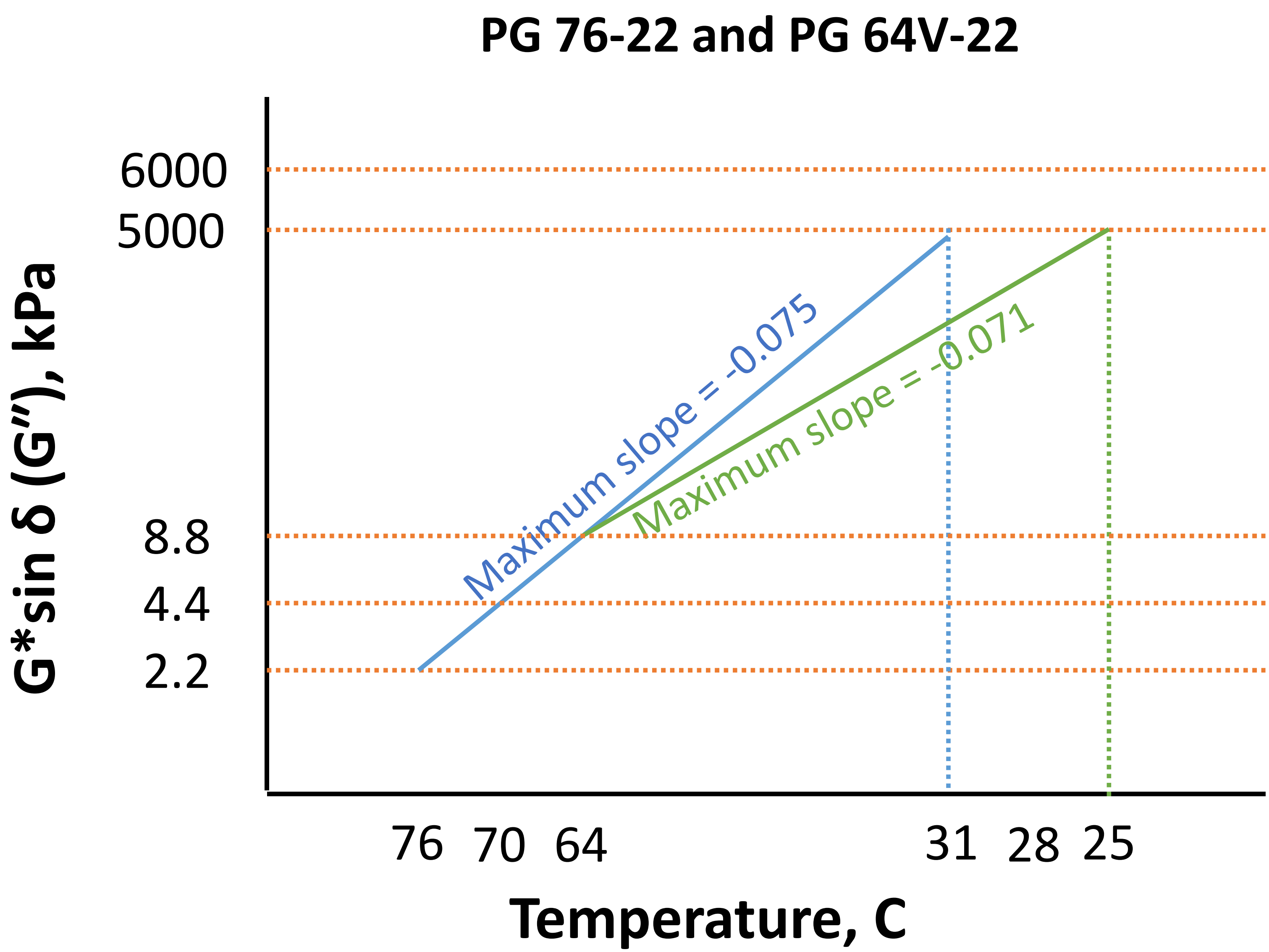

Effect of Intermediate Temperature on Temperature Susceptibility

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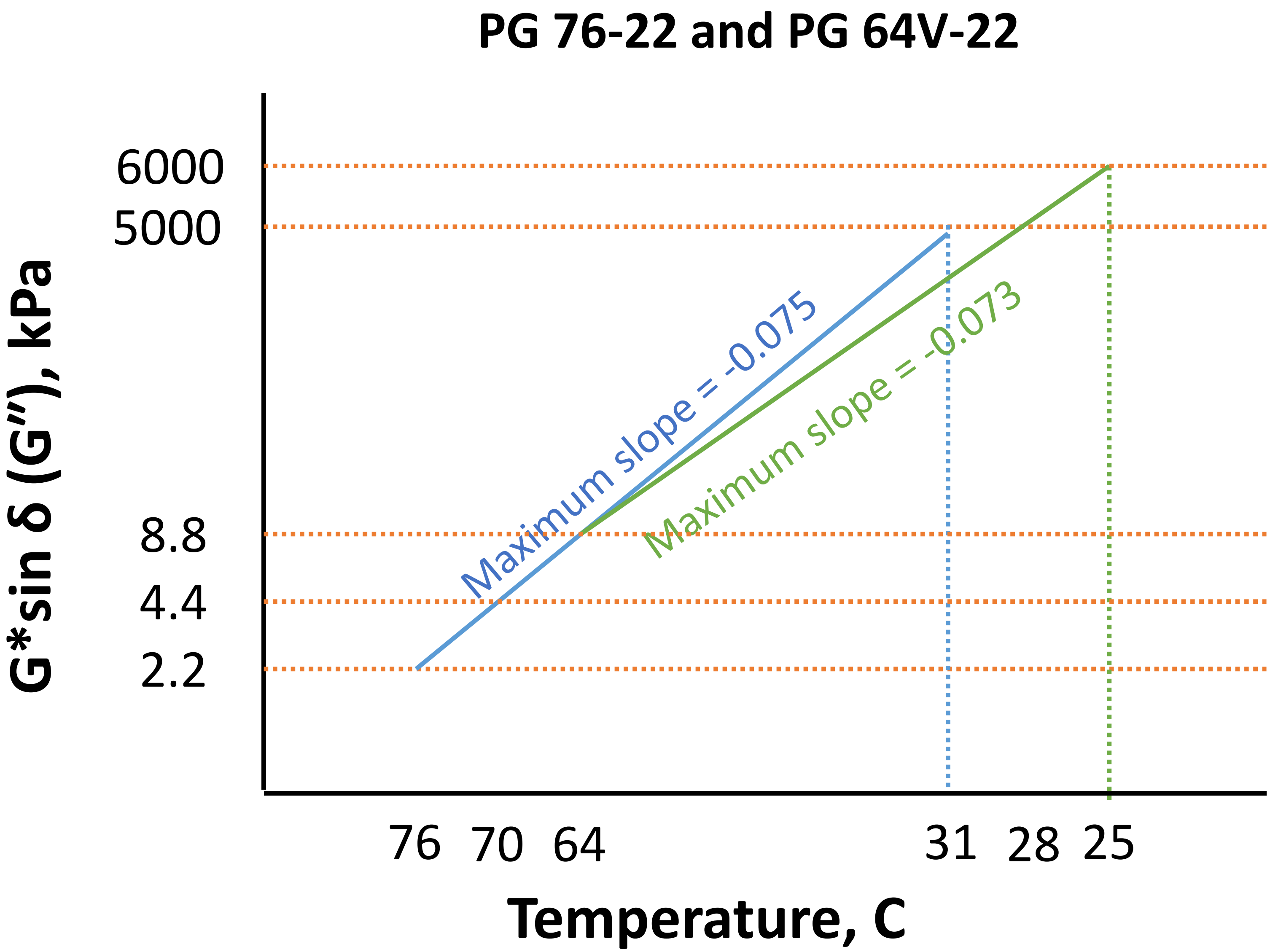

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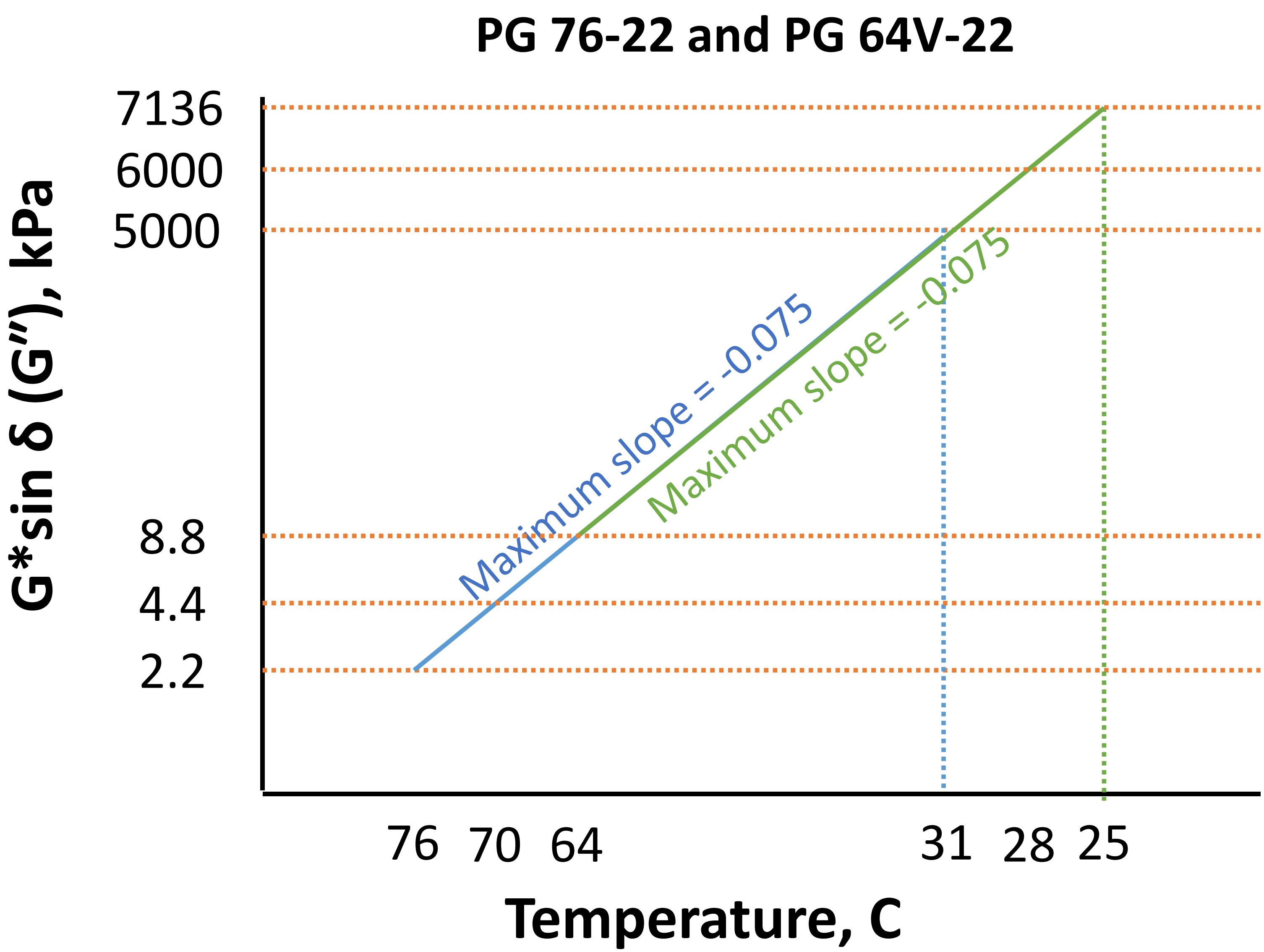

Effect of Intermediate Temperature on Temperature Susceptibility

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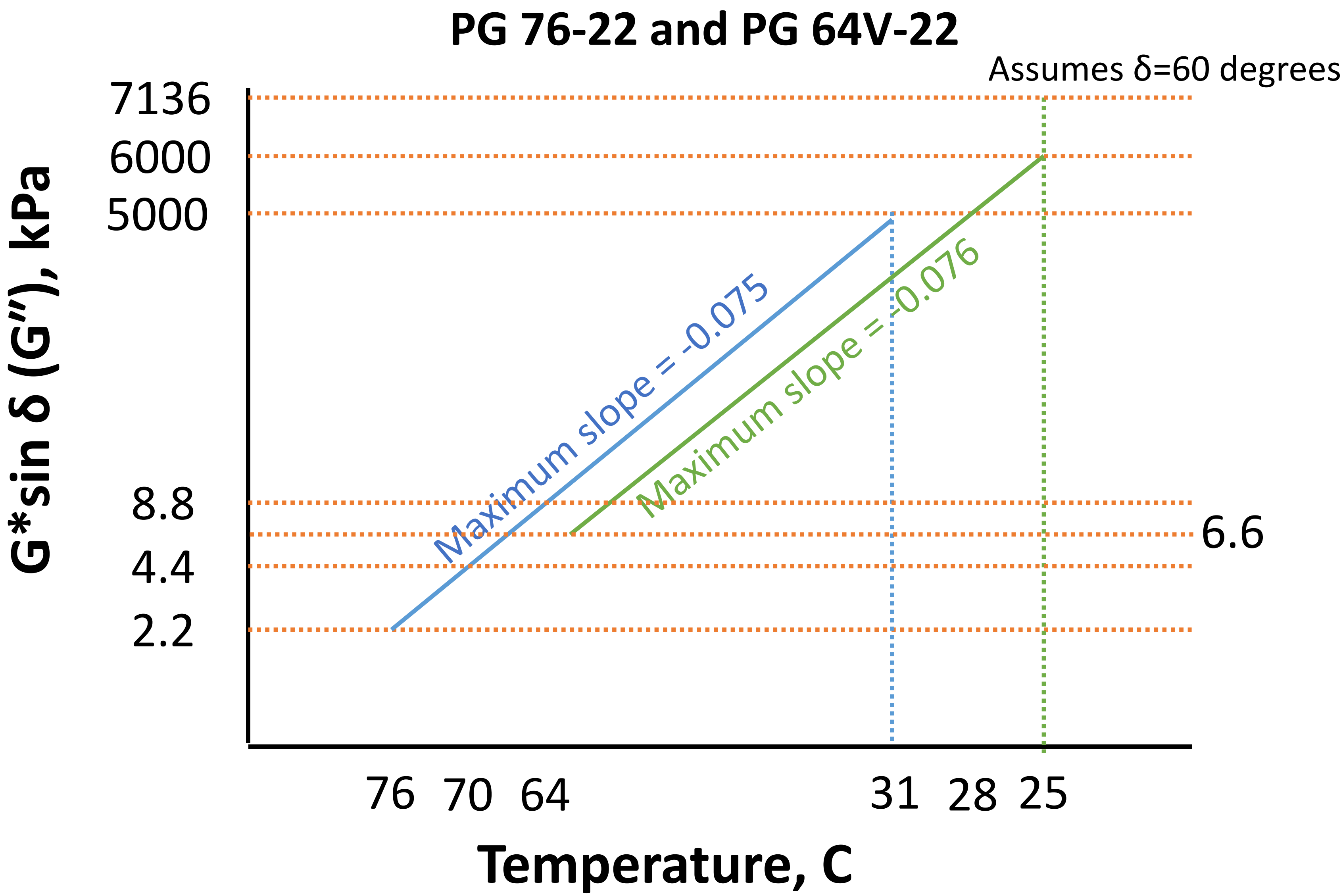

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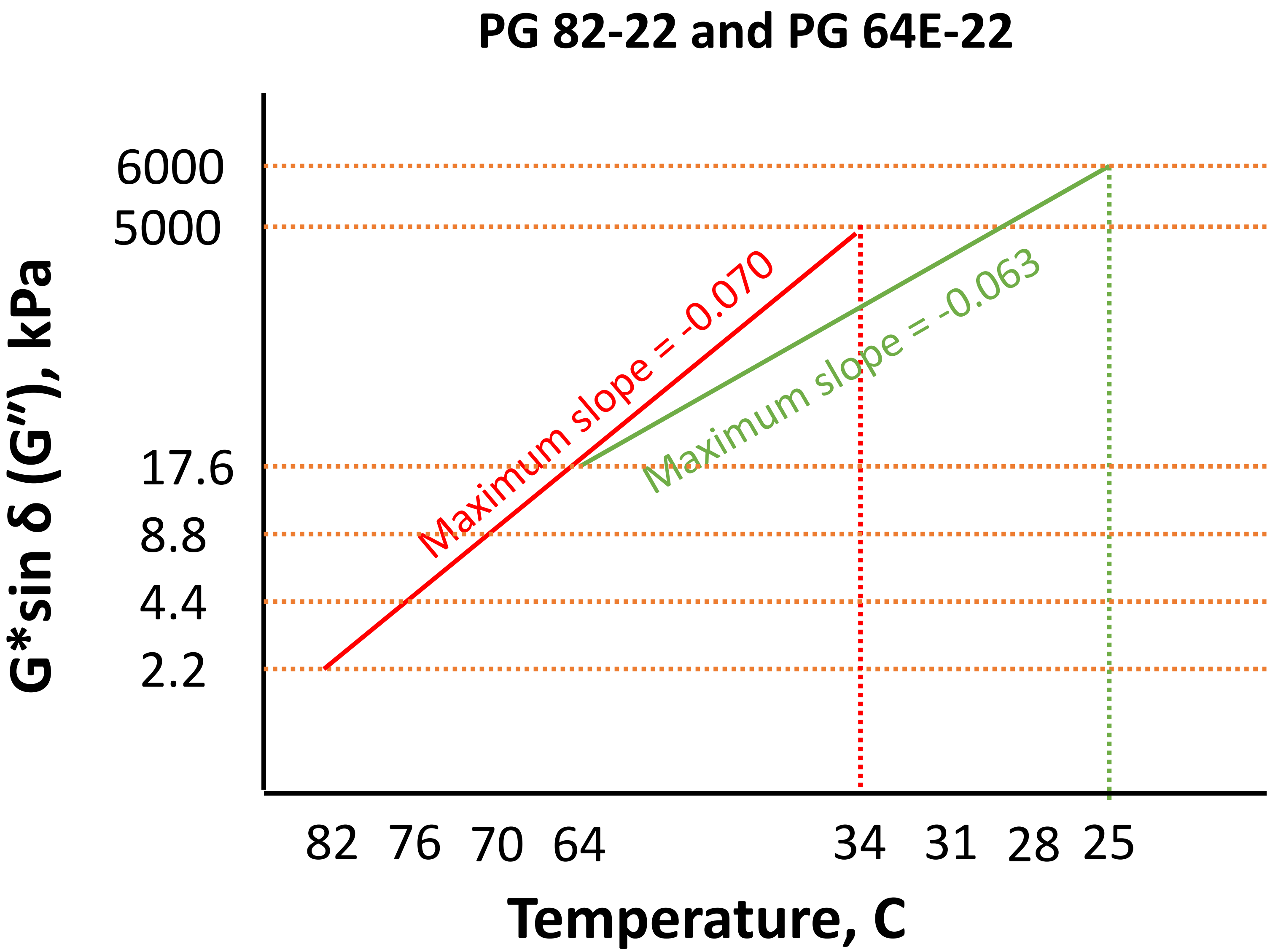

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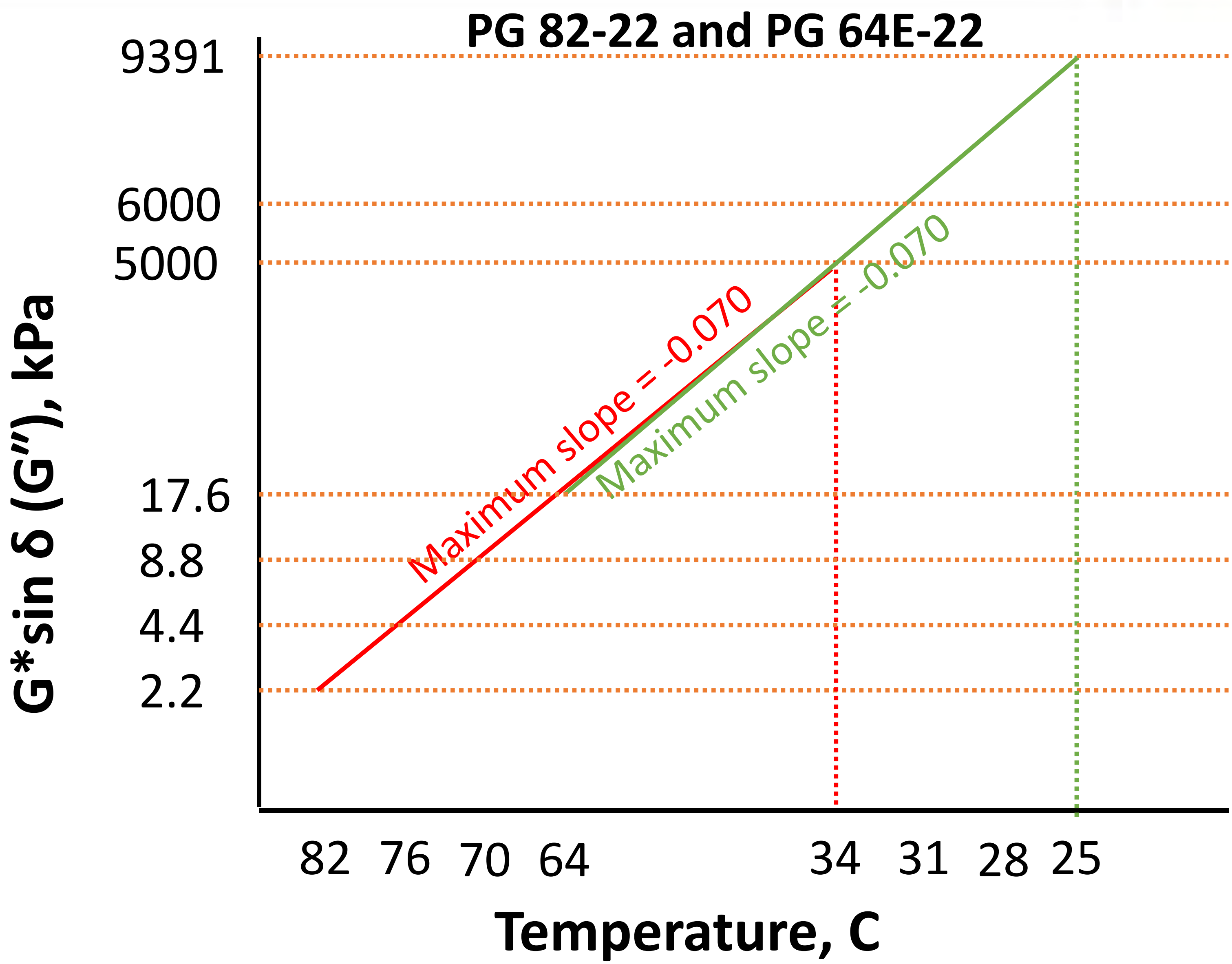

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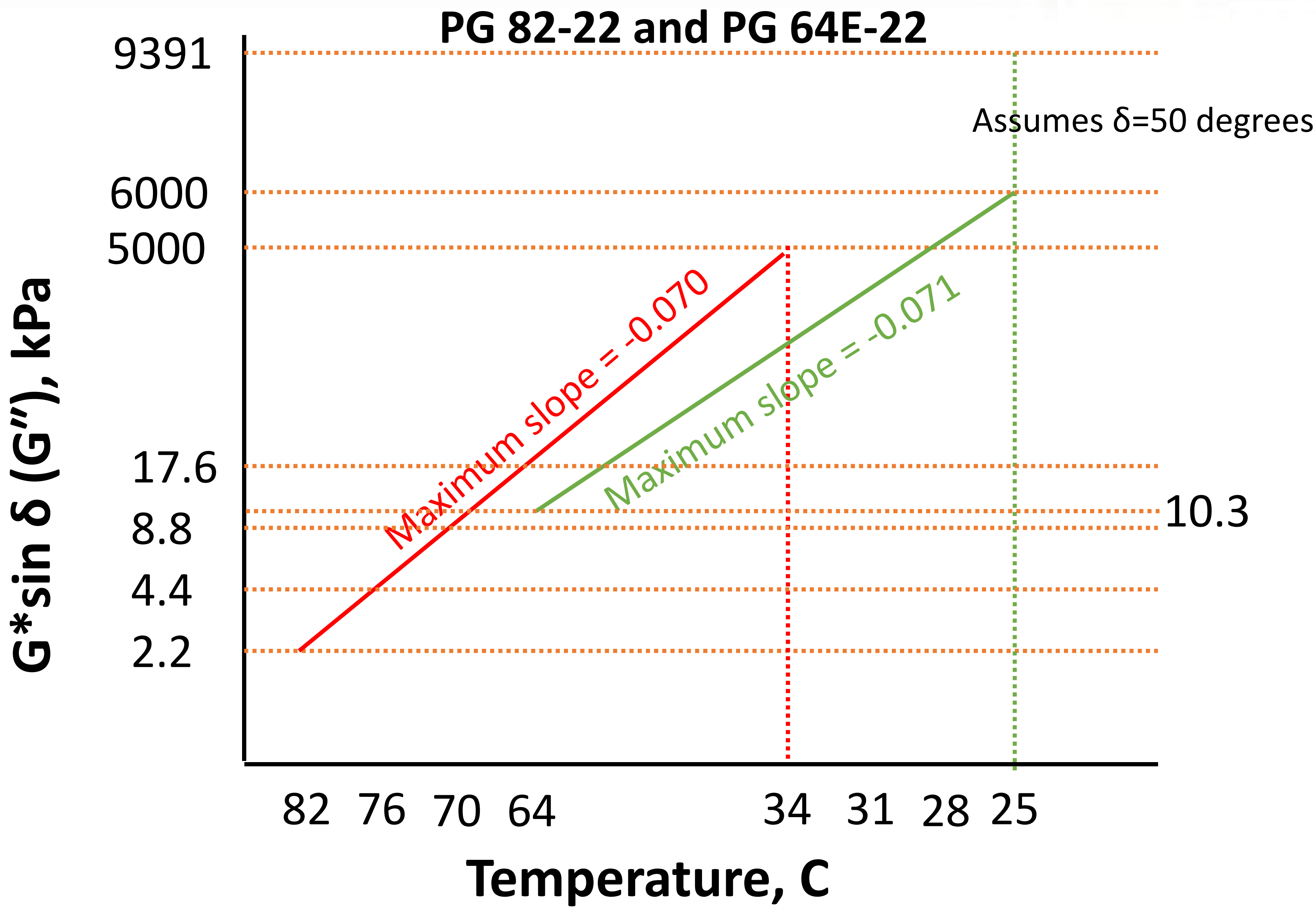

Effect of Intermediate Temperature on Temperature Susceptibility

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

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- 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

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- Quick QC Testing on Original Binder
  - Terminal labs may not have RTFO oven
  - Need to validate presence of modifier and verify grade before shipping
  - MSCR testing on original binder?
  - Use of phase angle as surrogate?

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

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- 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

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- 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

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92nd AAPT Annual Meeting and Technical Sessions

The 2017 Annual Meeting will be held March 19-22, 2017
The Island Hotel, Newport Beach, California USA

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Association of Asphalt Paving Technologists

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2017 Call for Papers

The Association of Asphalt Paving Technologists is actively soliciting paper offers for its 2017 Annual Meeting and Technical Sessions. Papers reporting on studies concerning any aspect of asphalt paving technology or related fields are considered. These can include research, design, construction and maintenance issues dealing with all types of asphalt binders, asphalt mixtures, and pavement applications – including innovative ideas and improvements to current practice. Papers will be considered for presentation at the Annual Meeting which is attended by specialists from academia, research organizations, material producers, contractors, national and state authorities, and consultants from around the world. Papers offered for the 2017 Annual Meeting must be submitted through the AAPT website.

Important dates

May 1, 2016 web site open for paper submission
August 15, 2016 - deadline for submitting papers
November 4, 2016 - notification of paper acceptance
December 2016 - registration open
March 19 to 22, 2017 - annual meeting and technical sessions

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Thanks!