Comparison of Binder and Mixture Characteristics with Respect to Cracking Performance

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UNH CIRC
University of New Hampshire
College of Engineering and Physical Sciences

Introduction

- Cracking is one of the main types of distresses in asphalt pavements
- Researchers have developed various cracking index parameters to evaluate the cracking potential of asphalt binders and mixtures

Primary Objective:

To compare several common and recently developed asphalt mixture and asphalt binder index parameters to determine if correlations exist with respect to fatigue and thermal cracking.

Acknowledgements

- NHDOT
  - Funding
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- Pike Industries, Inc.
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- Gerry Reinke, MTE Services
- UNH pavement research group

Materials

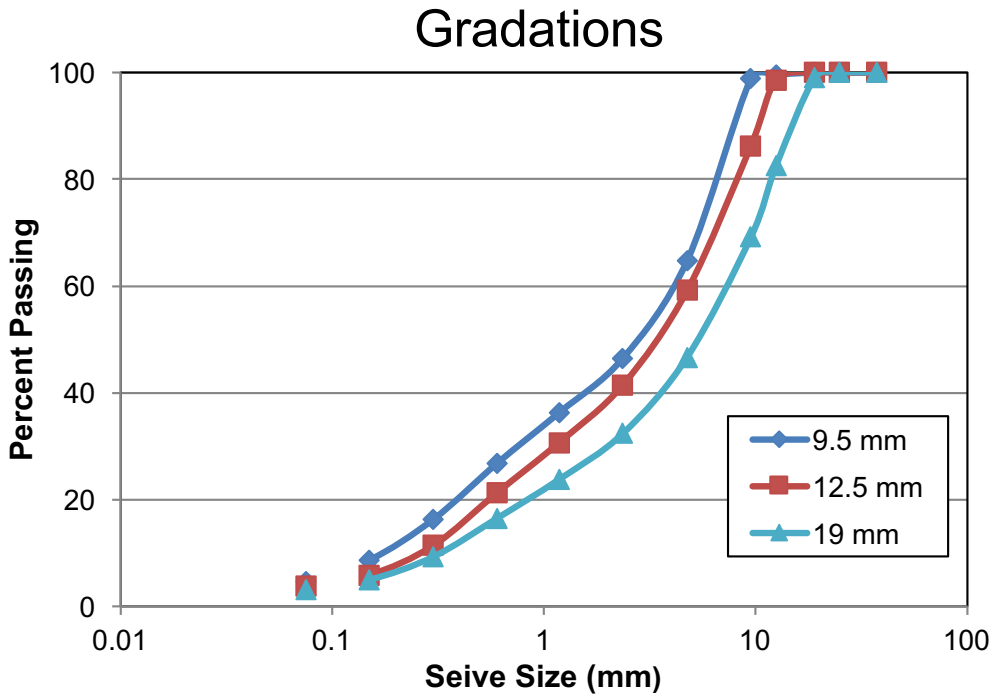
- Lebanon
  - ✓ 11 Mixtures (Plant)
  - ✓ Binder type (PG 58-28, PG 52-34)
  - ✓ Two sources for each binder grade
  - ✓ NMAS (12.5 and 19 mm)
  - ✓ Recycled Material (20-30% RAP and RAP/RAS)

- Hooksett
  - ✓ 3 Mixtures (Plant)
  - ✓ Binder type (PG 58-28, PG 64-28)
  - ✓ NMAS (9.5 and 12.5 mm)
  - ✓ Recycled Material (15-25% RAP)

Materials

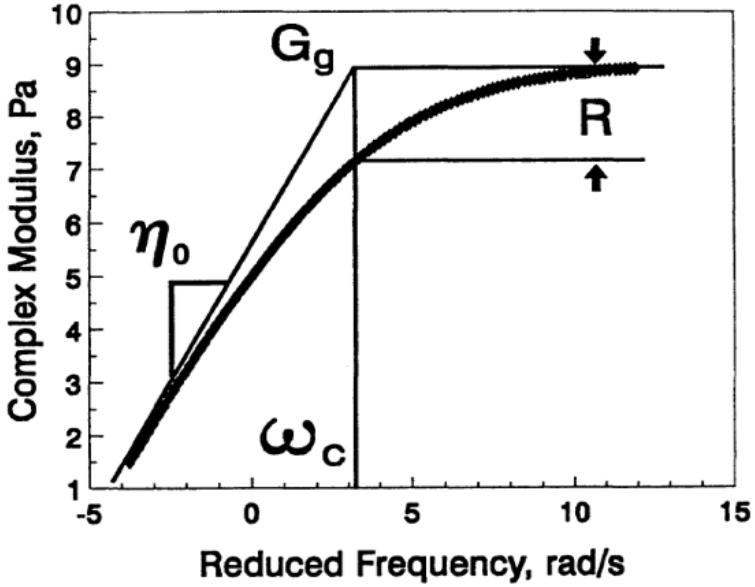
- Target Air Void (test specimen): 6% ± 0.5
- RAP Binder Grade
  - Westmoreland: PG 81.3-19.3° C
- Tear off Shingles

Mixture NMAS (mm)	%AC Design Total
19.0	4.7- 4.8
12.5	5.3
9.5	5.8- 6.0

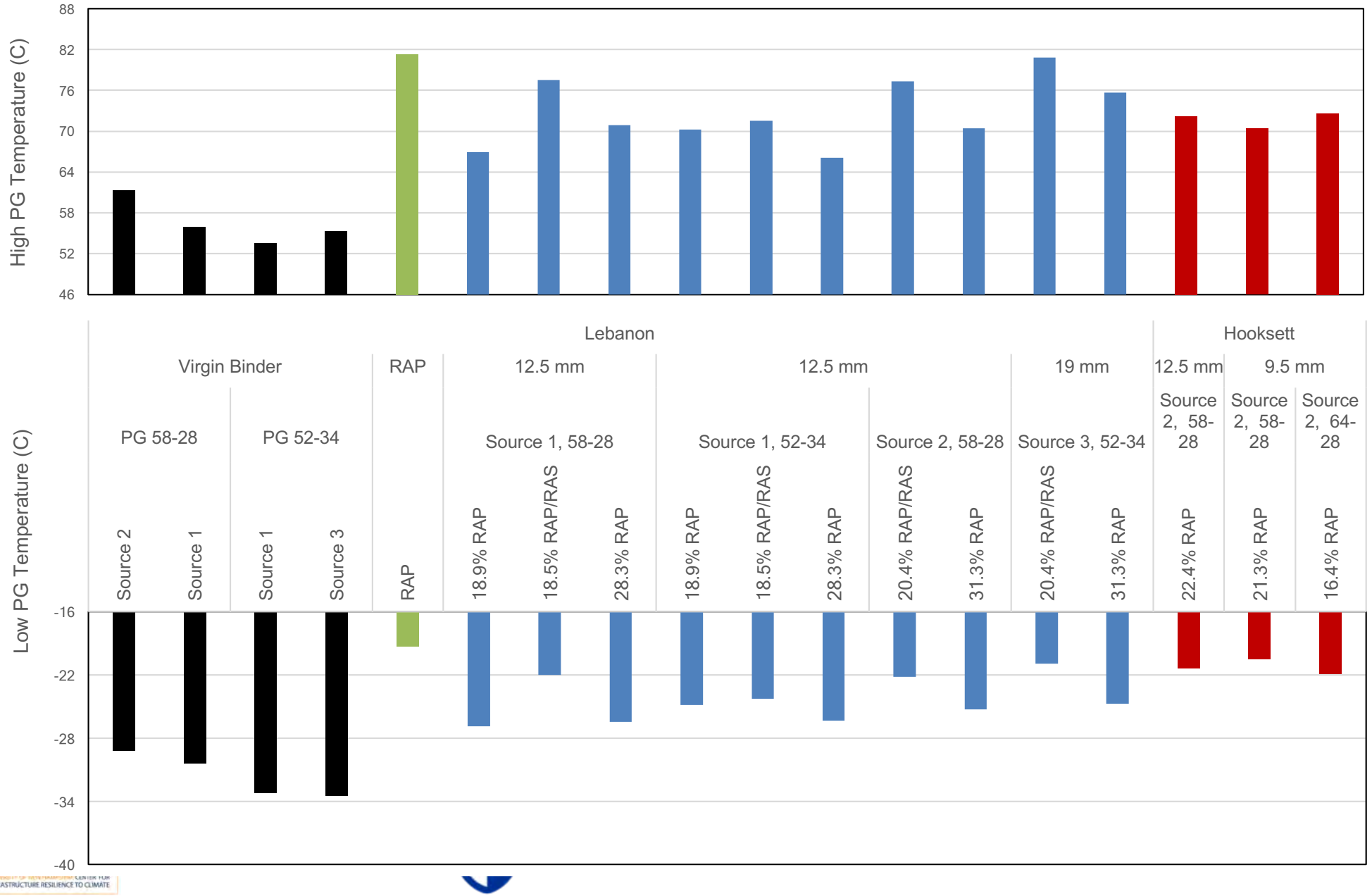


Binder Parameters

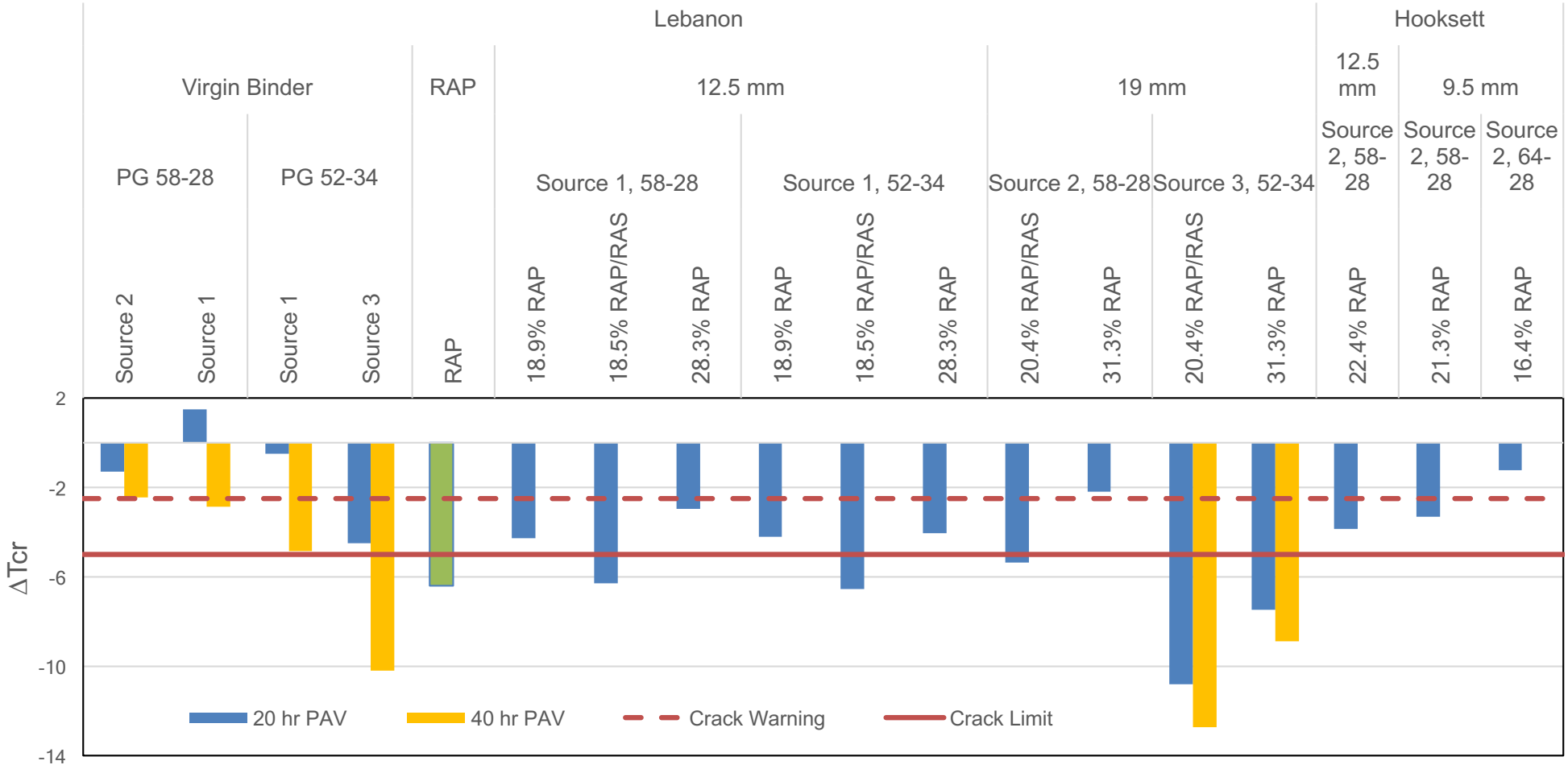
- High and Low Continuous PG Temperatures
- $\Delta T_{cr} = T_{cr\ (S=300)} - T_{cr\ (m=0.300)}$
- |G*| and δ master curves
- Rheological parameters
  - R-value
  - Crossover frequency
  - Glover-Rowe parameter



PG Temperatures



ΔT_{cr}



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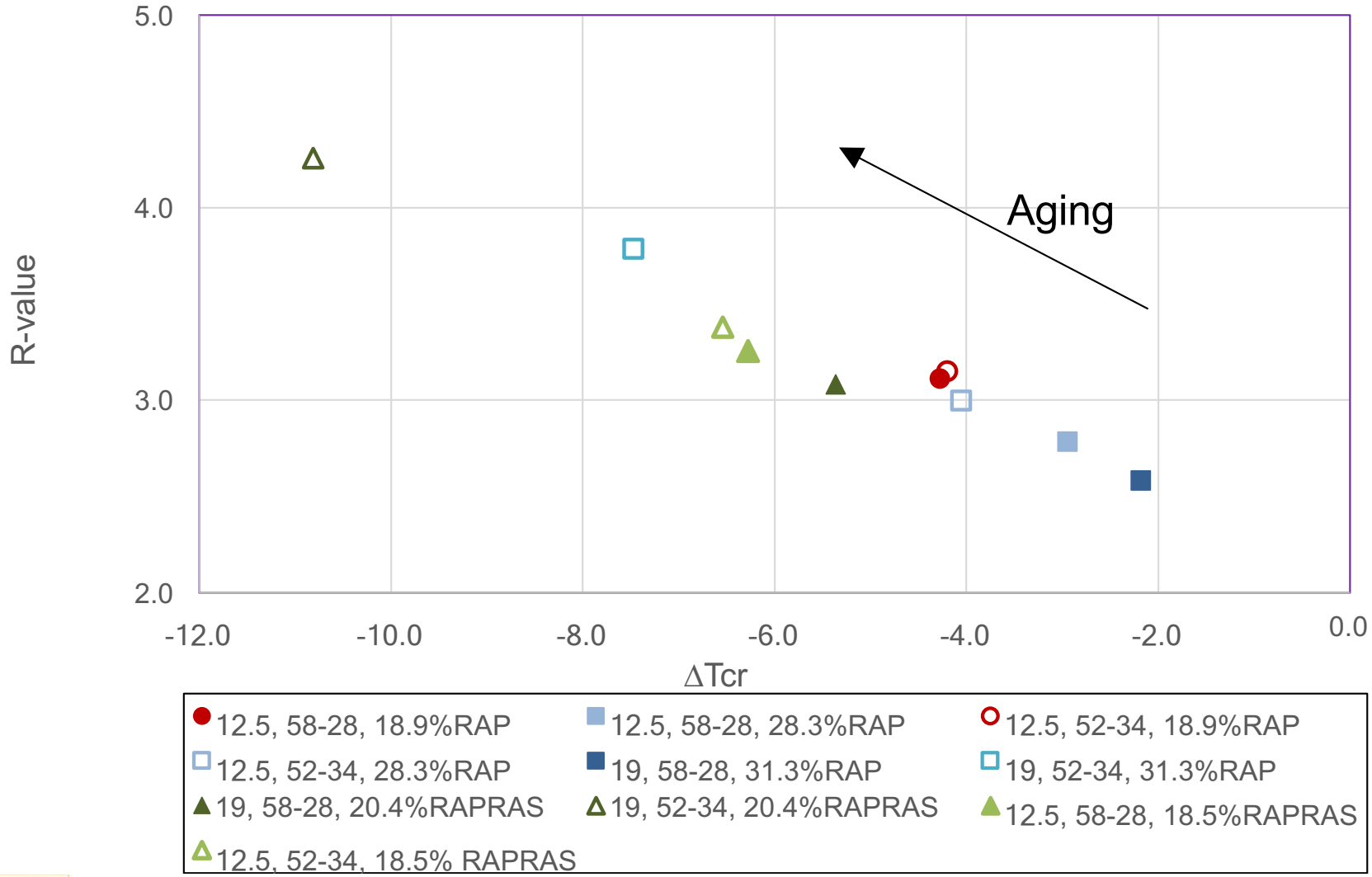
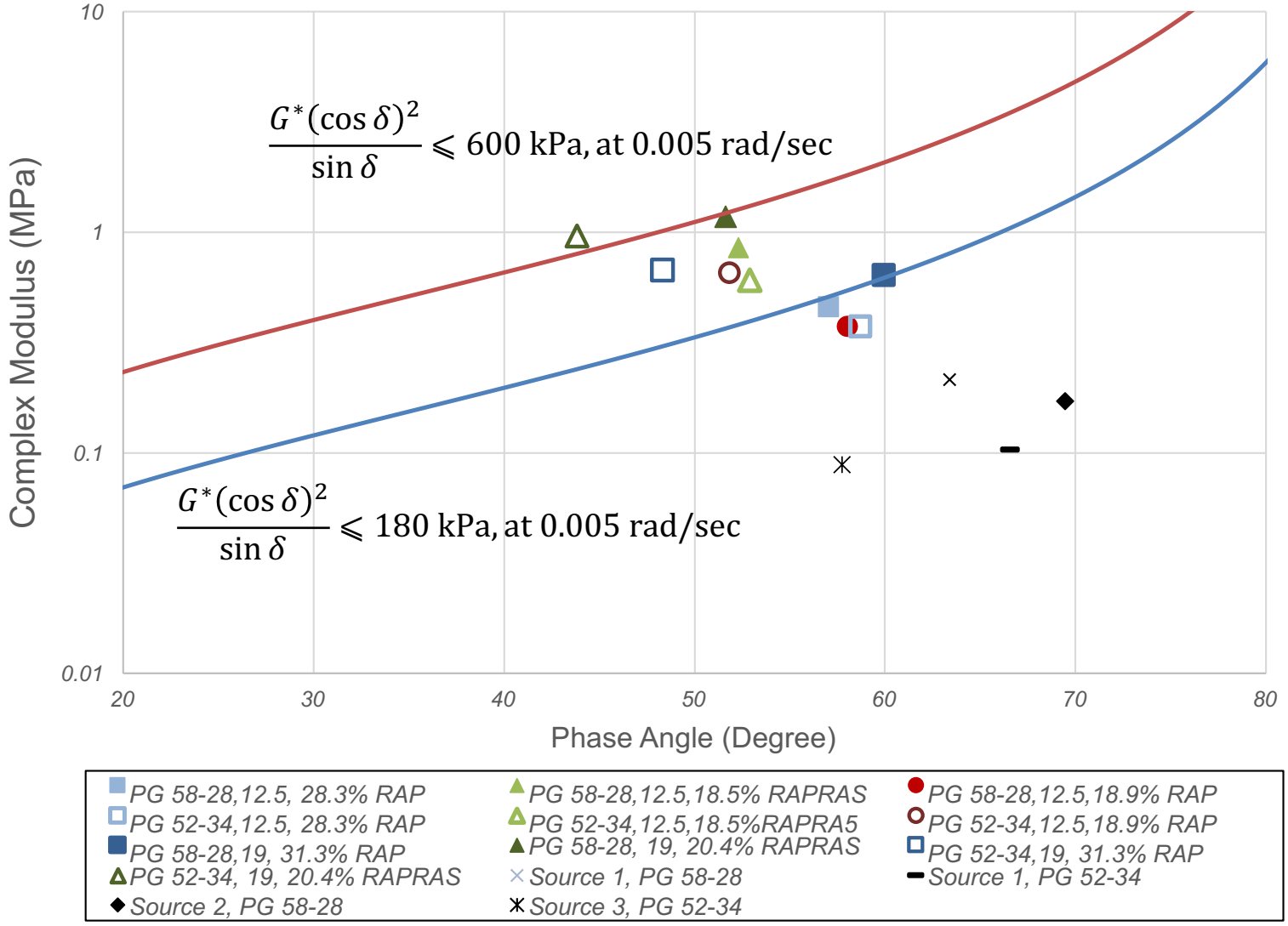
ΔT_{cr} vs R-value



Glover-Rowe Parameter



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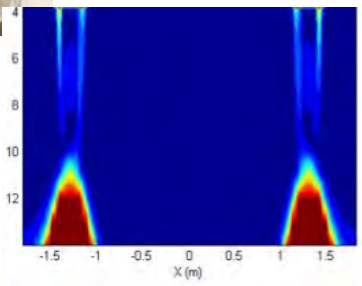
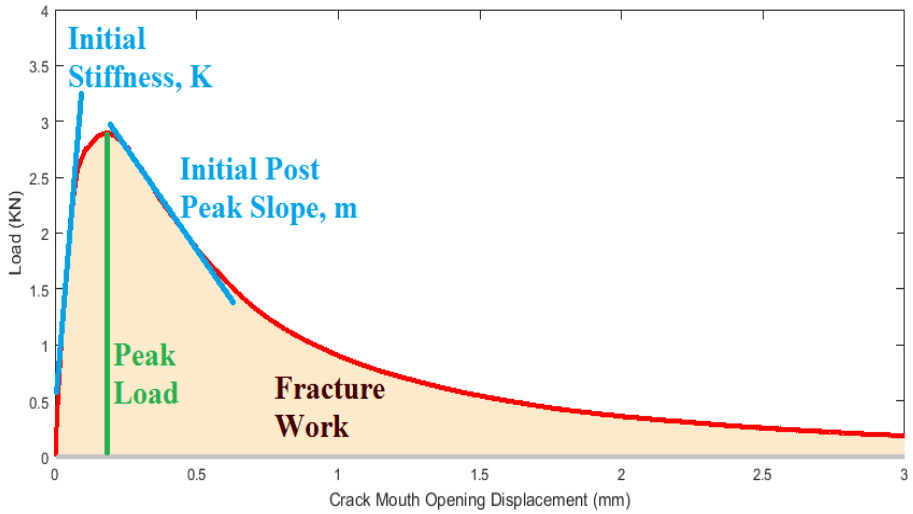
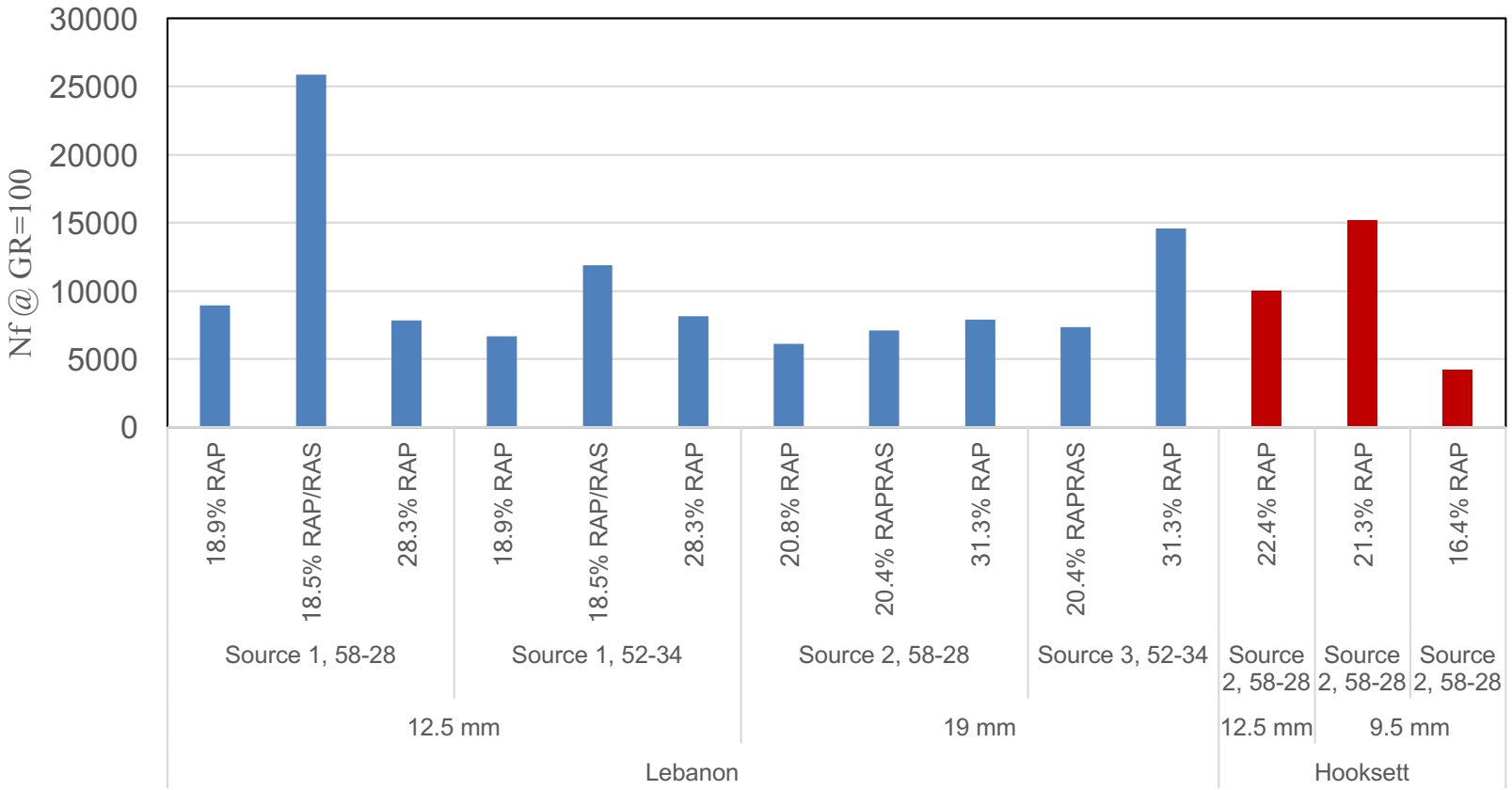
Mixture Parameters



- Complex Modulus (AASHTO T-342)
  - Master curve parameters
  - Mixture Glover-Rowe parameter
- Uniaxial Fatigue Testing (AASHTO TP-107)
  - SVECD and LVECD pavement evaluation
- Disc-Shaped Compact Tension (ASTM D7313-13)



SVECD Fatigue (N_f @ G^R=100)



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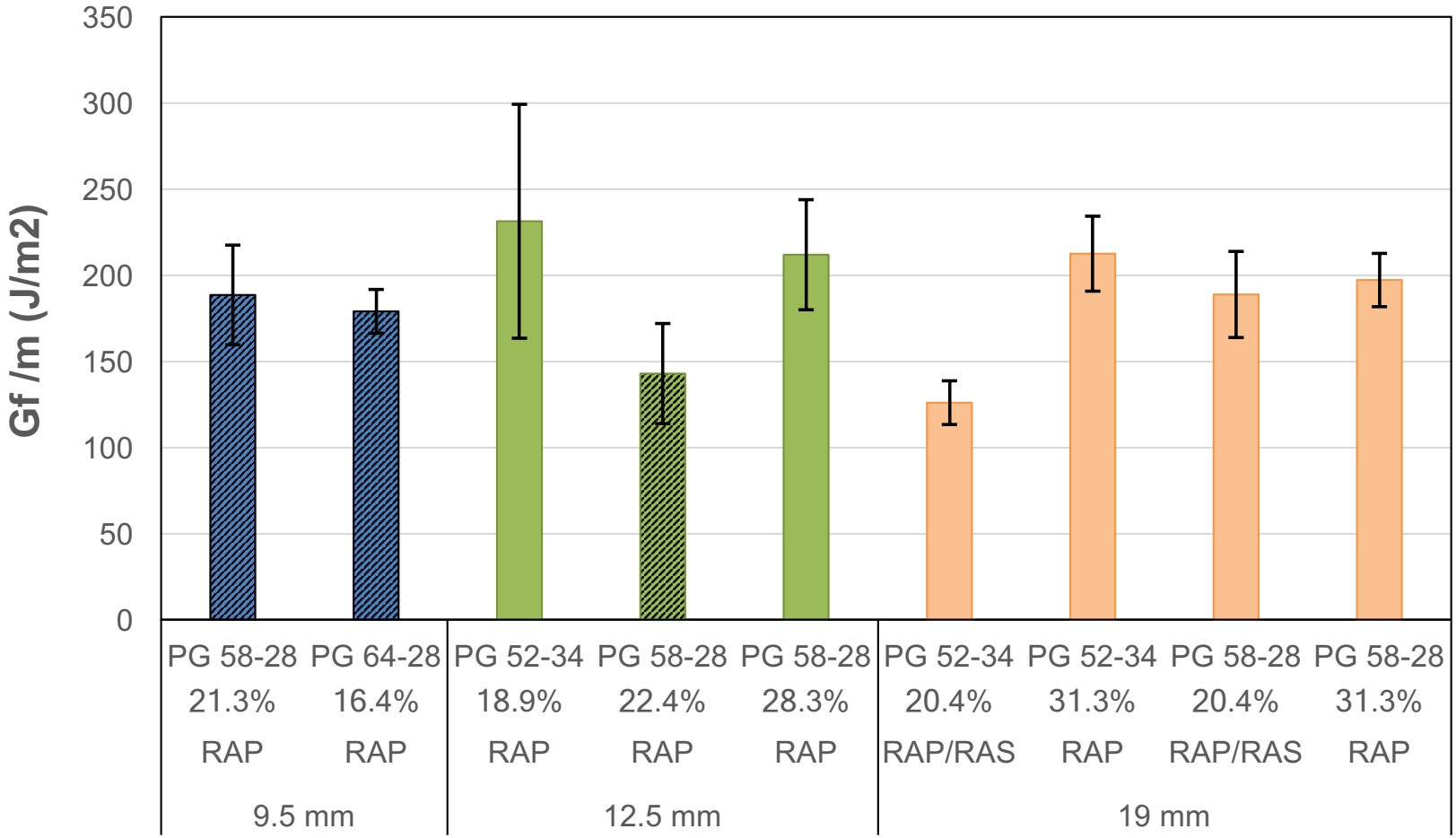
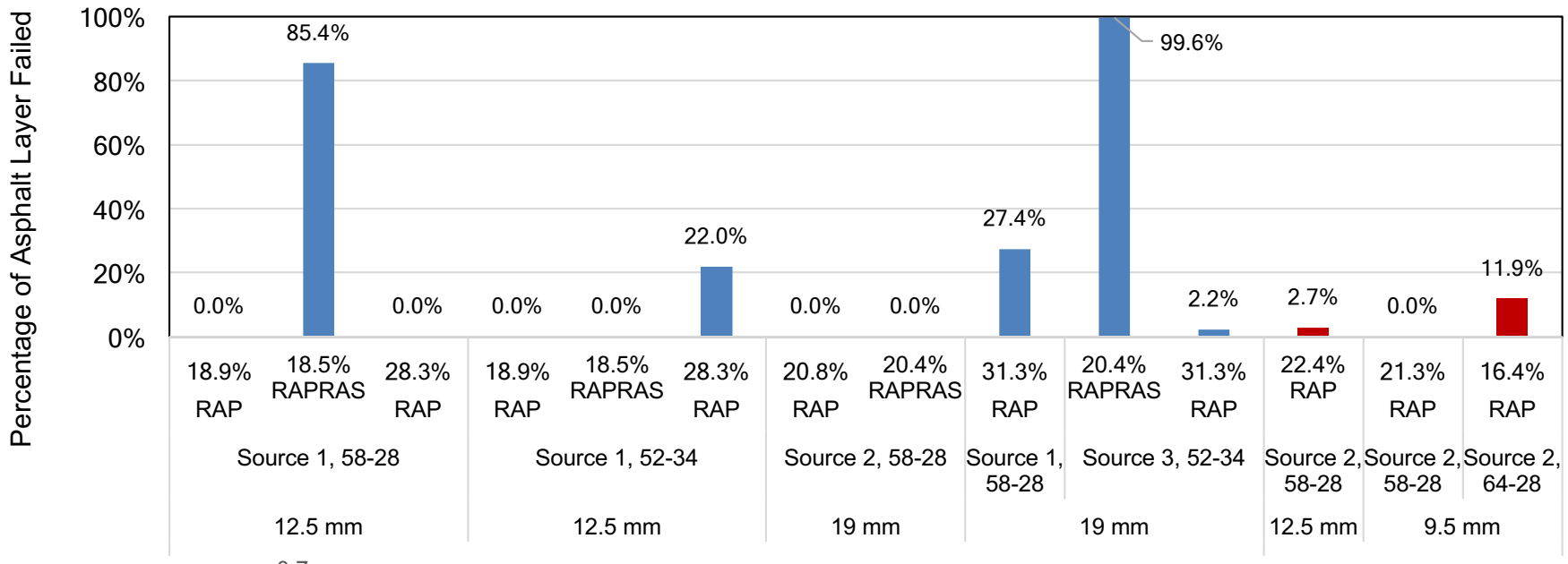
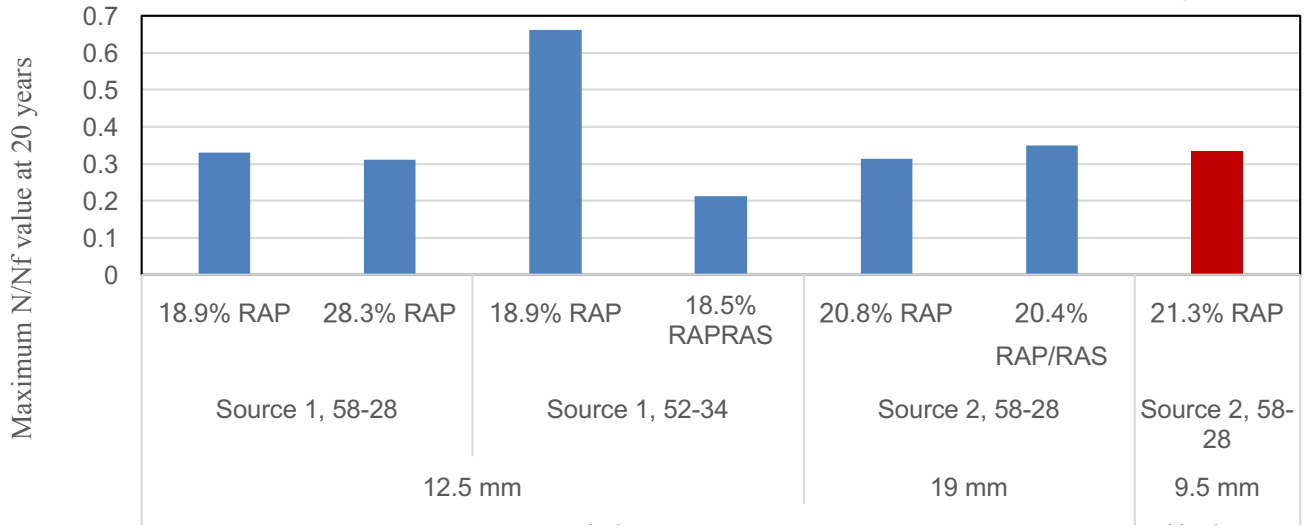
DCT Flexibility Index



Pavement Evaluation





Parameter Comparisons

- Pearson correlation factor: measure of linear relationship between two parameters
- Binder parameter comparisons
- Mixture parameter comparisons
- Binder-Mixture comparisons

Comparison of Binder Parameters

	G-R	ΔTcr	High PG Temp	Low PG Temp	R value	G* (0° C)	G* (25° C)	Phase binder (0° C)	Phase Binder (25° C)
G-R	1.00	-0.81	0.93	0.92	0.73	0.00	0.48	-0.84	-0.90
ΔTcr	-0.81	1.00	-0.76	-0.73	-0.98	0.54	-0.01	0.49	0.96
High PG Temp.	0.93	-0.76	1.00	0.92	0.66	0.07	0.59	-0.88	-0.88
Low PG Temp.	0.92	-0.73	0.92	1.00	0.60	0.08	0.62	-0.86	-0.84
R value	0.73	-0.98	0.66	0.60	1.00	-0.65	-0.16	-0.36	-0.92
G* (0° C)	0.00	0.54	0.07	0.08	-0.65	1.00	0.80	-0.45	0.35
G* (25° C)	0.48	-0.01	0.59	0.62	-0.16	0.80	1.00	-0.85	-0.23
Phase binder (0° C)	-0.84	0.49	-0.88	-0.86	-0.36	-0.45	-0.85	1.00	0.68
Phase Binder (25°C)	-0.90	0.96	-0.88	-0.84	-0.92	0.35	-0.23	0.68	1.00

Comparison of Mixture Parameters

	Nf @ GR=100	Fracture Energy	Flex Index	Mix-based G-R	Gamma	E* (4.4°C)	E* (21°C)	Phase binder (4.4° C)	Phase Binder (21° C)
Nf @ GR=100	1.00	-0.08	0.10	0.02	-0.32	0.04	0.07	-0.09	0.13
Fracture Energy	-0.08	1.00	0.44	0.19	0.01	0.16	0.10	-0.33	-0.11
Flex Index	0.10	0.44	1.00	-0.31	-0.56	0.13	-0.26	0.24	0.65
Mix-based G-R	0.02	0.19	-0.31	1.00	0.67	0.71	0.67	-0.64	-0.68
Gamma	-0.32	0.01	-0.56	0.67	1.00	0.18	0.21	-0.23	-0.51
E* (4.4°C)	0.04	0.16	0.13	0.71	0.18	1.00	0.76	-0.66	-0.37
E* (21° C)	0.07	0.10	-0.26	0.67	0.21	0.76	1.00	-0.89	-0.80
Phase binder (4.4° C)	-0.09	-0.33	0.24	-0.64	-0.23	-0.66	-0.89	1.00	0.80
Phase Binder (21° C)	0.13	-0.11	0.65	-0.68	-0.51	-0.37	-0.80	0.80	1.00

Comparison of Binder and Mixture Parameters

Category	Comparison	Pearson Correlation Coefficient	
		Parameter Values	Parameter Rankings
Stiffness	G* at 0C vs E* at 4.4C	0.64	0.59
	G* at 25C vs E* at 21.1 C	0.85	0.78
Relaxation	Phase Angle (0 C binder vs 4.4 C mixture)	0.36	0.58
	Phase Angle (25 C binder vs 21.1 C mixture)	0.38	0.22
Aging	G-R vs mixed-based G-R	-0.22	-0.26
	R value vs Gamma	0.59	0.47
Low Temp. Cracking	ΔTcr vs DCT Flex Index	0.41	0.07
Fatigue Cracking	G-R vs N_f@ G^R=100	0.08	0.16
	G-R vs LVECD	-	0.36
	ΔTcr vs N_f@ G^R=100	-0.34	-0.26
	ΔTcr vs LVECD	-	0.12

Conclusions

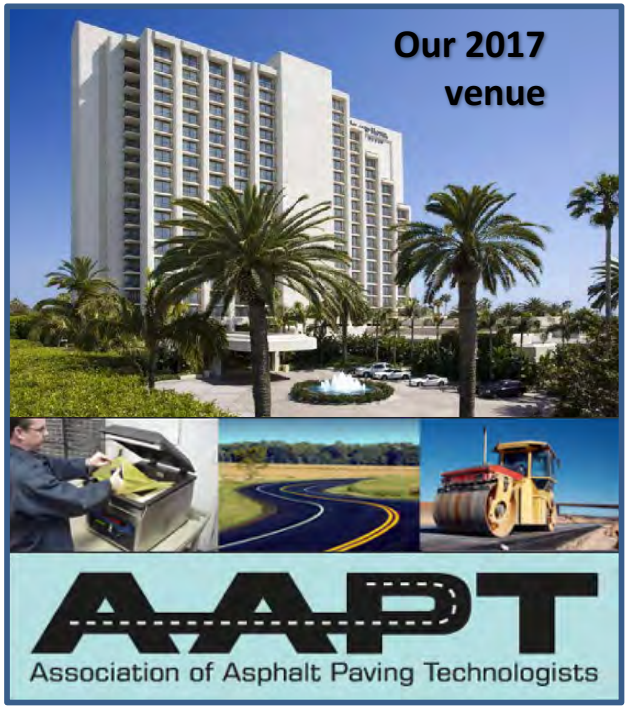
- Very good to good correlations between binder index parameters
- The strongest correlation is between R value and ΔT_{cr}
- The mixture factors did not show strong correlation with each other
- Binder and mixture stiffness are strongly correlated, as expected
- Short-term cracking behavior of mixtures may not be accurately predicted only by rheological parameters of the binder

Future work

- The actual field cracking performance of mixtures needs to be incorporated in the analysis
- Testing on long term aged mixtures is needed to conduct a better comparison
- Additional statistical analysis may help to identify stronger mixture and binder relationships

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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2017 Annual Meeting

The Annual Business Meeting and Technical Sessions of the Association of Asphalt Paving Technologists (AAPT) will be March 19-22, 2017 in Newport Beach, California at The Island Hotel (www.islandhotel.com). The annual meeting includes asphalt-related technical sessions comprised of peer-reviewed papers, and invited presentations on specific topics in the Leading Edge Workshop, AAPT-ISAP International Forum, and Symposium. Please see the Annual Meeting page (http://asphalttechnology.org/annual-meeting.html) for more details as they become available.

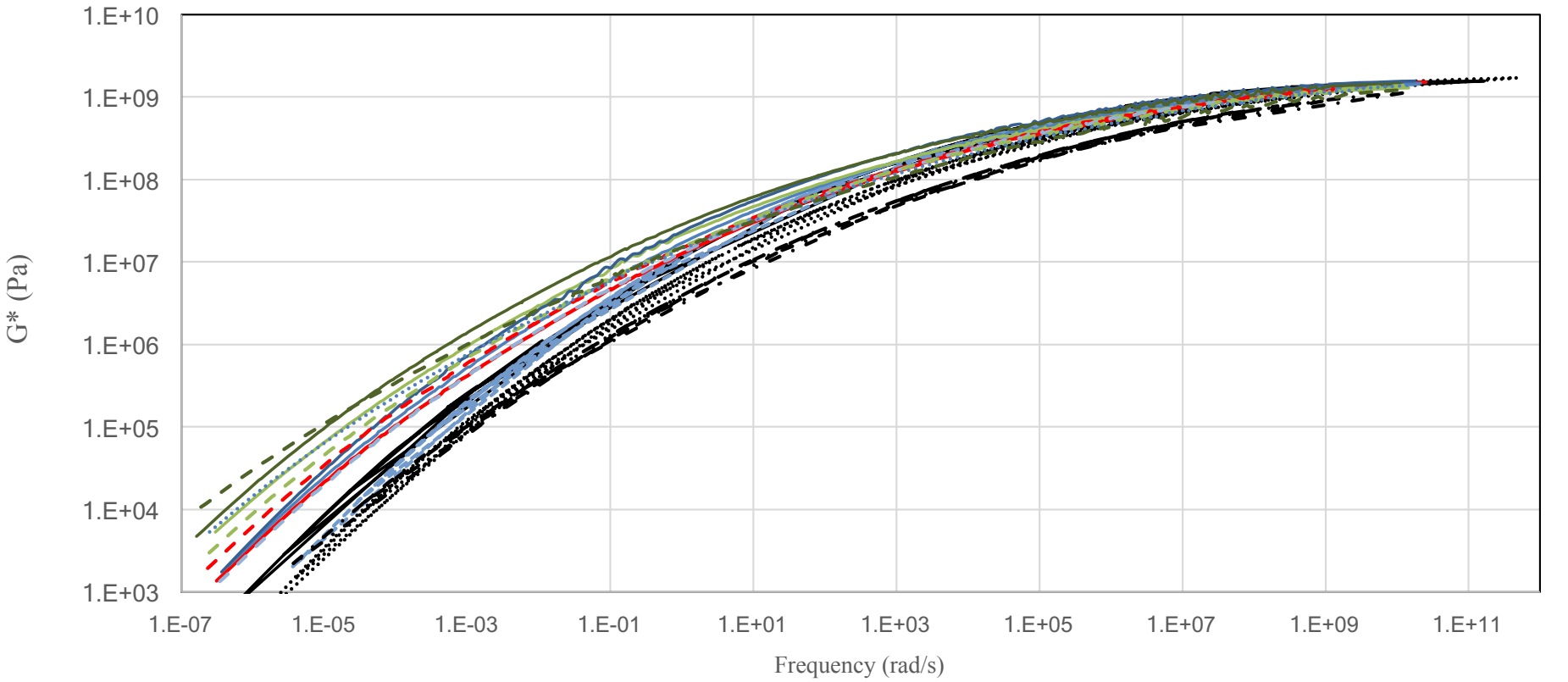
Important dates

August 15, 2016 - deadline for submitting papers **(CLOSED)**
October 10, 2016 - peer reviews completed
November 4, 2016 - notification of paper acceptance
December 2016 – Annual Meeting registration opens
March 19 to 22, 2017 - Annual Business Meeting and Technical Sessions

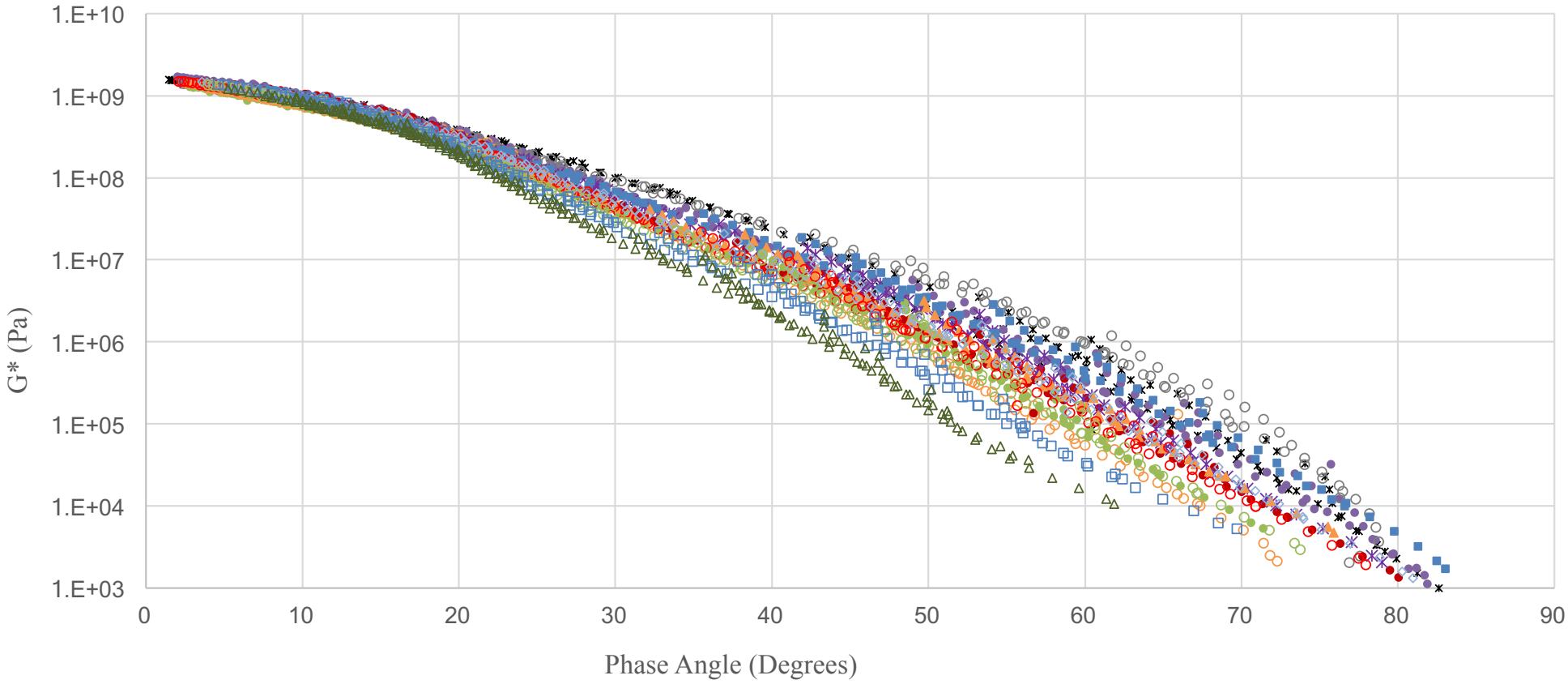
For the latest information please check our web site at: http://www.asphalttechnology.org

Questi ons?

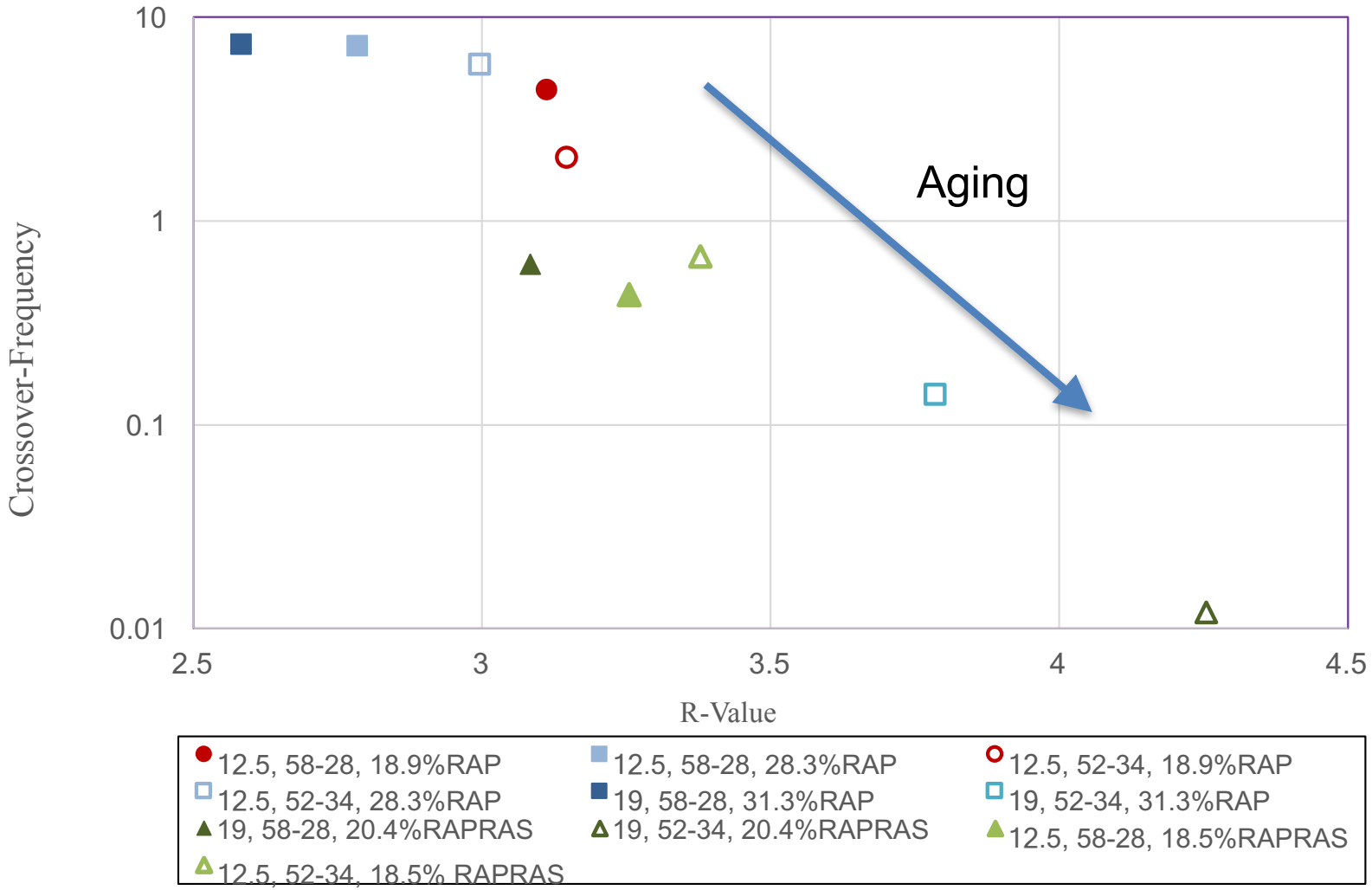
Shear Modulus Mastercurve



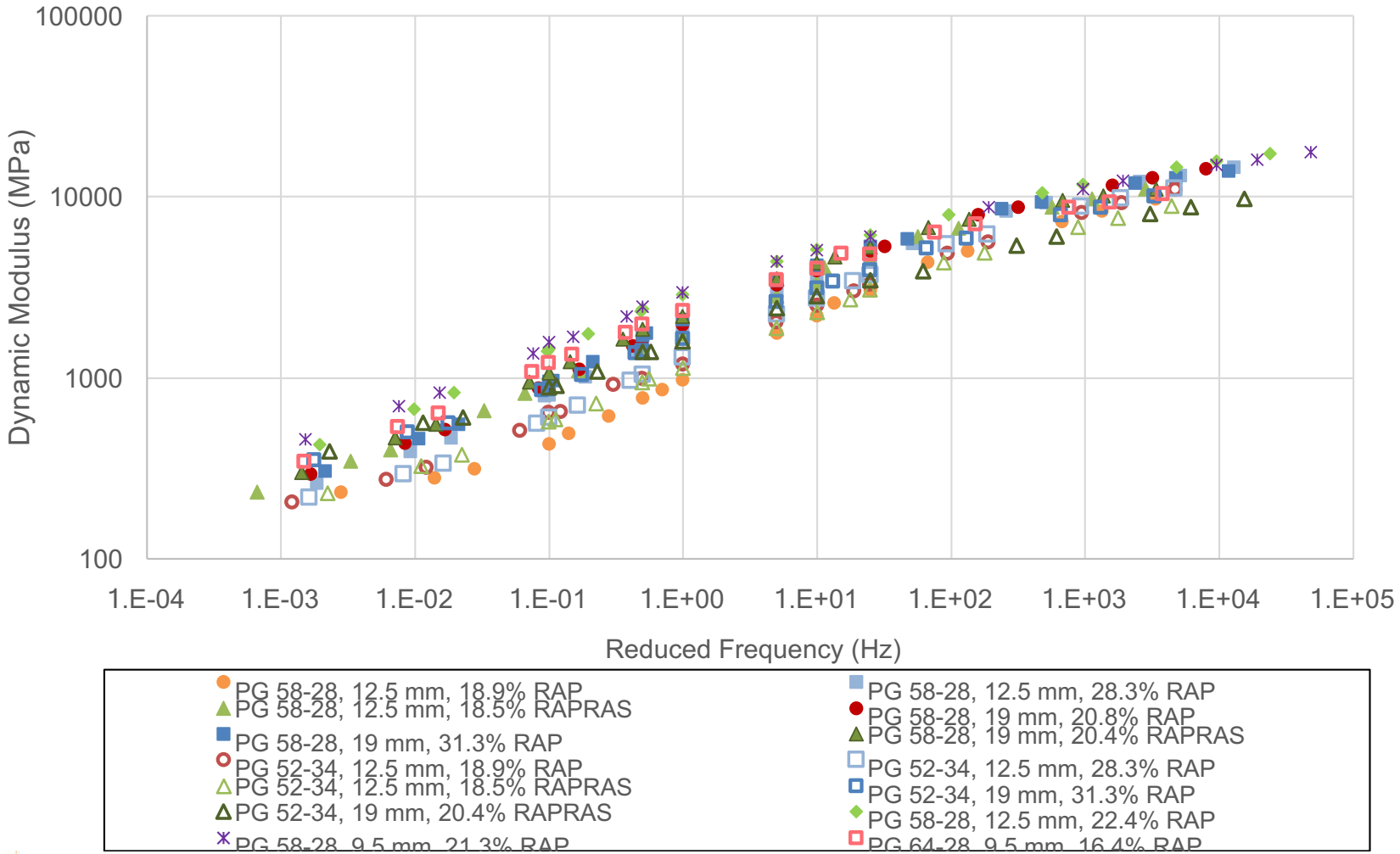
Phase Angle Diagrams



Crossover Frequency- R value



Dynamic Modulus Mastercurves



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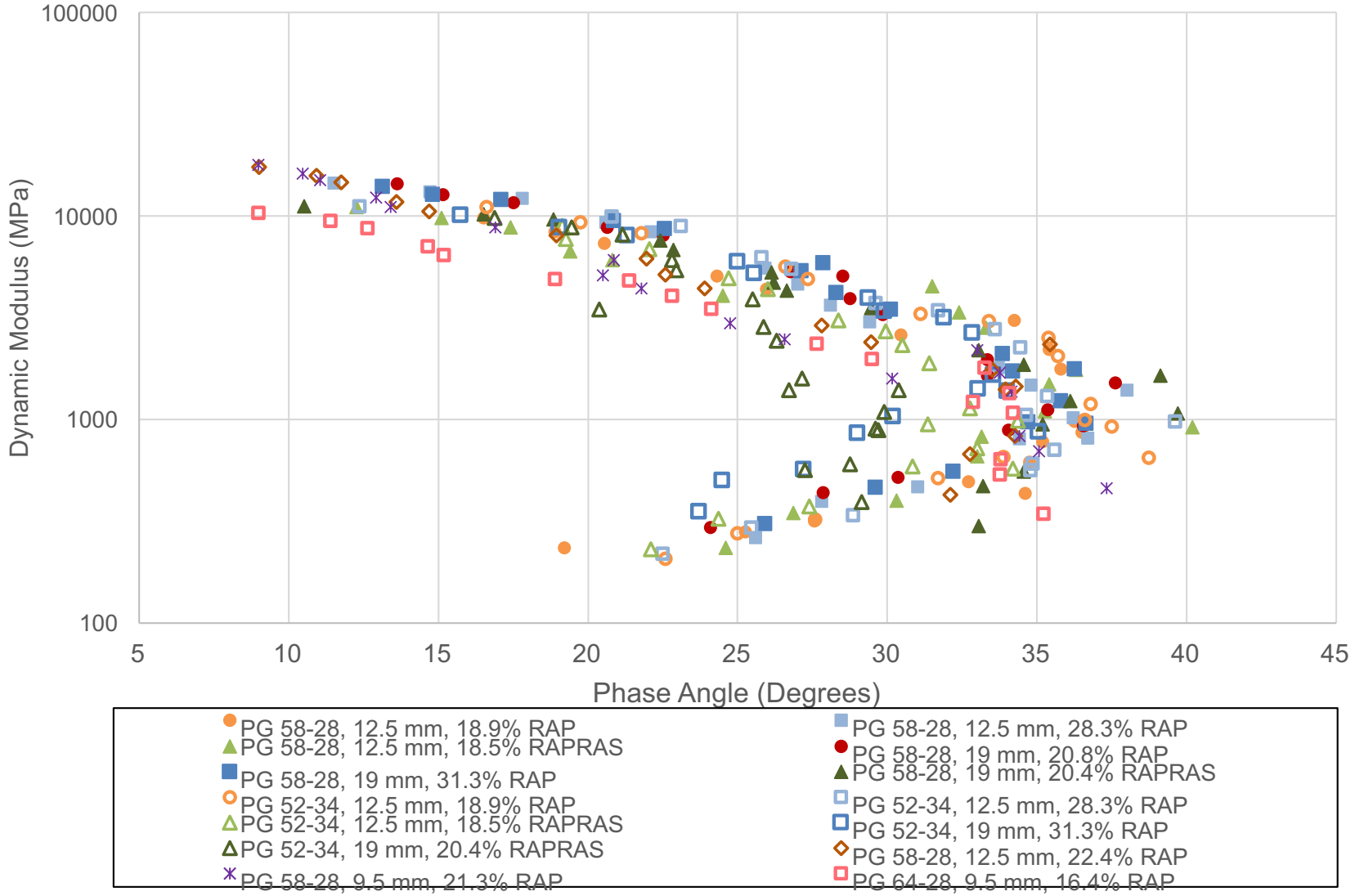
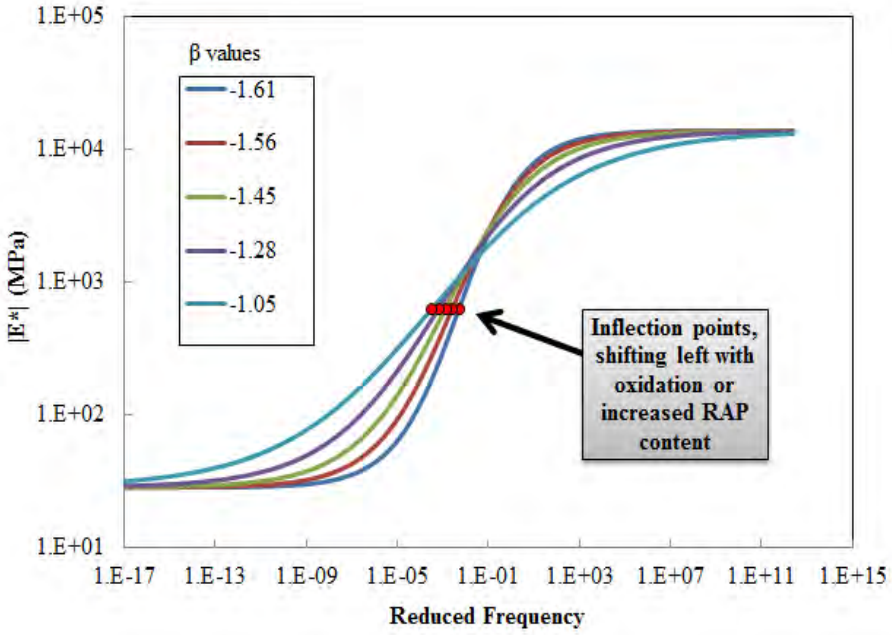
Black Space Diagrams

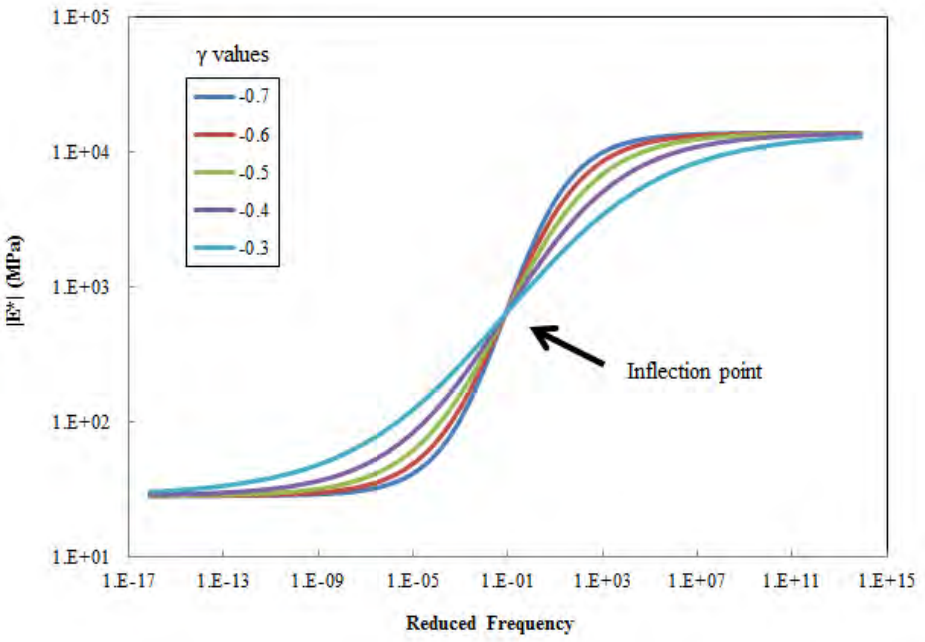


Mixture Parameters

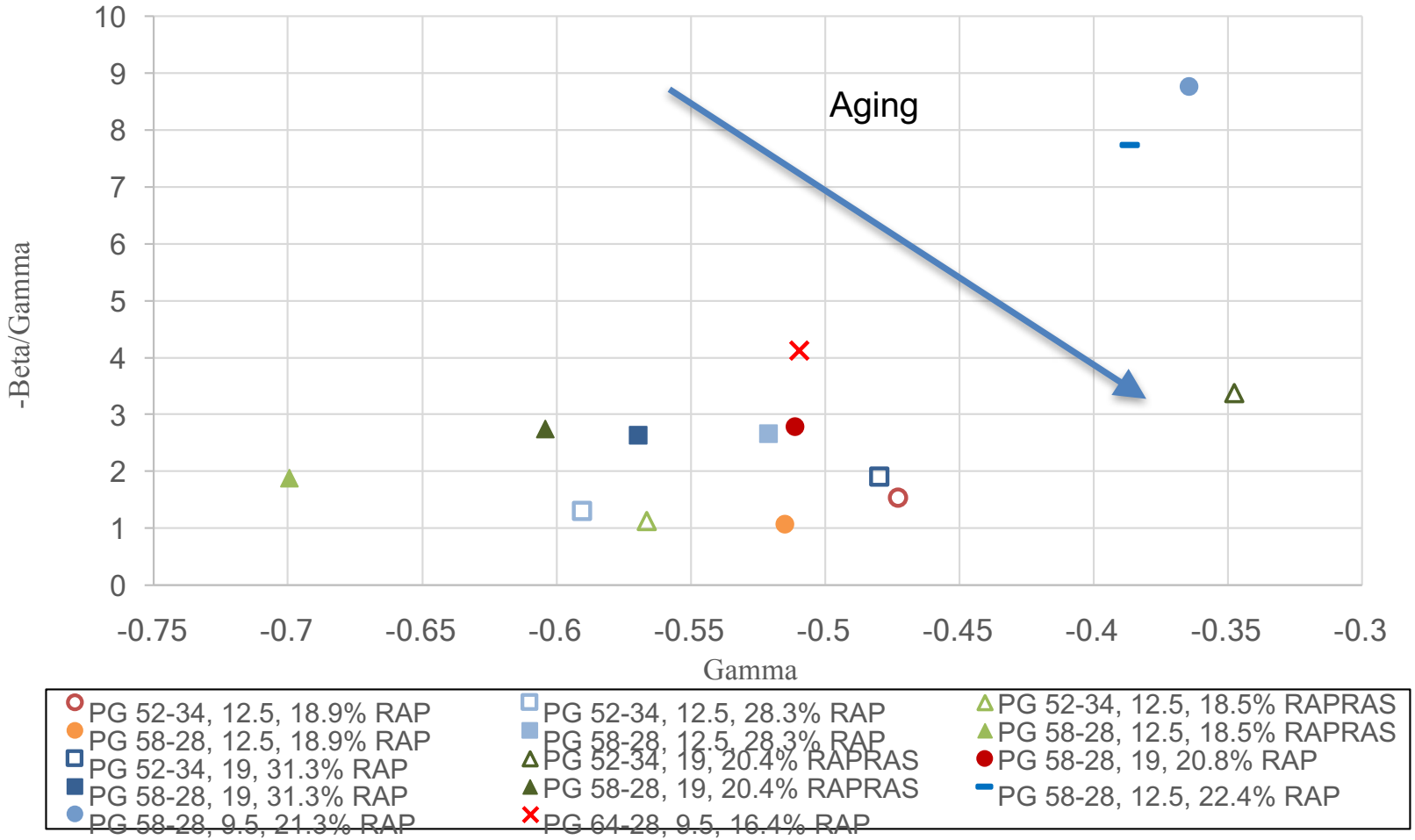
- **-Beta/Gamma vs. Gamma**

$$\log|E^*| = \delta + \frac{\alpha}{(1+\lambda(\exp(\beta+\gamma(\log \omega_r))^{1/\lambda}} \quad \text{(Generalized sigmoidal)}$$



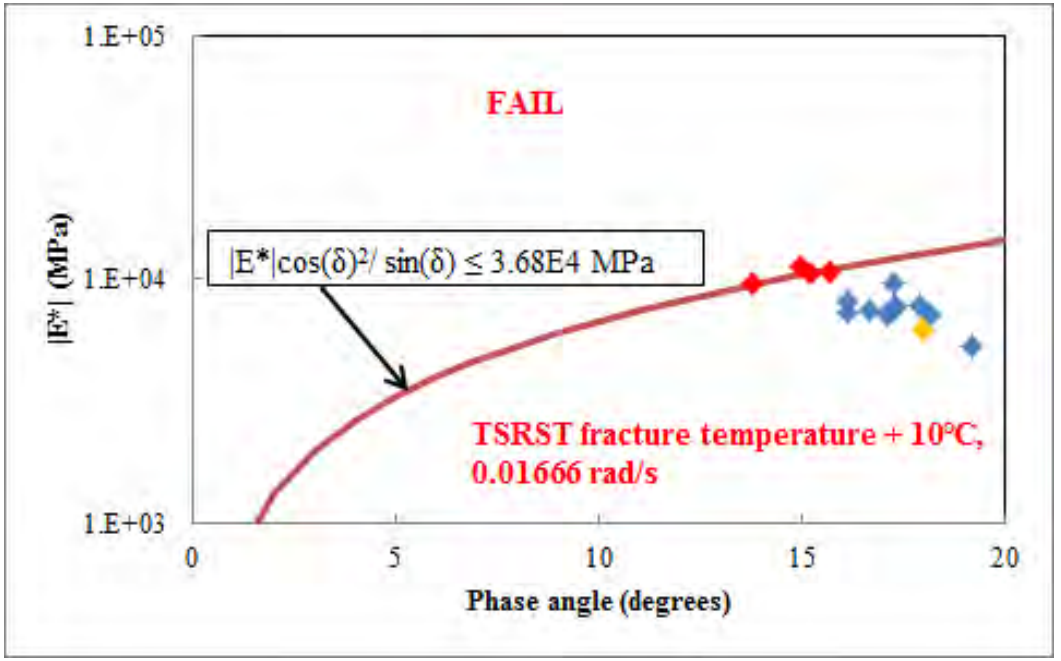


-Beta/gamma vs. Gamma



Mixture Parameters

- **Mix-based Glover-Rowe Parameter**
- Mensching et al., 2016
- $\frac{E^* (\cos \delta)^2}{Sin\ \delta}$
- at 0.01666 rad/s and PGLT + 10 C



Mix-based Black Space