Asphalt Binder and Mixture Properties Produced with REOB Modified Asphalt Binders

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- Rutgers Staff
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- University of Massachusetts-Dartmouth
  - TSRST Testing
- Asphalt Institute
  - DENT Testing
- Axeon Specialty Products
  - Ron Corun

Overview of Study

- Research focused on how a binder supplier would utilize REOB in asphalt binder
- Use REOB to modify stiffer asphalt binders to achieve a softer binder grade (PG64-22 and PG58-28 for this study)
  - Usage in cold temperature climates
  - Usage with higher recycled asphalt mixtures (RAP and/or RAS)
- Asphalt binders (base asphalt from Axeon - Paulsboro, NJ)
  - Neat PG64-22
  - Neat PG58-28
  - REOB modified PG58-28 (20% REOB; 80% PG70-22)
  - REOB modified PG58-28 (6% REOB; 94% PG64-22)
  - REOB modified PG64-22 (10% REOB; 90% PG70-22)
- 2 REOB Sources
- Total of 8 binders evaluated
- Mix: NJDOT approved 9.5mm NMAS, 5.4% asphalt content

Overall Workplan – Lab Testing

- Asphalt Binder Testing
  - PG grading (BBR 20 and 40 hr PAV aging)
  - Master Stiffness Curves
    - Original, RTFO, PAV 20 hr, PAV 40 hr
    - Glover-Rowe Parameter, Rheological Properties
  - DENT test (PAV aged)
- Asphalt Mixture Testing (STOA & LTOA)
  - Dynamic Modulus
  - Flow Number
  - Overlay Tester
  - Flexural Beam Fatigue
  - SCB Intermediate Temperature
  - TSRST

Binder Test Results

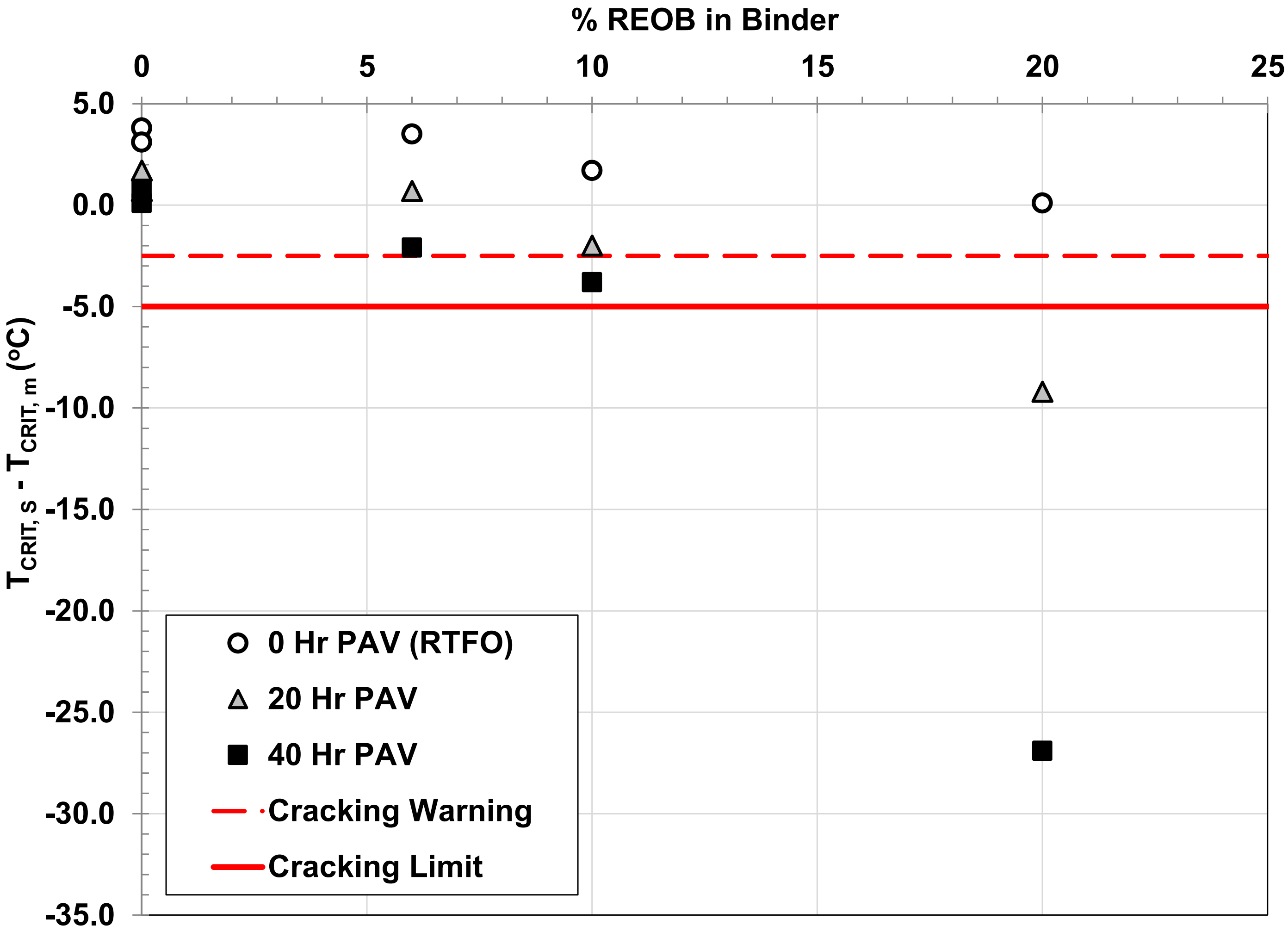
PG Grading (1 of 2)

REOB Supplier	Target Grade	% REOB	High Temperature		Multiple Stress Creep Recovery (MSCR)				Inter. Temp
					58°C		64°C		
			Orig	RFTO	J_{nr} (1/kPa)	% Rec	J_{nr} (1/kPa)	% Rec	
N.A.	58-28	0%	61.3	66.9	2.81	1.3	6.24	0.2	14.3
	64-22	0%	68.7	70.2	0.78	9.1	1.98	2.4	18.8
Supplier #1	58-28	6% REOB + 94% 64-22	60.5	60.5	2.70	1.4	6.06	0.2	15.1
	58-28	20% REOB + 80% 70-22	61.4	65.3	2.25	2.3	5.17	0.5	12.4
	64-22	10% REOB + 90% 70-22	67.0	73.1	1.28	3.3	3.01	1.0	17.6
Supplier #2	58-28	6% REOB + 94% 64-22	64.5	64.7	1.74	2.74	4.06	0.79	16.5
	58-28	20% REOB + 80% 70-22	61.0	62.6	2.32	3.27	3.04	1.10	9.3
	64-22	10% REOB + 90% 70-22	66.6	67.0	1.27	4.98	3.04	1.73	17.8

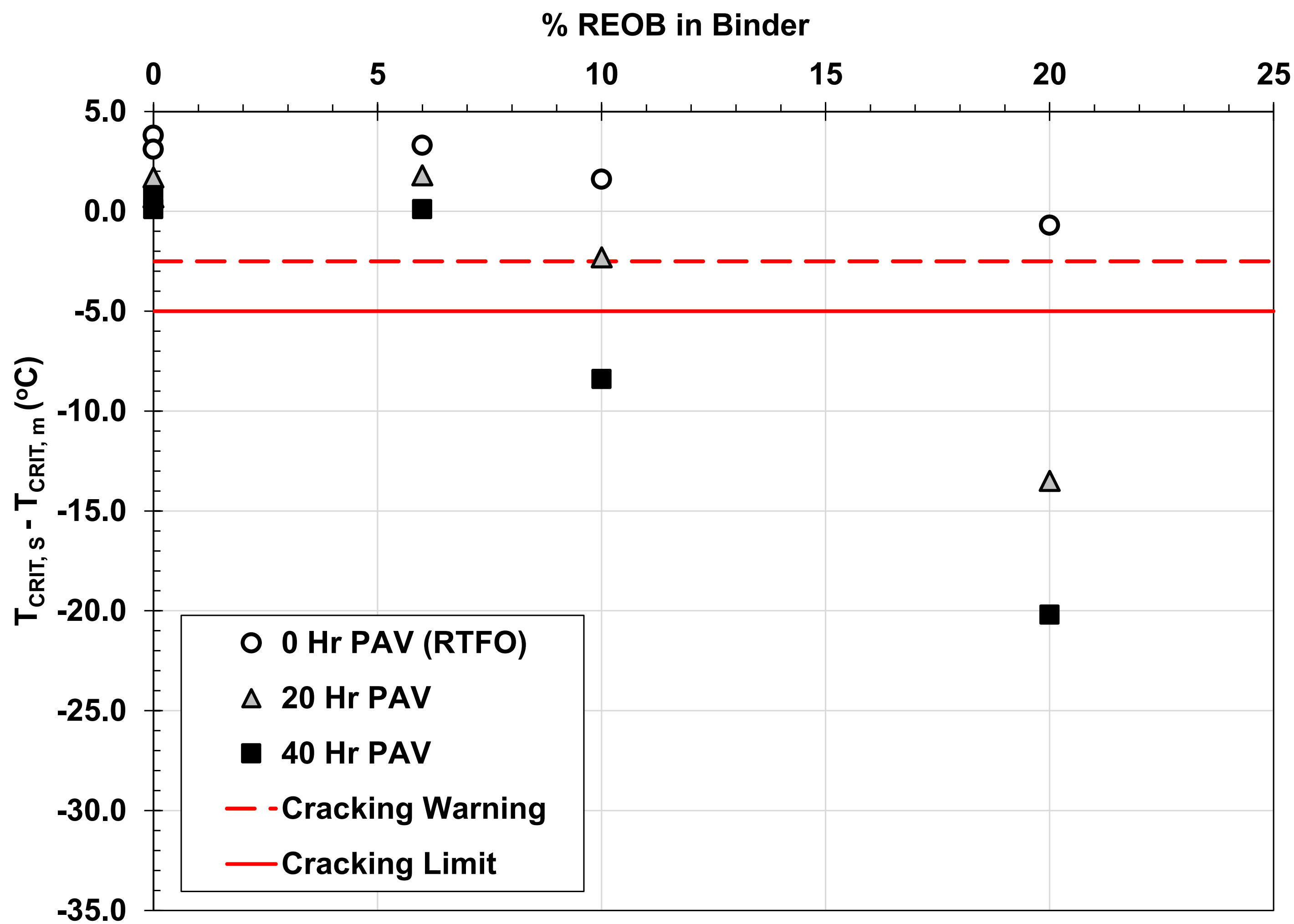
PG Grading (2 of 2)

REOB Supplier	Target Grade	% REOB	Low Temperature							PG Grade
			RFTO		PAV (20 Hrs)		PAV (40 Hrs)		R49 (20 Hr)	
			m-slope	S (MPa)	m-slope	S (MPa)	m-slope	S (MPa)		
N.A.	58-28	0%	-38.0	-34.2	-33.8	-32.1	-32.5	-31.7	-30.2	PG58-28
	64-22	0%	-34.4	-31.3	-30.1	-29.4	-28.7	-28.6	-27.6	PG64-28
Supplier #1	58-28	6% REOB + 94% 64-22	-37.9	-34.4	-33.5	-32.8	-29.5	-31.6	-32.2	PG58-28
	58-28	20% REOB + 80% 70-22	-39.7	-39.6	-28.6	-37.8	-10.0	-36.9	-33.9	PG58-28
	64-22	10% REOB + 90% 70-22	-35.0	-33.3	-29.1	-31.1	-26.5	-30.3	-27.8	PG64-28
Supplier #2	58-28	6% REOB + 94% 64-22	-35.5	-32.2	-31.7	-29.9	-28.8	-28.7	-34.8	PG64-28
	58-28	20% REOB + 80% 70-22	-41.5	-42.2	-26.1	-39.6	-18.0	-38.2	-36.9	PG58-22
	64-22	10% REOB + 90% 70-22	-35.9	-34.3	-29.8	-32.1	-22.9	-31.3	-30.2	PG64-28

BBR ΔT_{crit} vs Aging (Source #1)

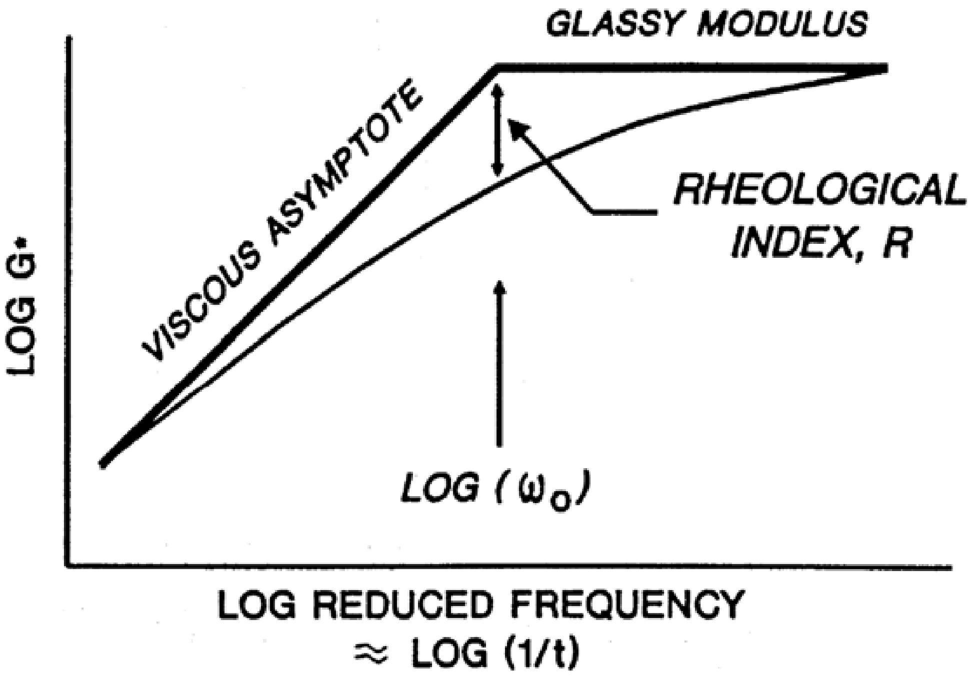


BBR ΔT_{crit} vs Aging (Source #2)

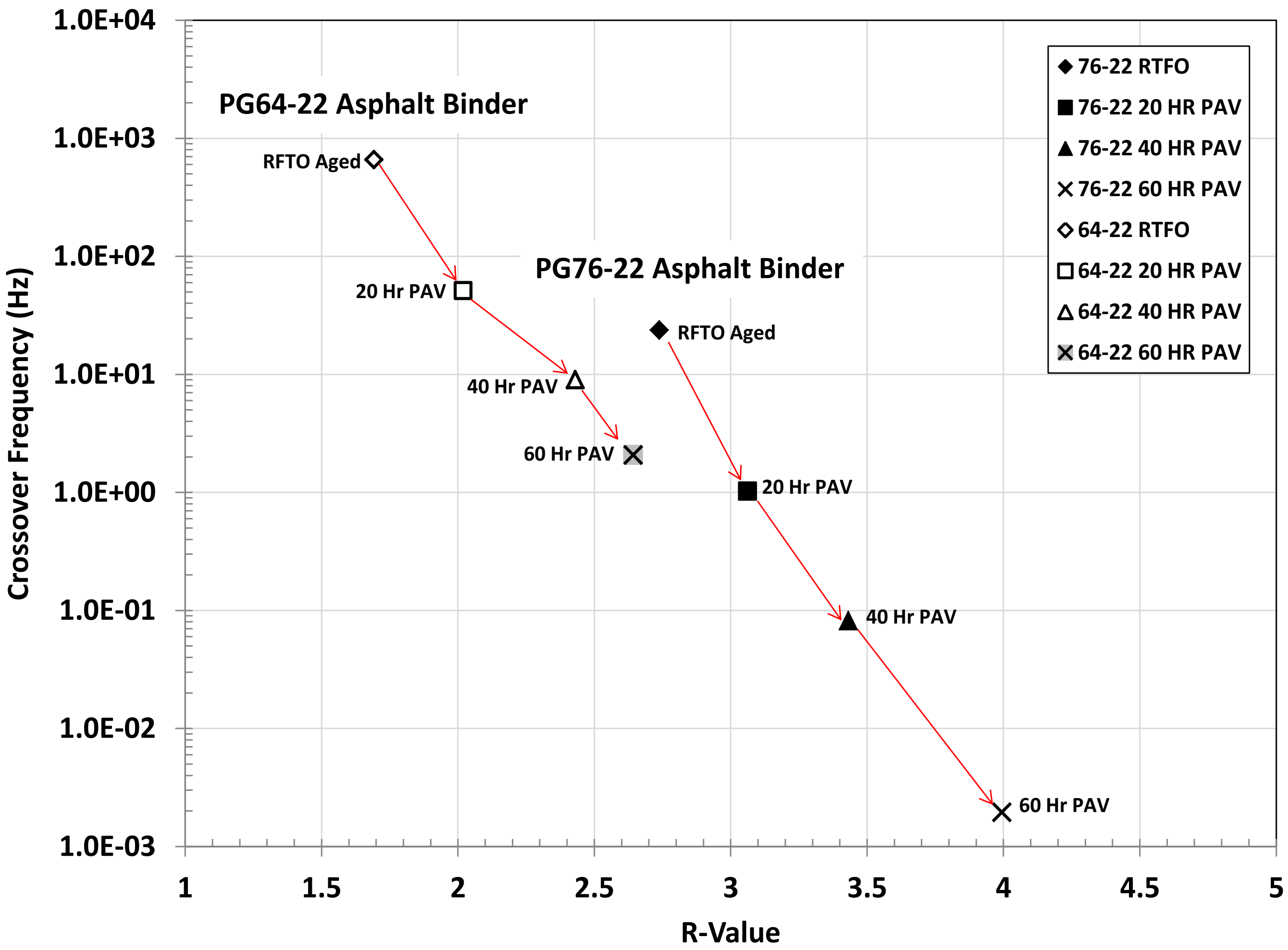


Master Stiffness (G*) Curves - Form of Master Curve (Christensen & Anderson, 2001)

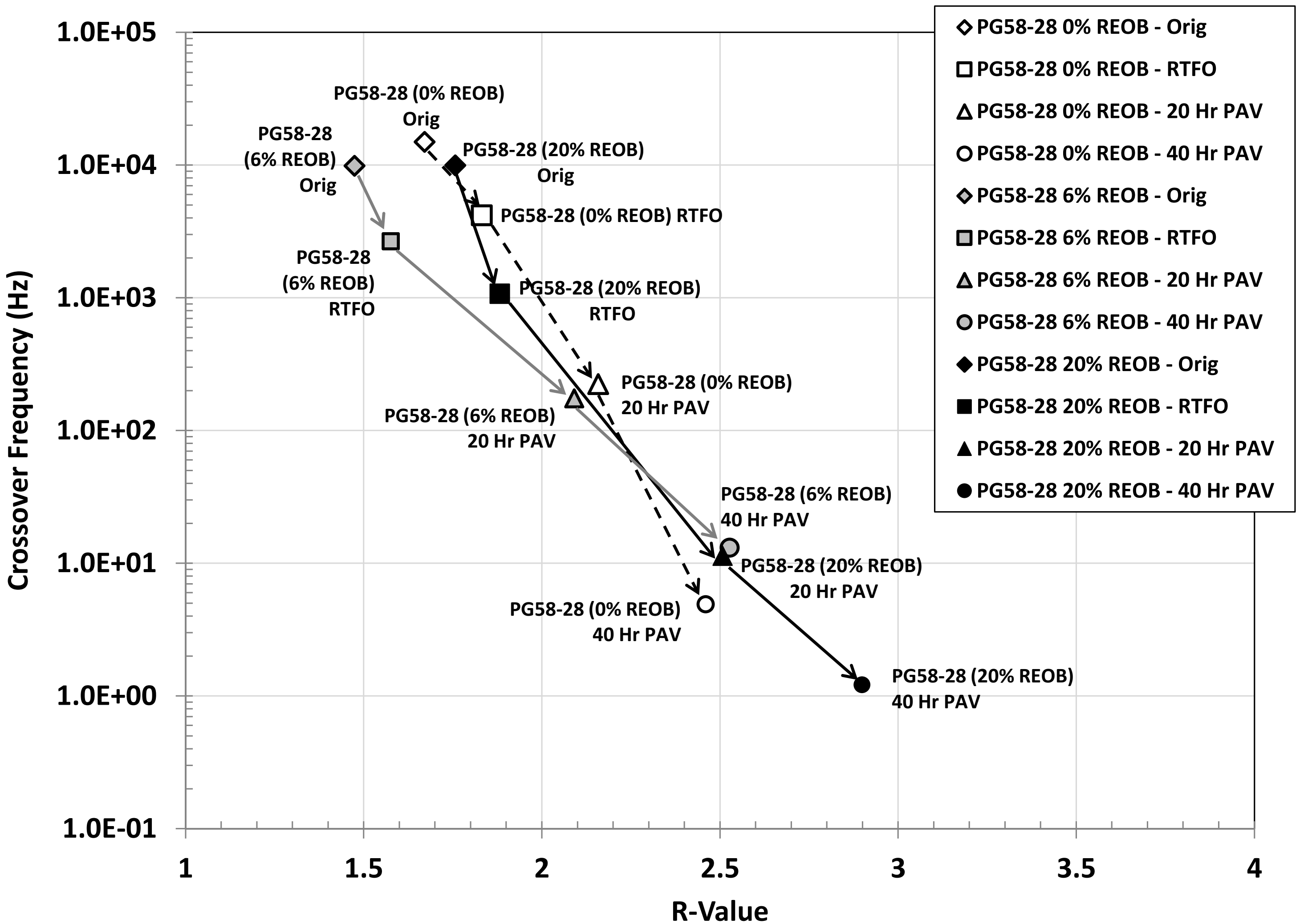
- Master Stiffness (G*) curves generated using frequency sweep in the DSR
- Shape of master curve related to overall stiffness of the asphat binder
- As binders age, increase in stiffening



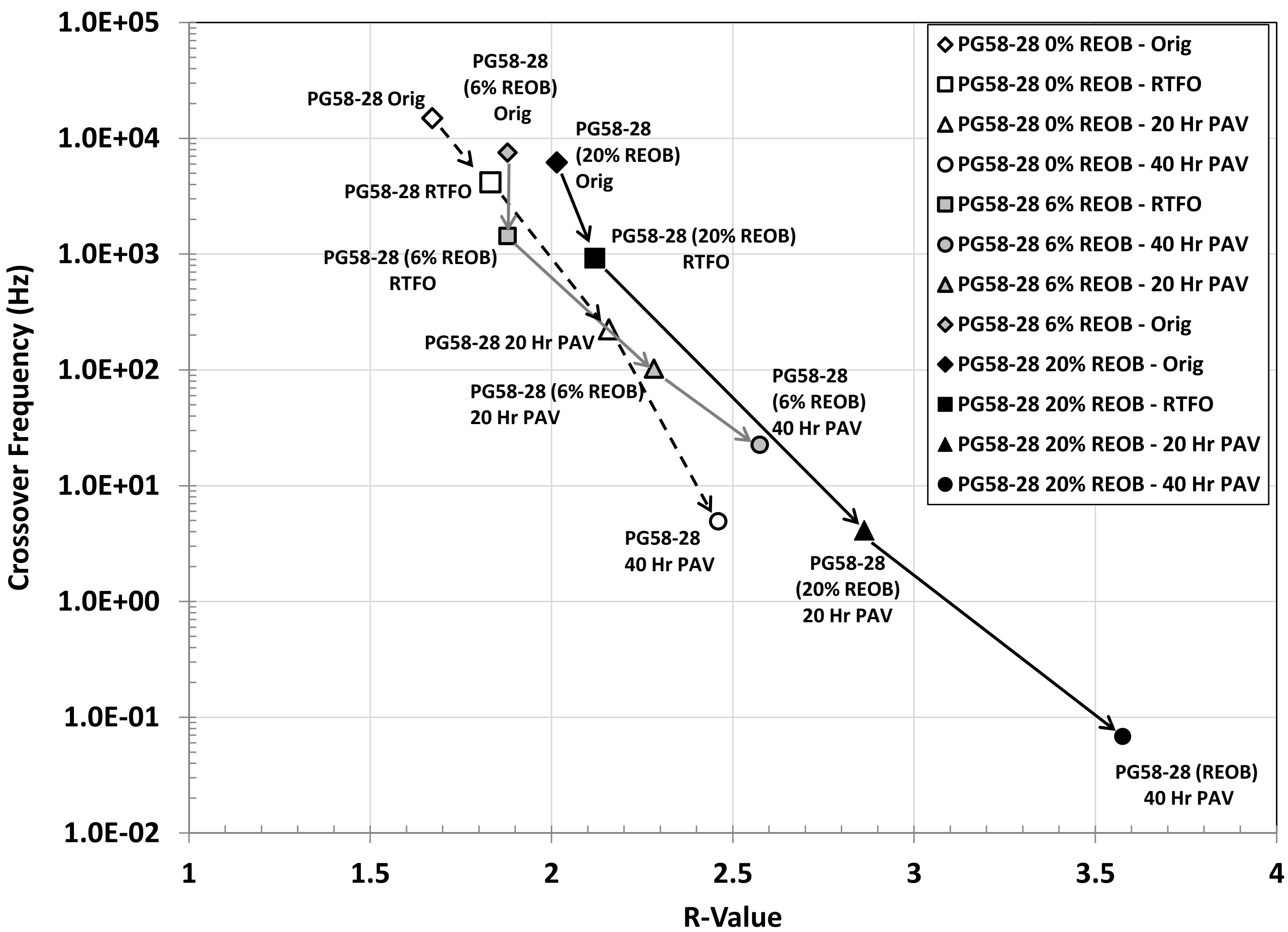
PG64-22 & PG76-22 in ω_o & R-value Space



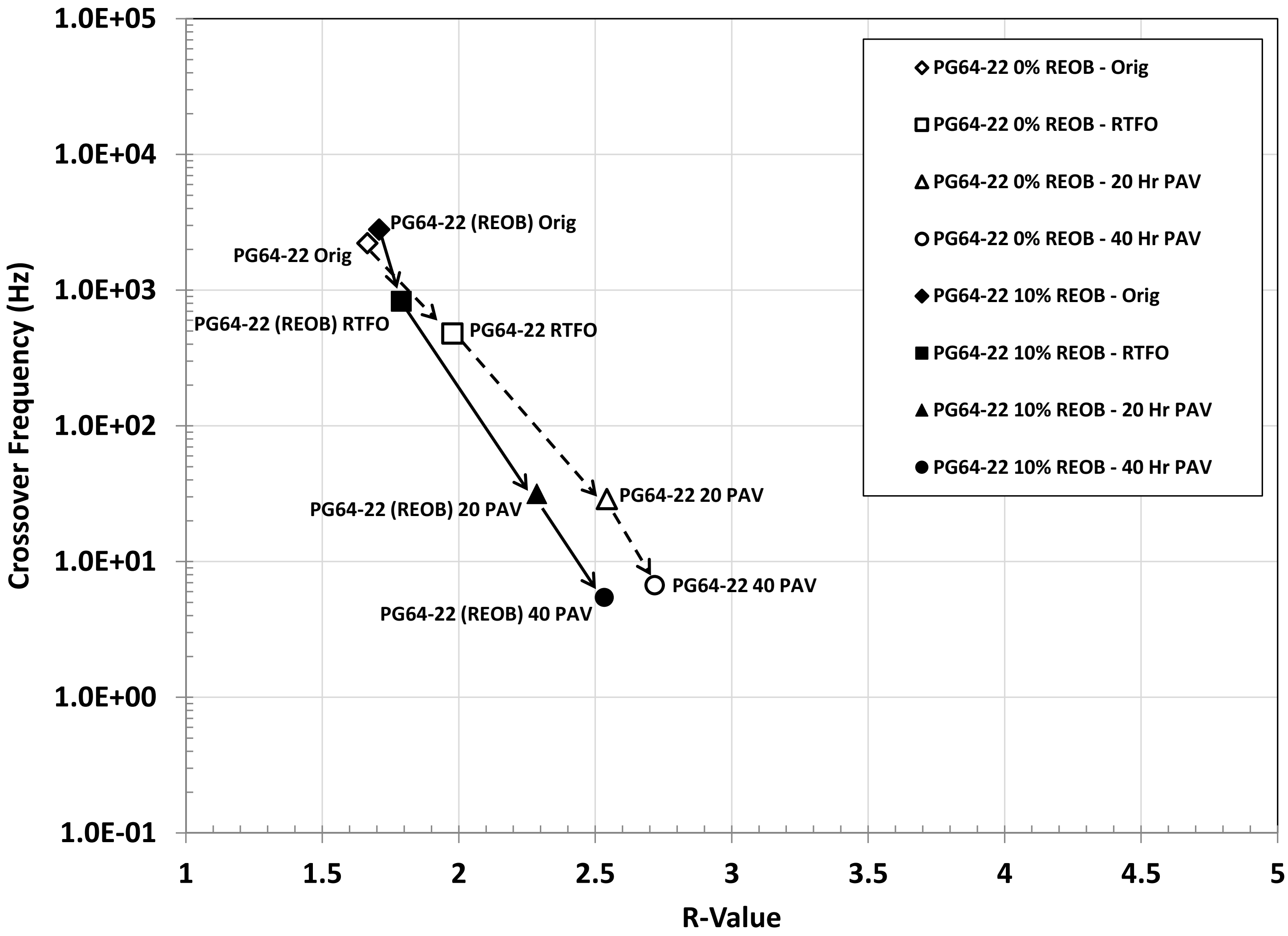
Master Curve (R-value & Crossover Frequency) – PG58-28 Source #1



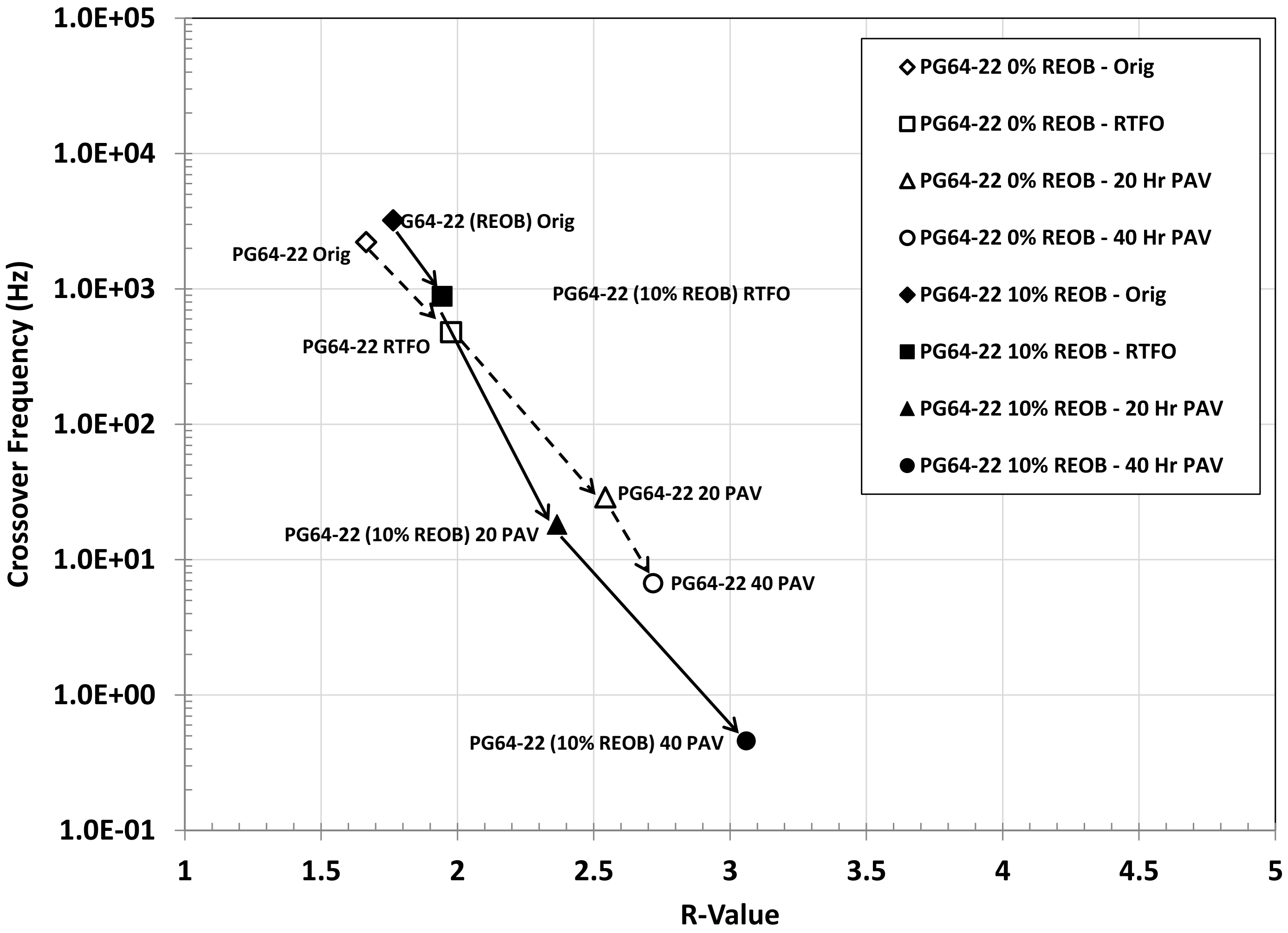
Master Curve (R-value & Crossover Frequency) – PG58-28 Source #2



Master Curve (R-value & Crossover Frequency) – PG64-22 Source #1

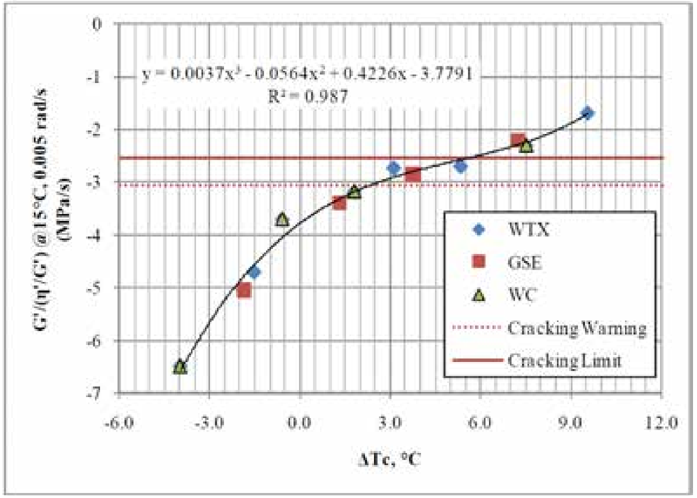


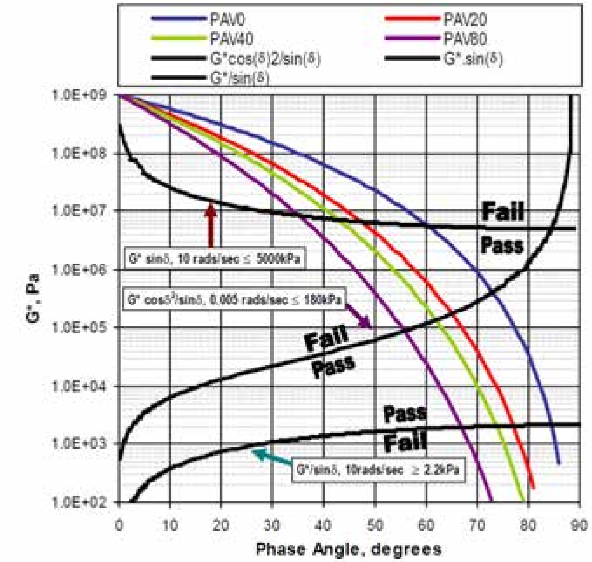
Master Curve (R-value & Crossover Frequency) – PG64-22 Source #2



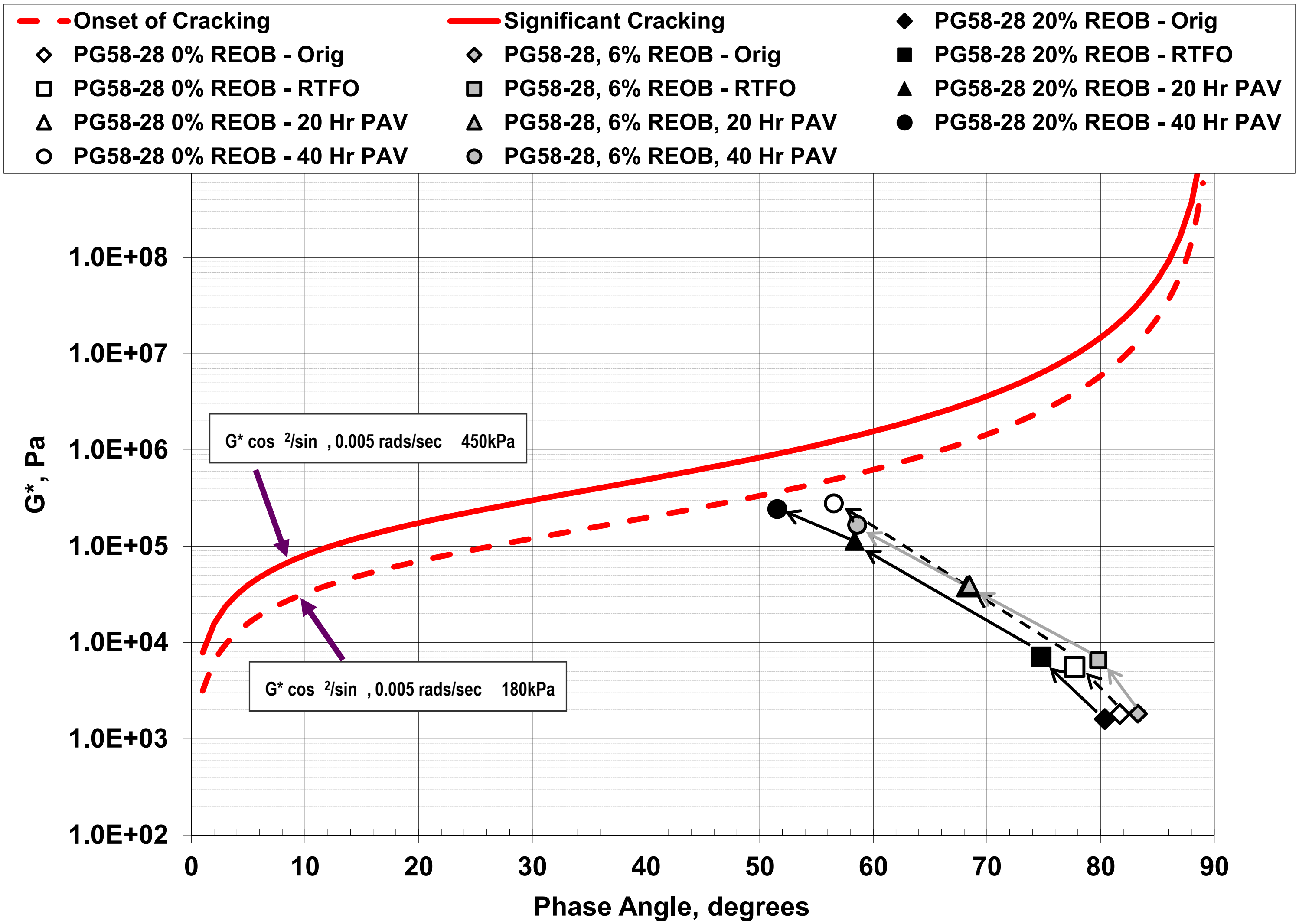
Glover-Rowe Parameter (G-R)

- Due to equipment and material size restraints, Ductility testing may not be available
- Rowe (AAPT, 2011) proposed the DSR master curve analysis to calculate the "Glover-Rowe" parameter
  - As G-R parameter increases, the binder is more prone to fatigue cracking
  - Correlates to both ductility and BBR ΔTc

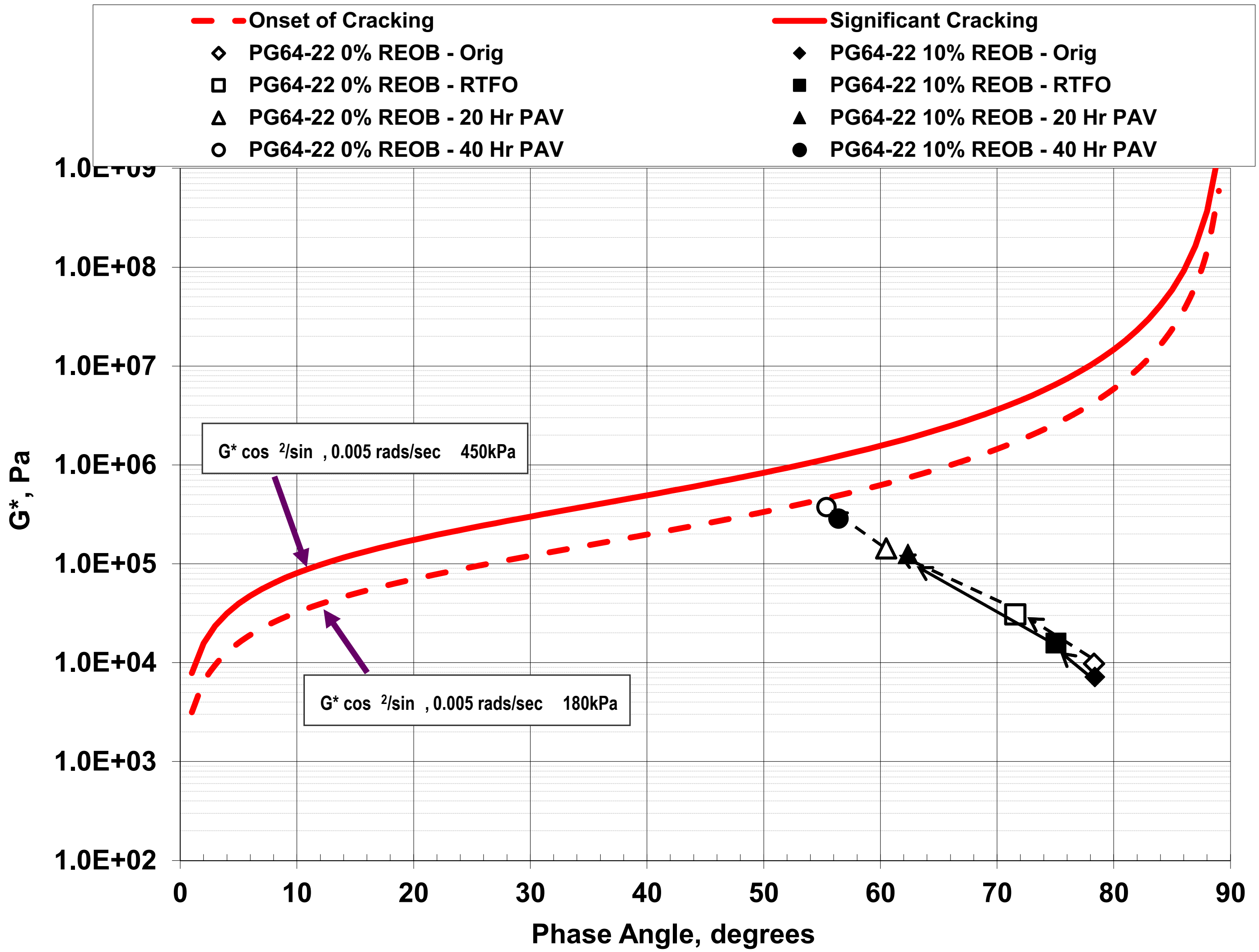




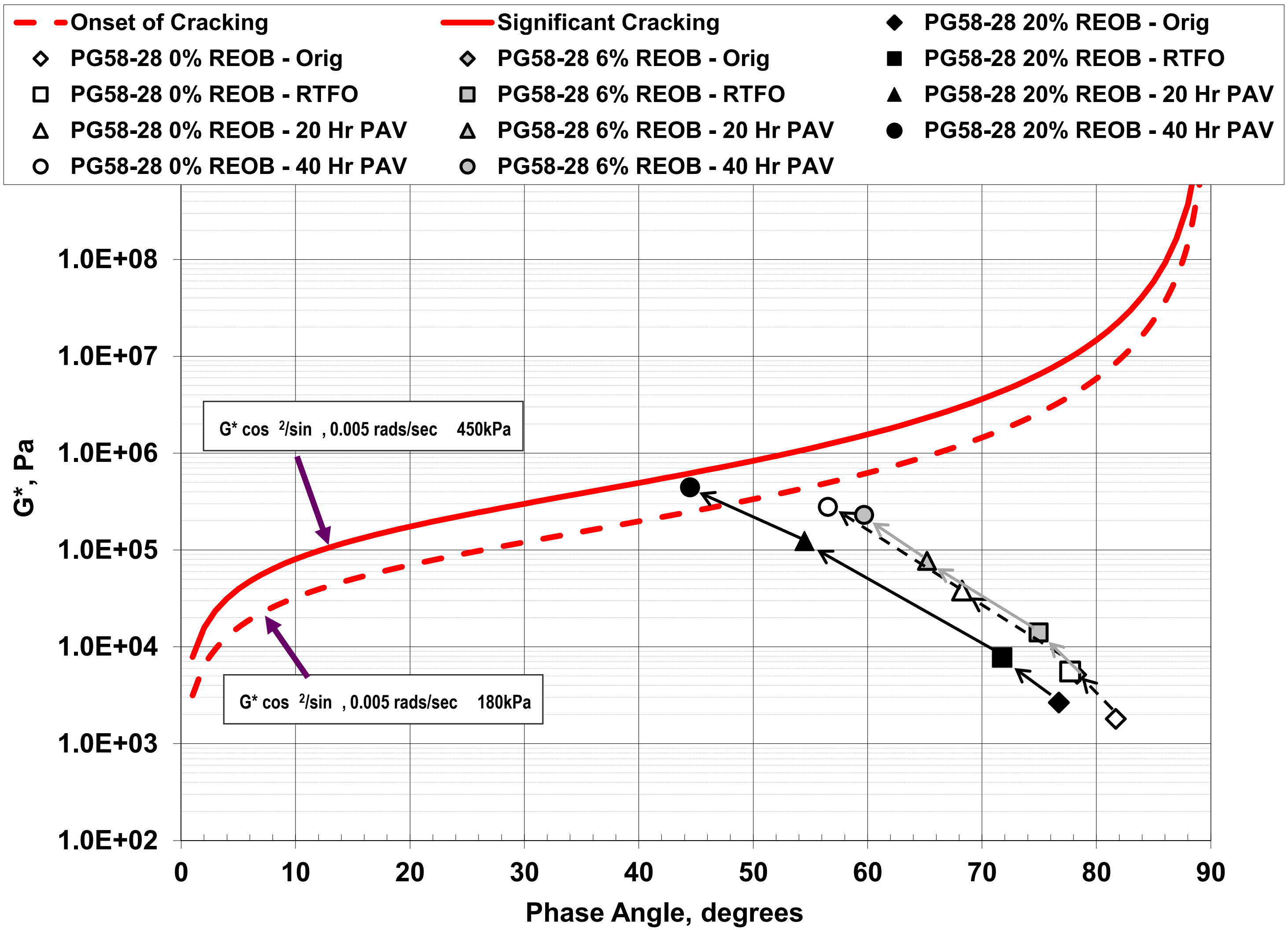
Glover-Rowe Parameter vs Aging (Source #1, PG58-28)



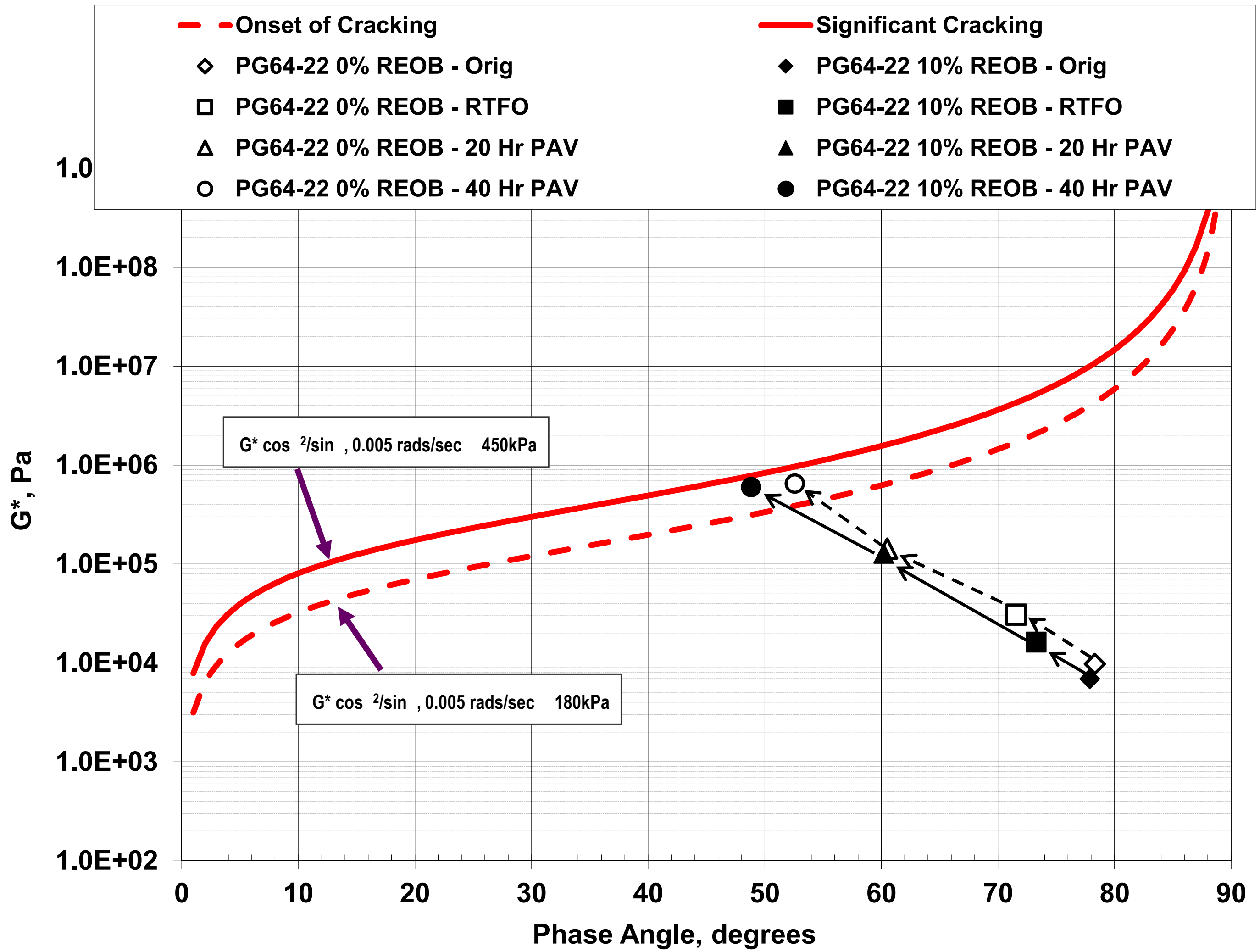
Glover-Rowe Parameter vs Aging (Source #1, PG64-22)



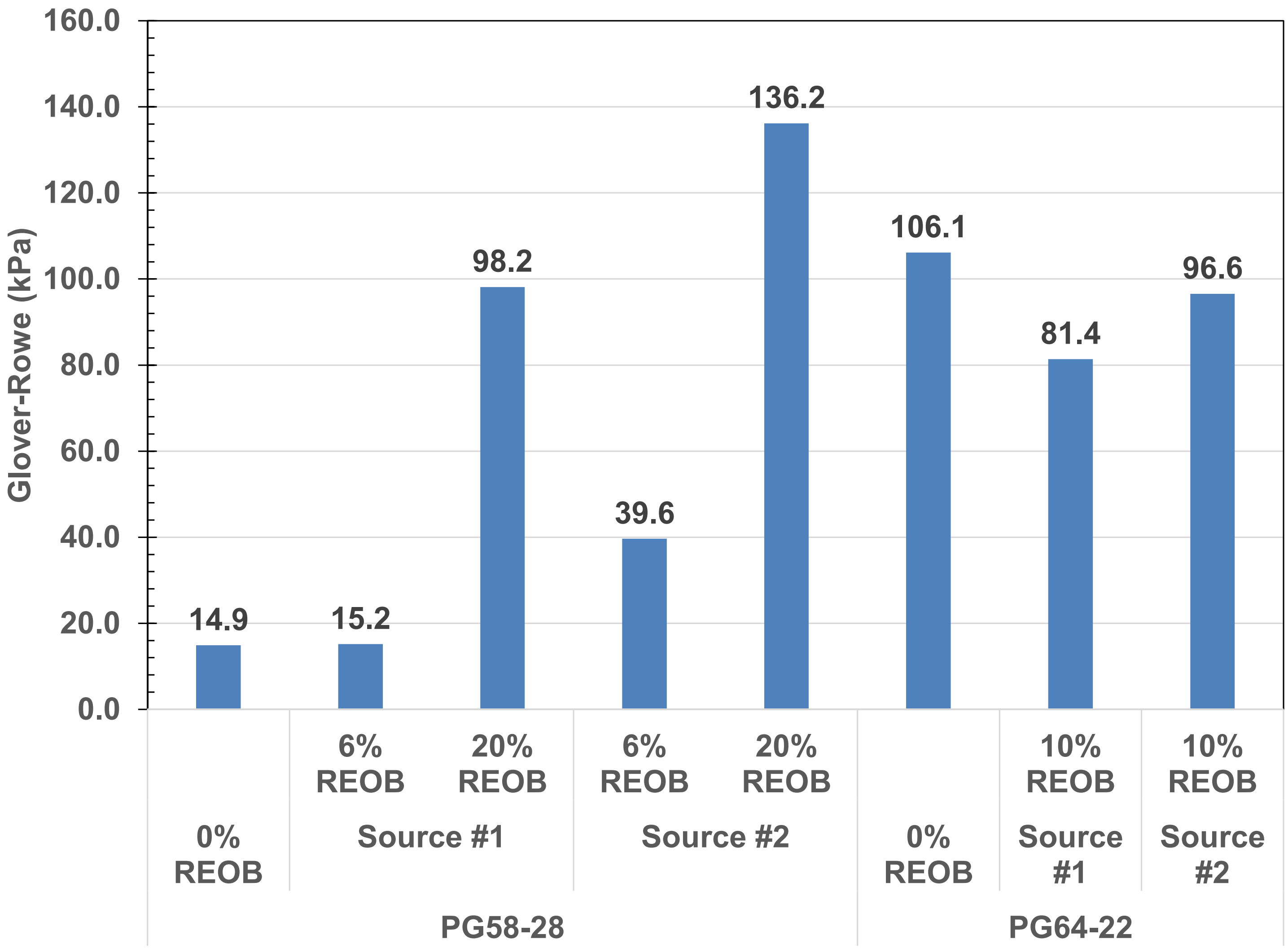
Glover-Rowe Parameter vs Aging (Source #2, PG58-28)



Glover-Rowe Parameter vs Aging (Source #2, PG64-22)

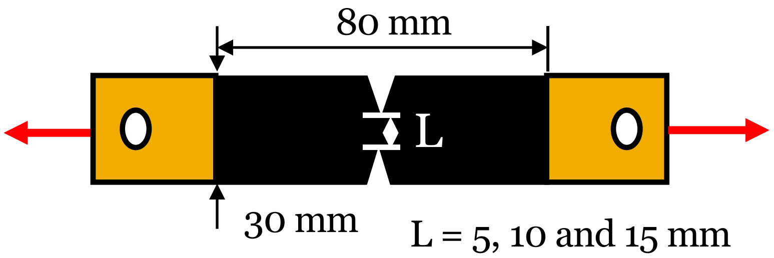


Glover-Rowe Parameter – 20 Hr PAV (15°C, 0.005 rad/sec)

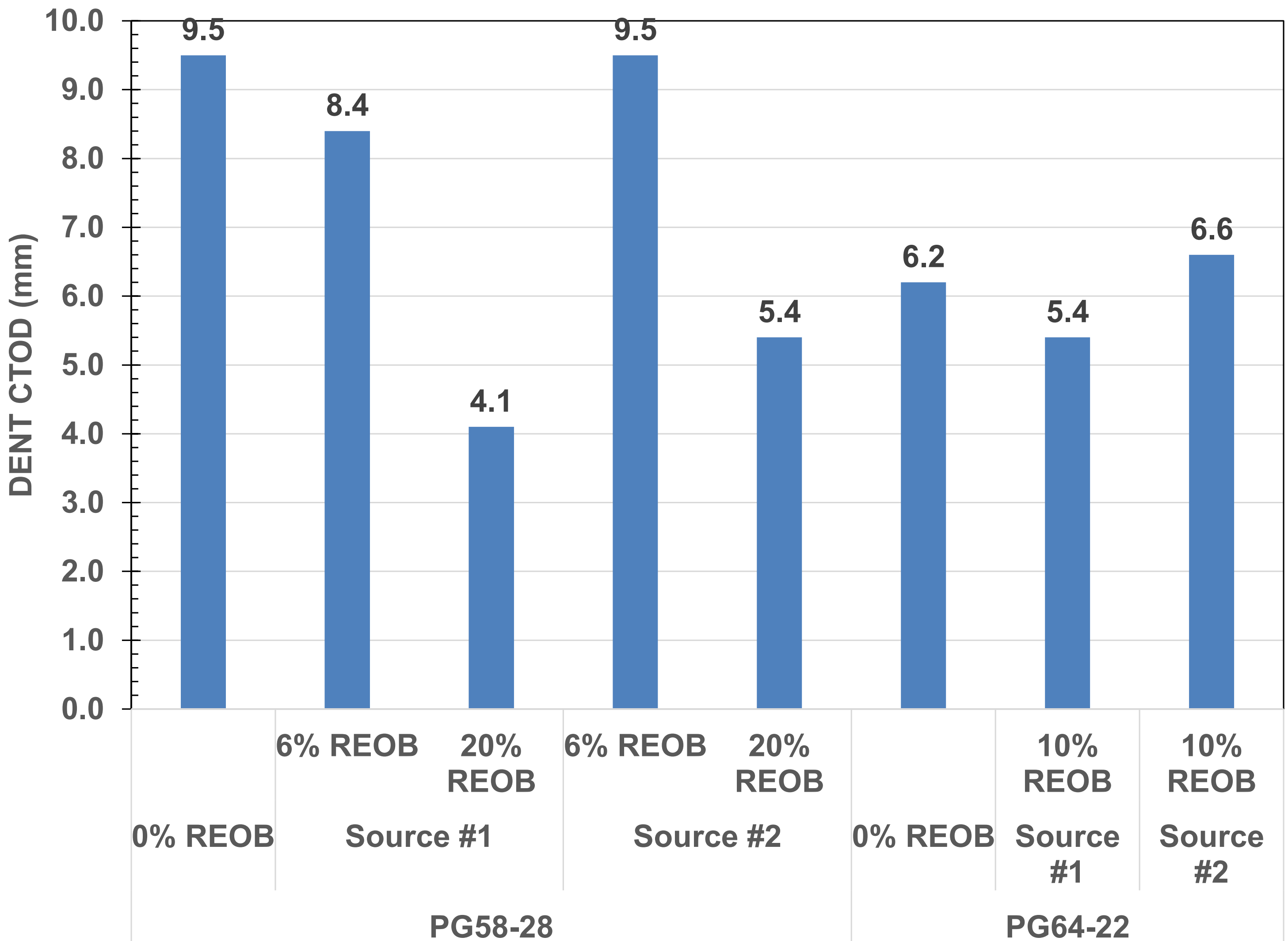


Double Edge Notched Tension (DENT) Test – AASHTO TP113

- Test evaluates the energy required for fracturing ductile materials
  - Test measures the Work of Fracture and Critical Opening Displacement (CTOD)
  - CTOD represents ultimate elongation, or strain tolerance, in the vicinity of a crack (i.e. – notch)
  - As CTOD increases, more resistant to fracturing
- Test has been found to correlate well to field cracking performance



DENT CTOD (15°C)



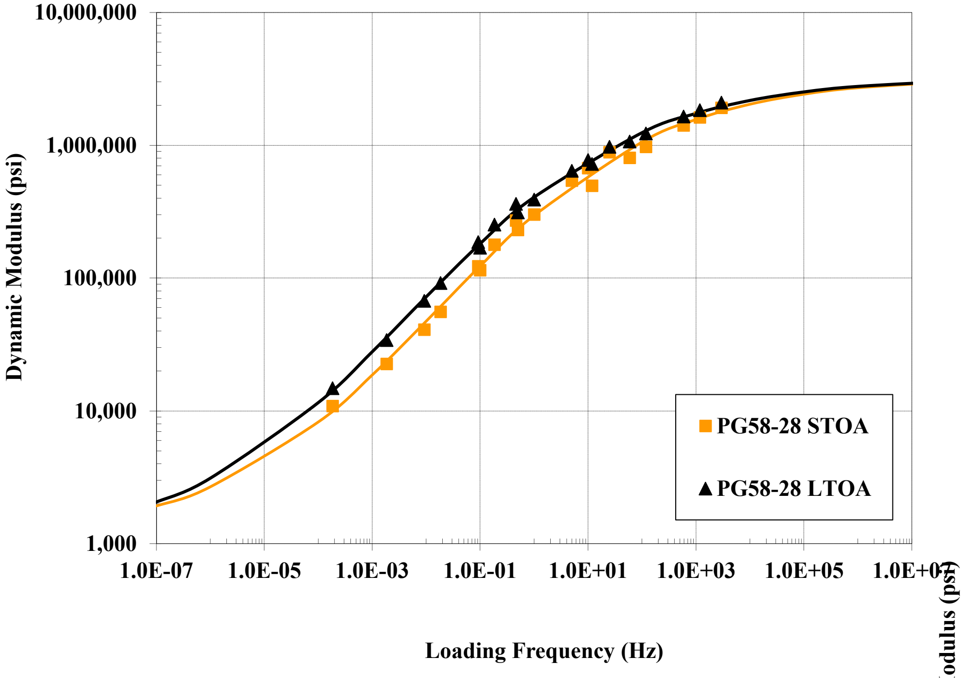
Mixture Test Results

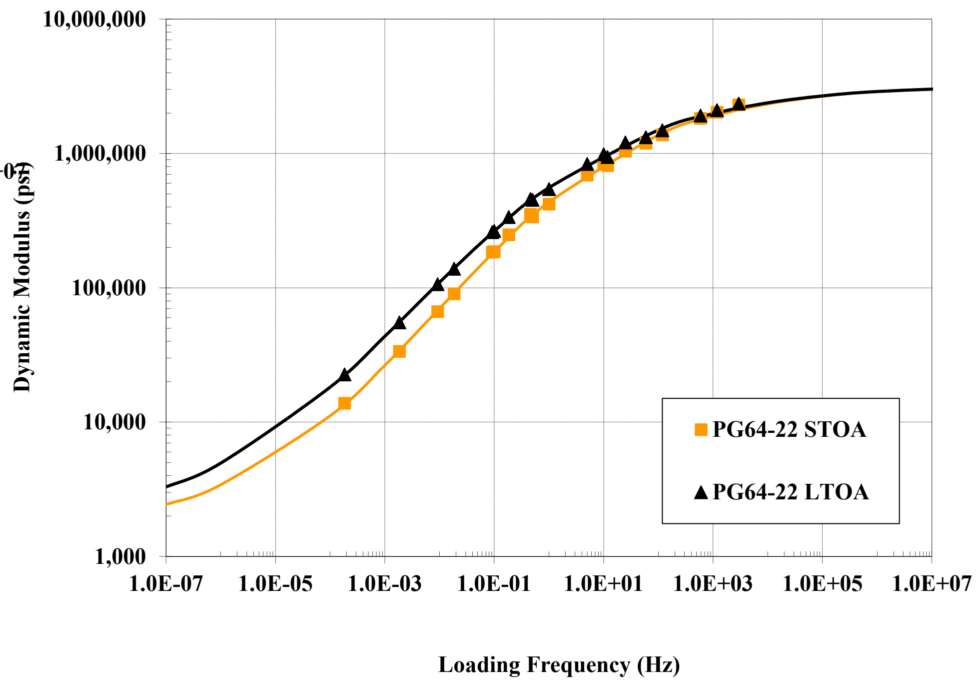
Laboratory Mix Design

- Trap Rock aggregate
- 5.4% asphalt content; 0% RAP
- Short-term (STOA) and Long-term (LTOA) oven aged according to AASHTO R30

Property	% Passing
Sieve Size	Lab Study Design
1/2" (12.5 mm)	100.0
3/8" (9.5 mm)	95.0
No. 4 (4.75 mm)	68.0
No. 8 (2.36 mm)	46.6
No. 16 (1.18 mm)	32.4
No. 30 (0.600 mm)	23.1
No. 50 (0.425 mm)	16.7
No. 100 (0.15 mm)	11.7
No. 200 (0.075 mm)	7.6
Gsb (g/cm^3)	2.862
Gmm (g/cm^3)	2.680
Design AV%	4.0
Asphalt Content (%)	5.4
VMA (%)	15.0

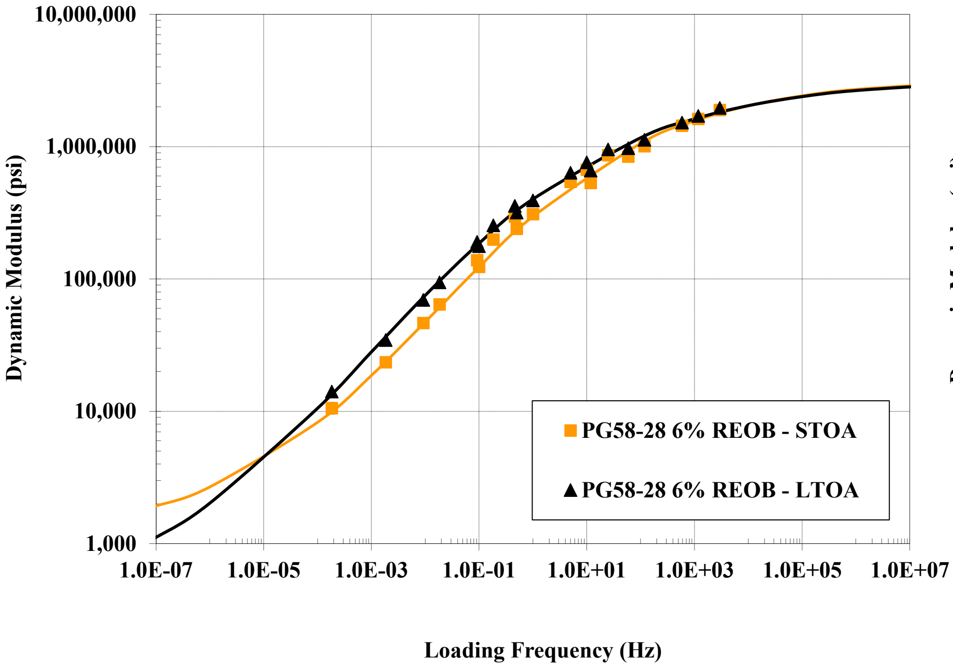
Dynamic Modulus

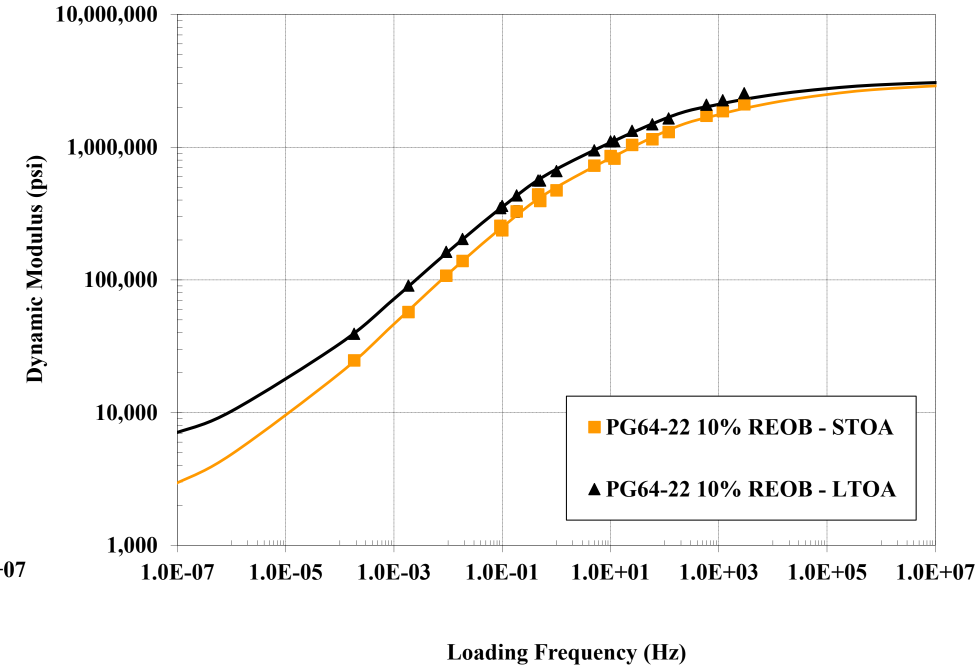


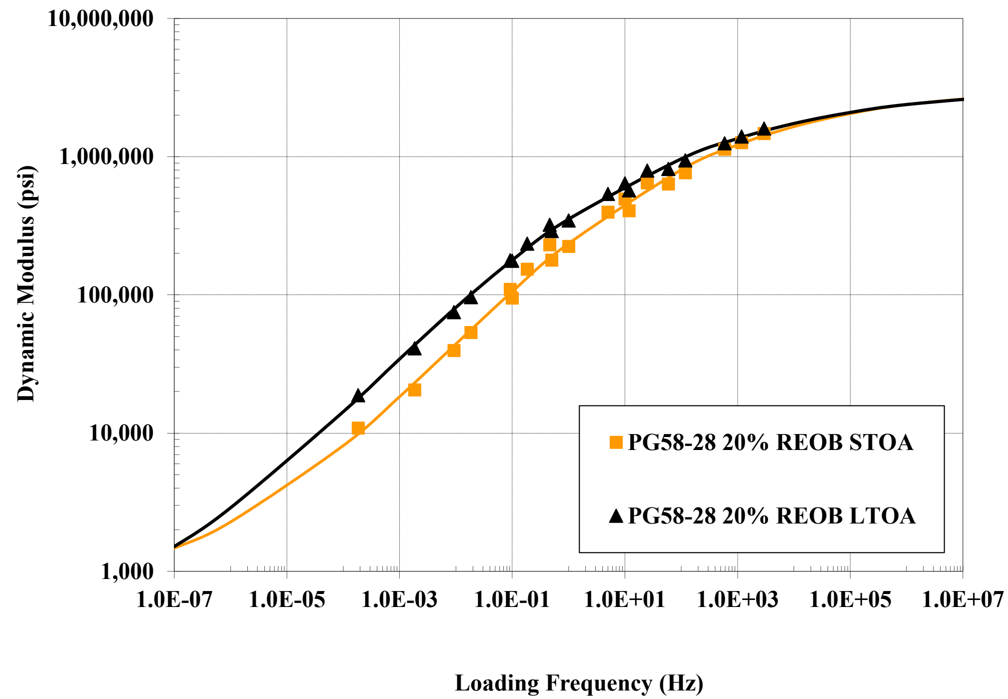


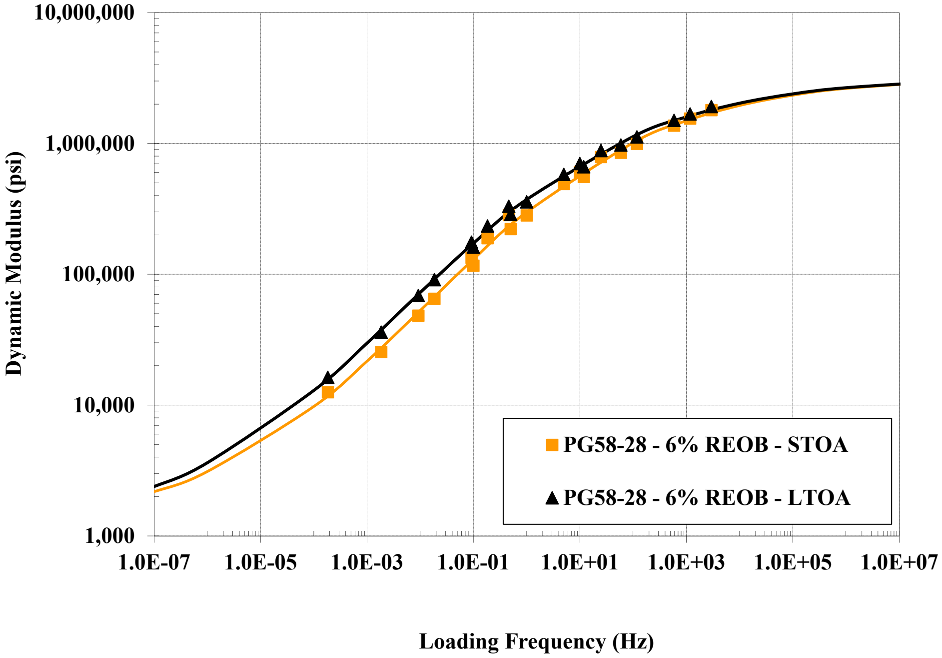
No REOB

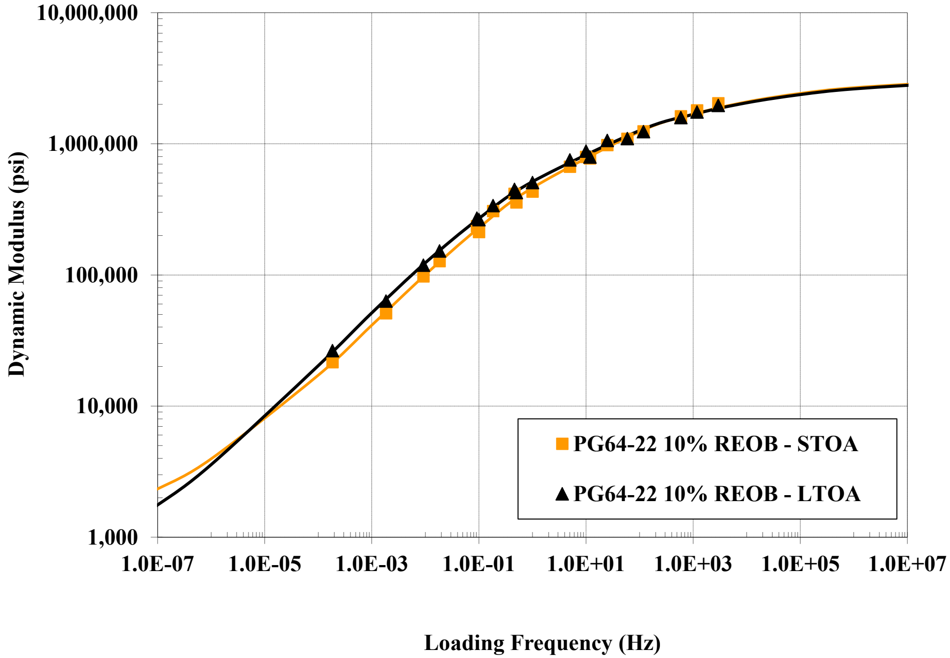
REOB Source #1



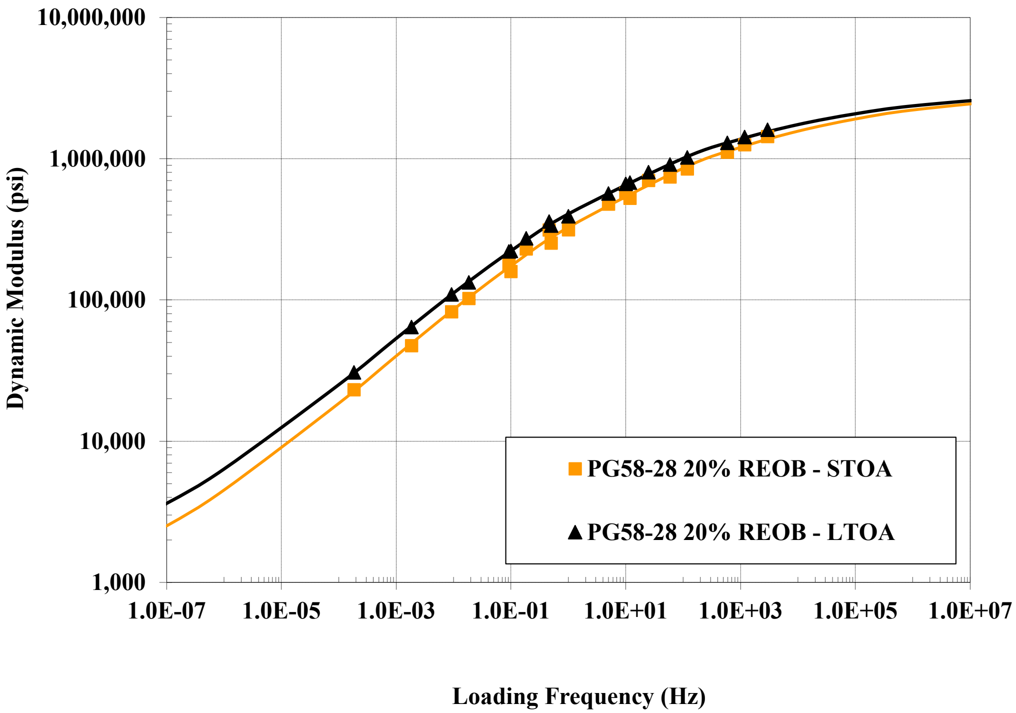




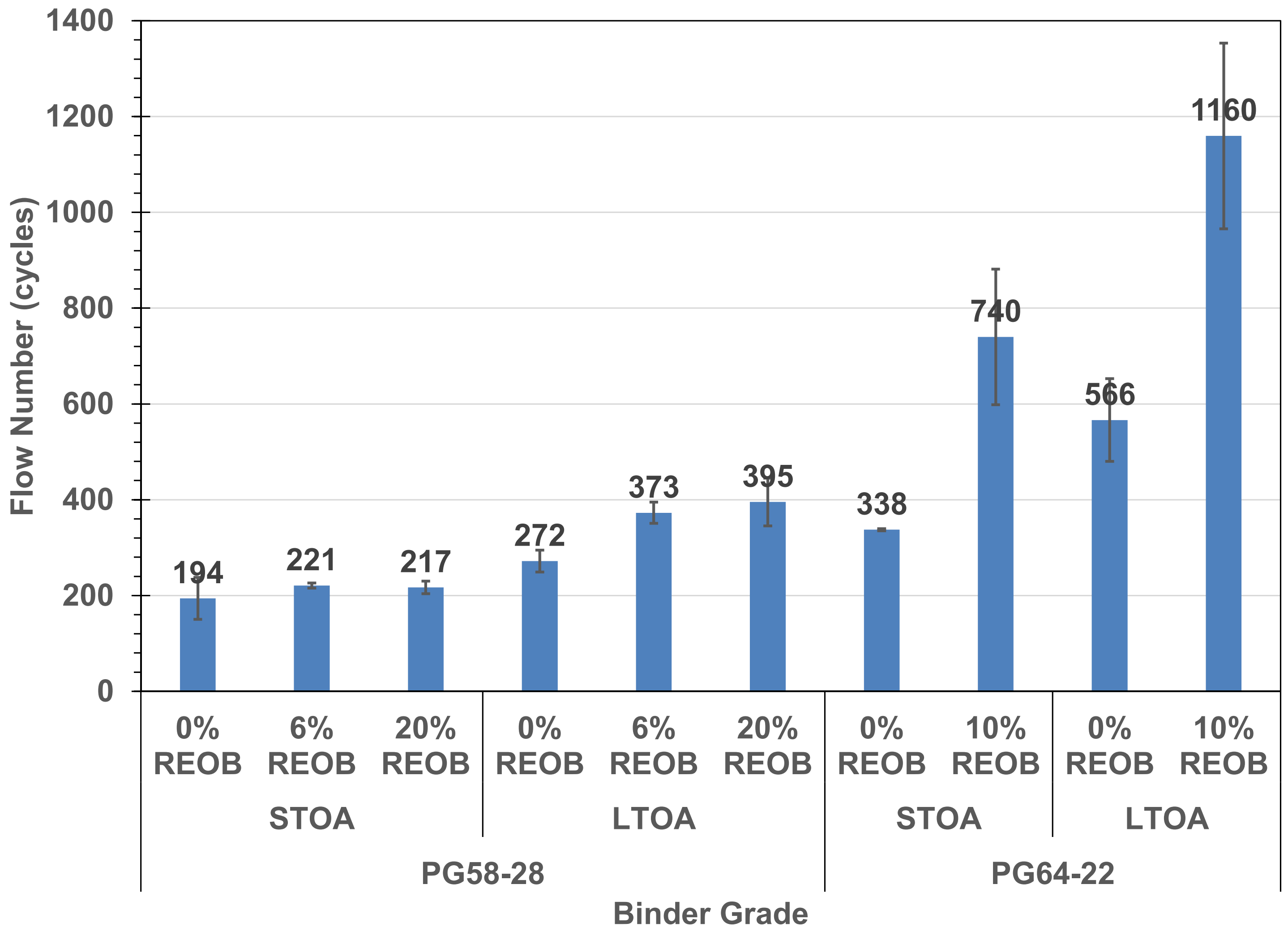




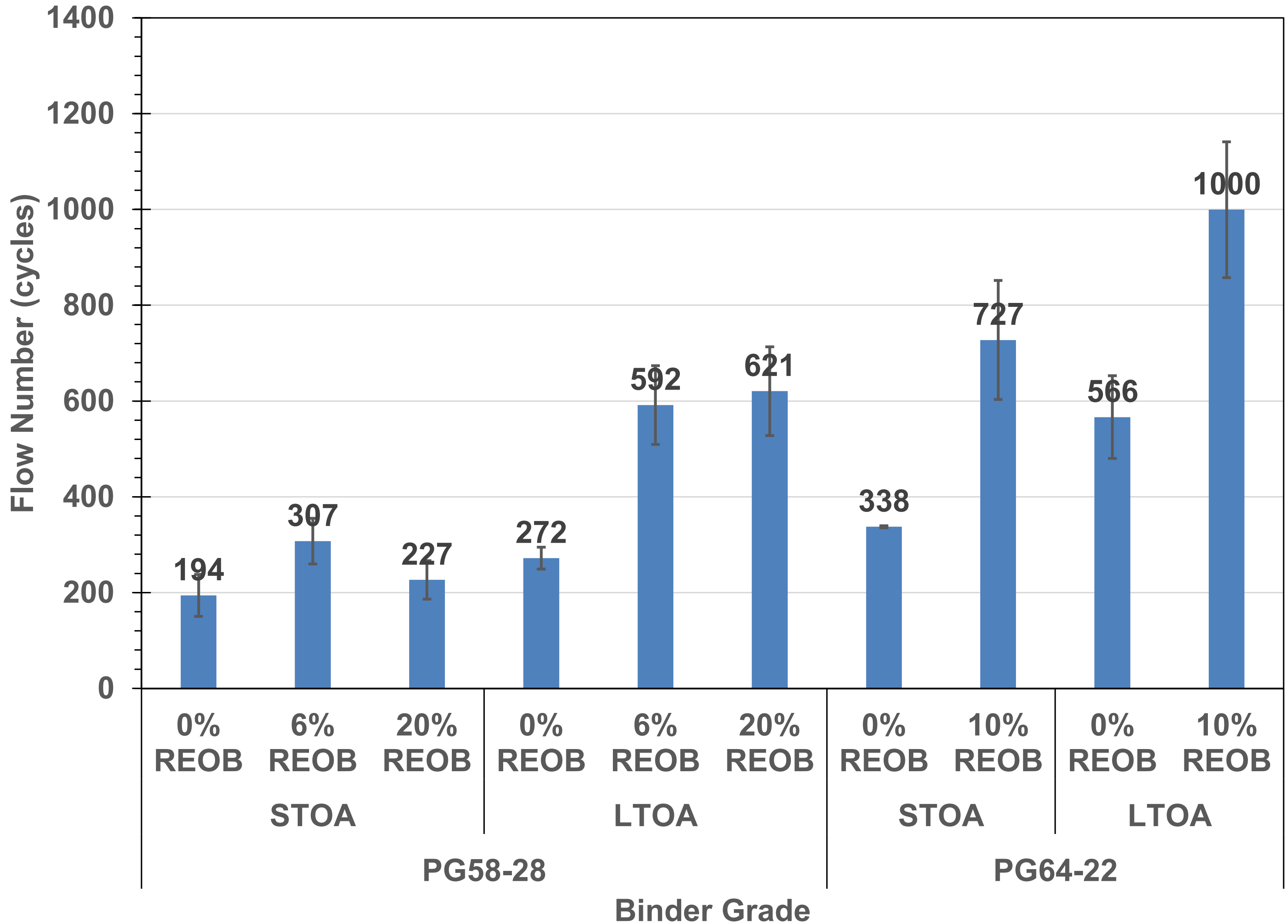
REOB Source #2



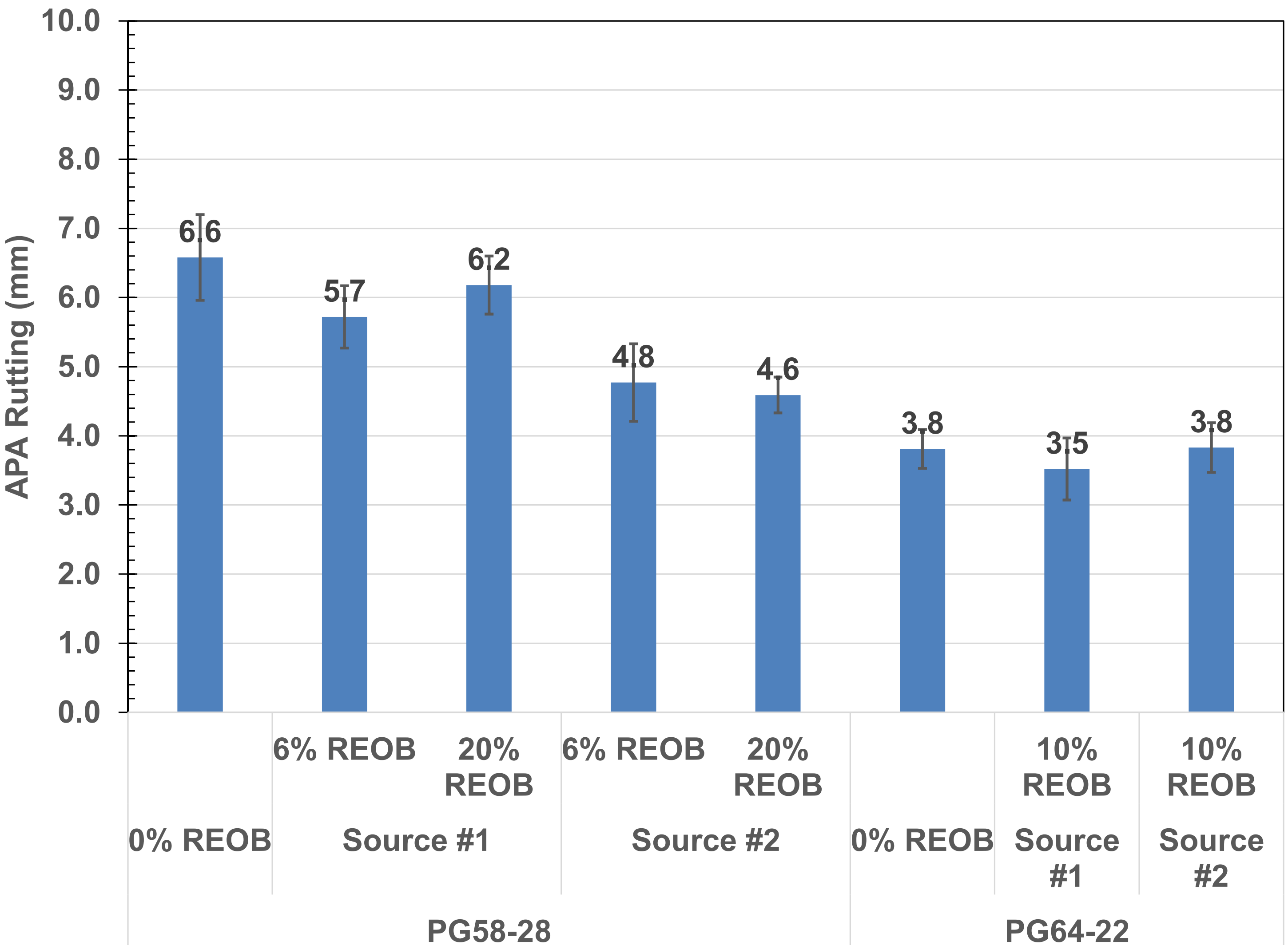
Flow Number (54°C) – Source #1



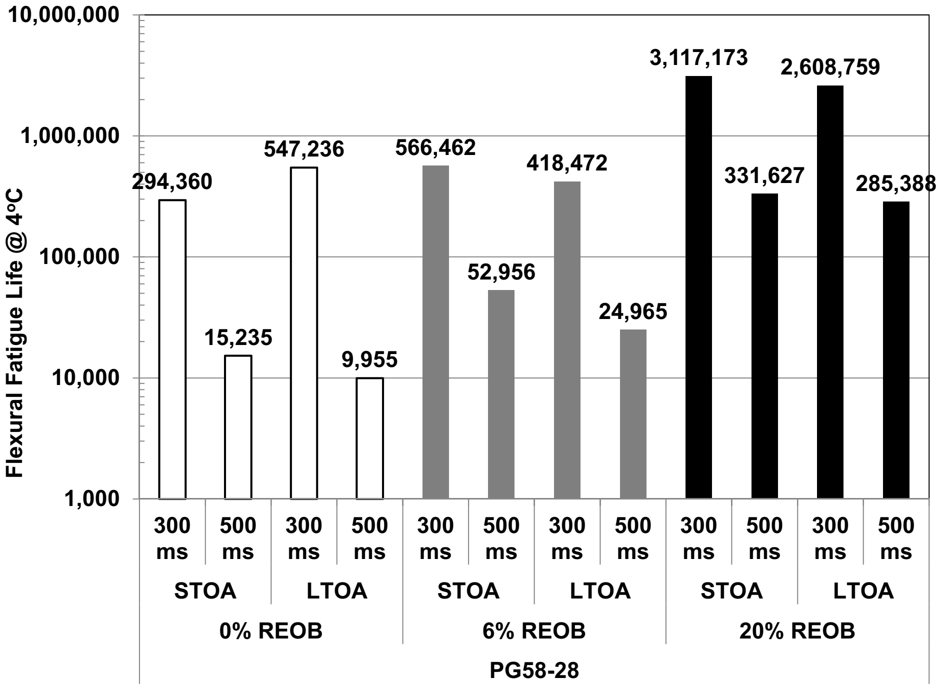
Flow Number (54°C) – Source #2

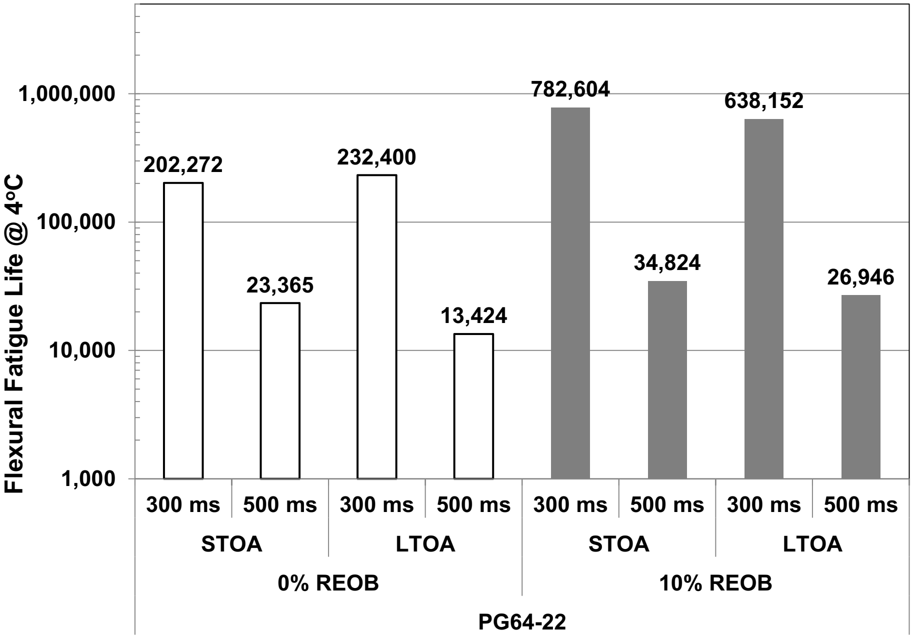


APA Rutting (64°C)

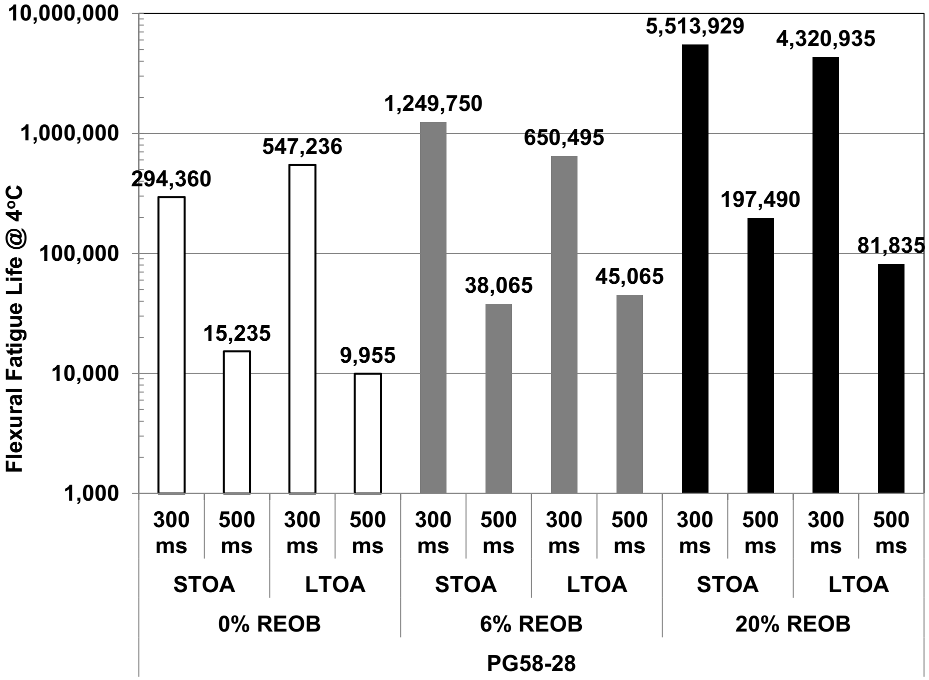


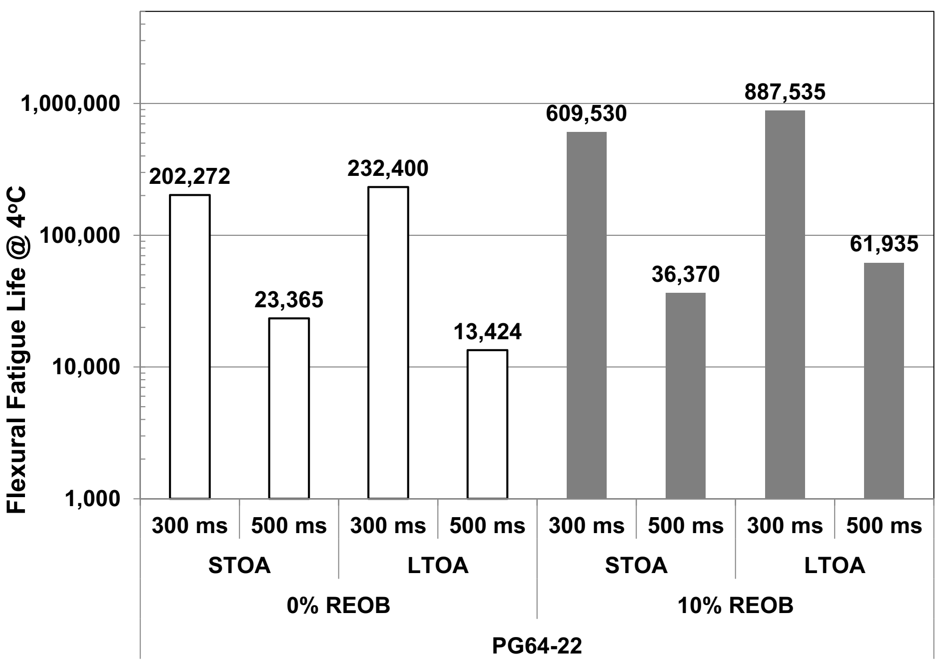
Flexural Beam Fatigue – Source #1



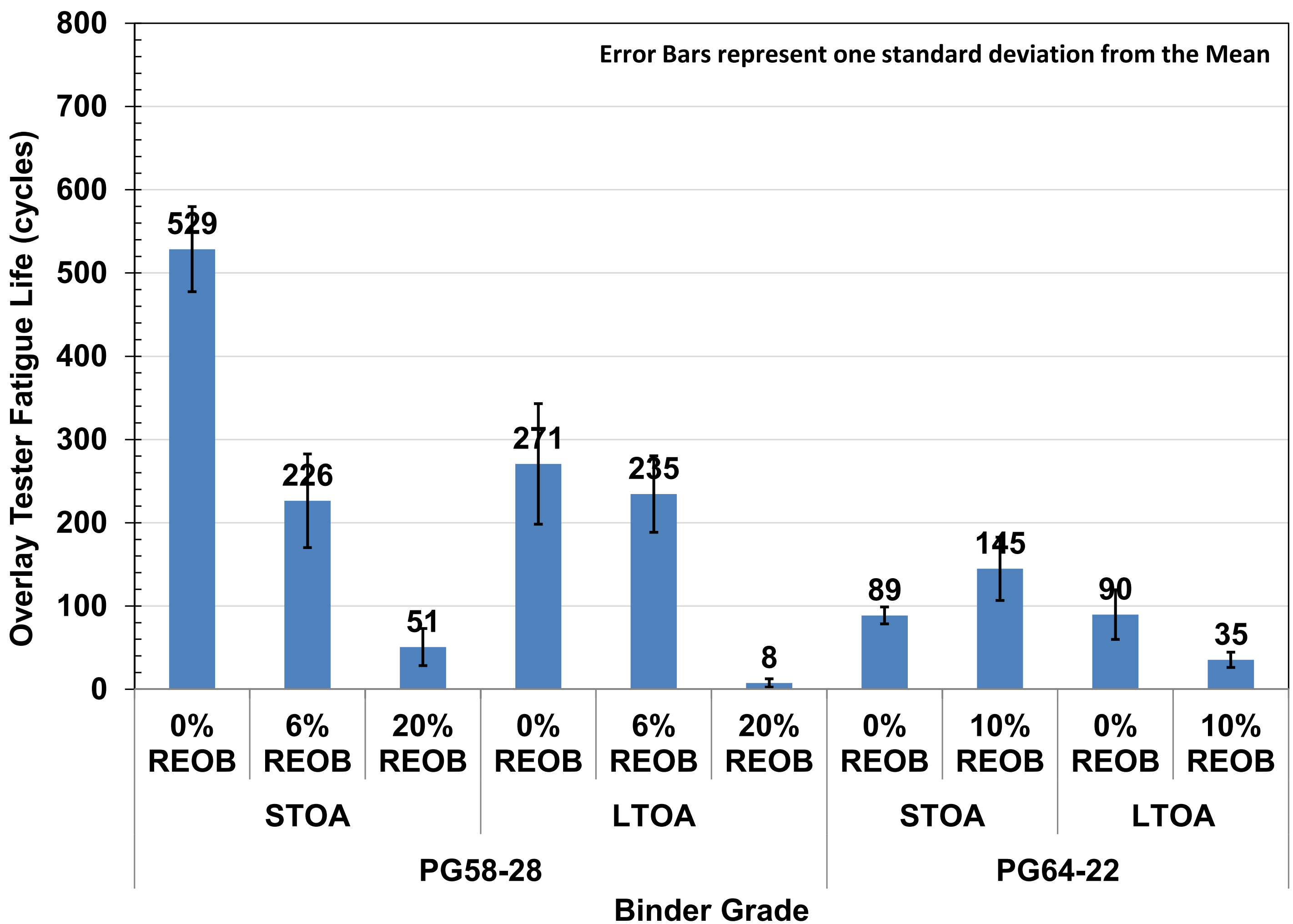


Flexural Beam Fatigue – Source #2

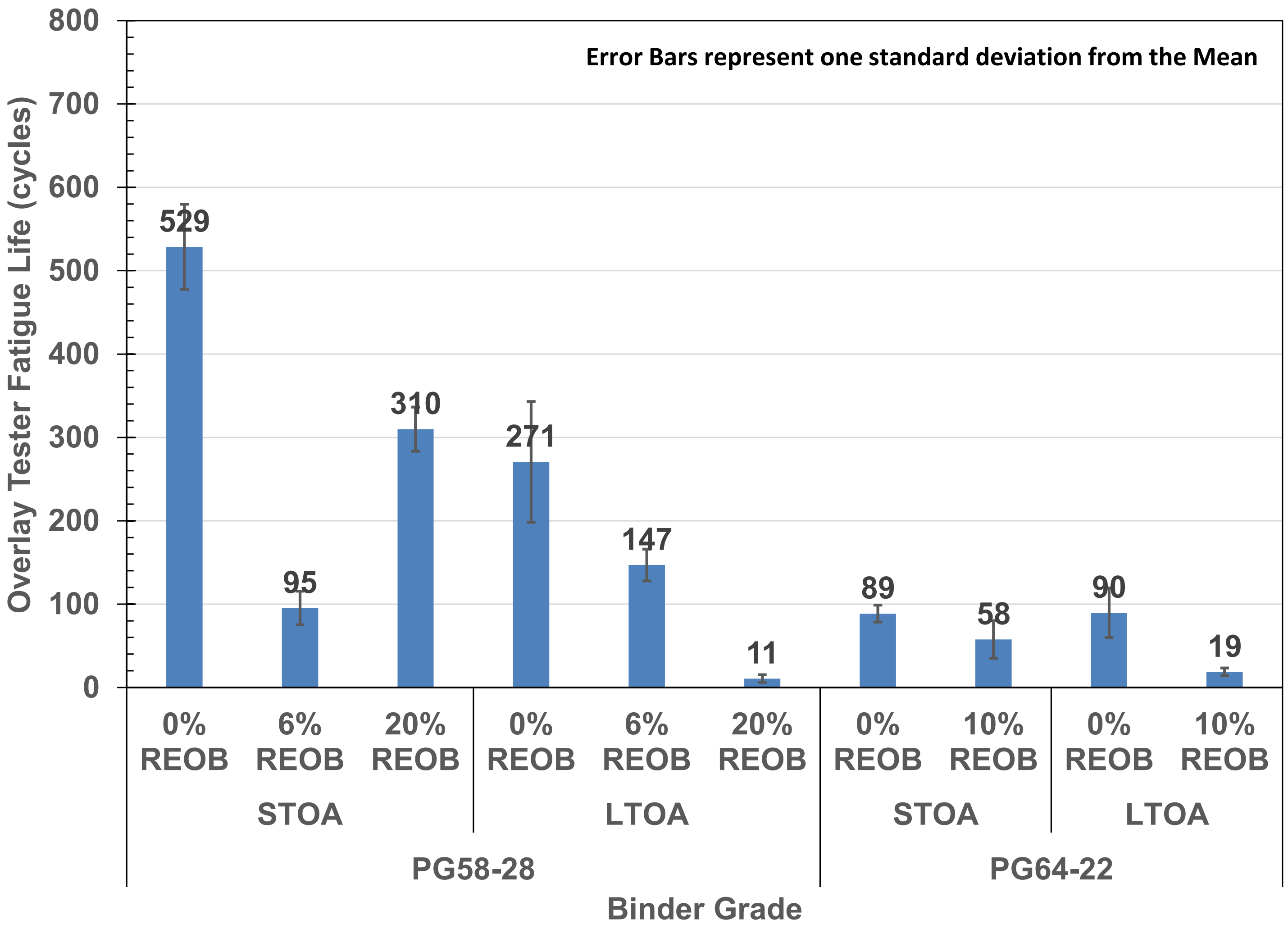




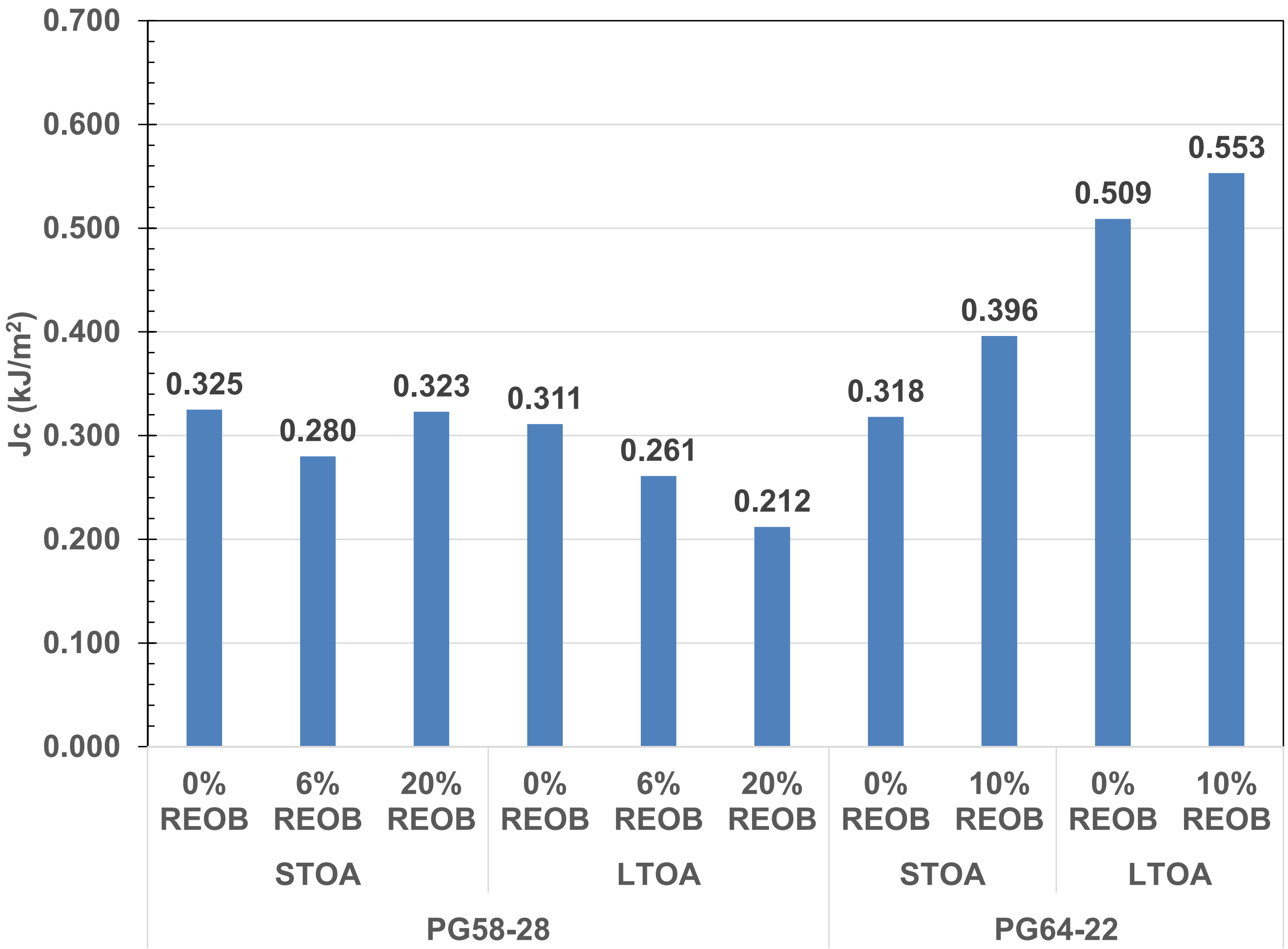
Overlay Tester – Source #1



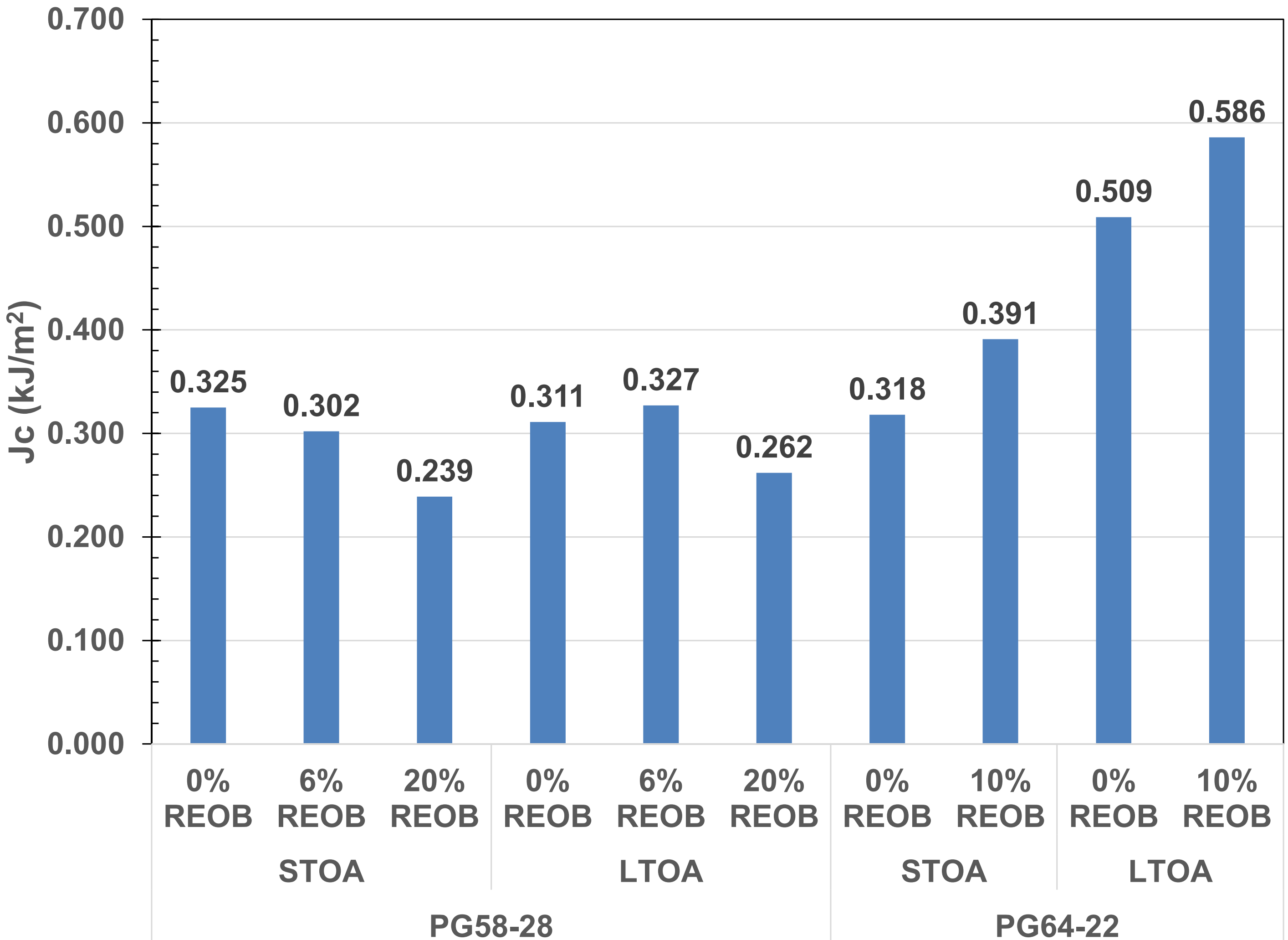
Overlay Tester – Source #2



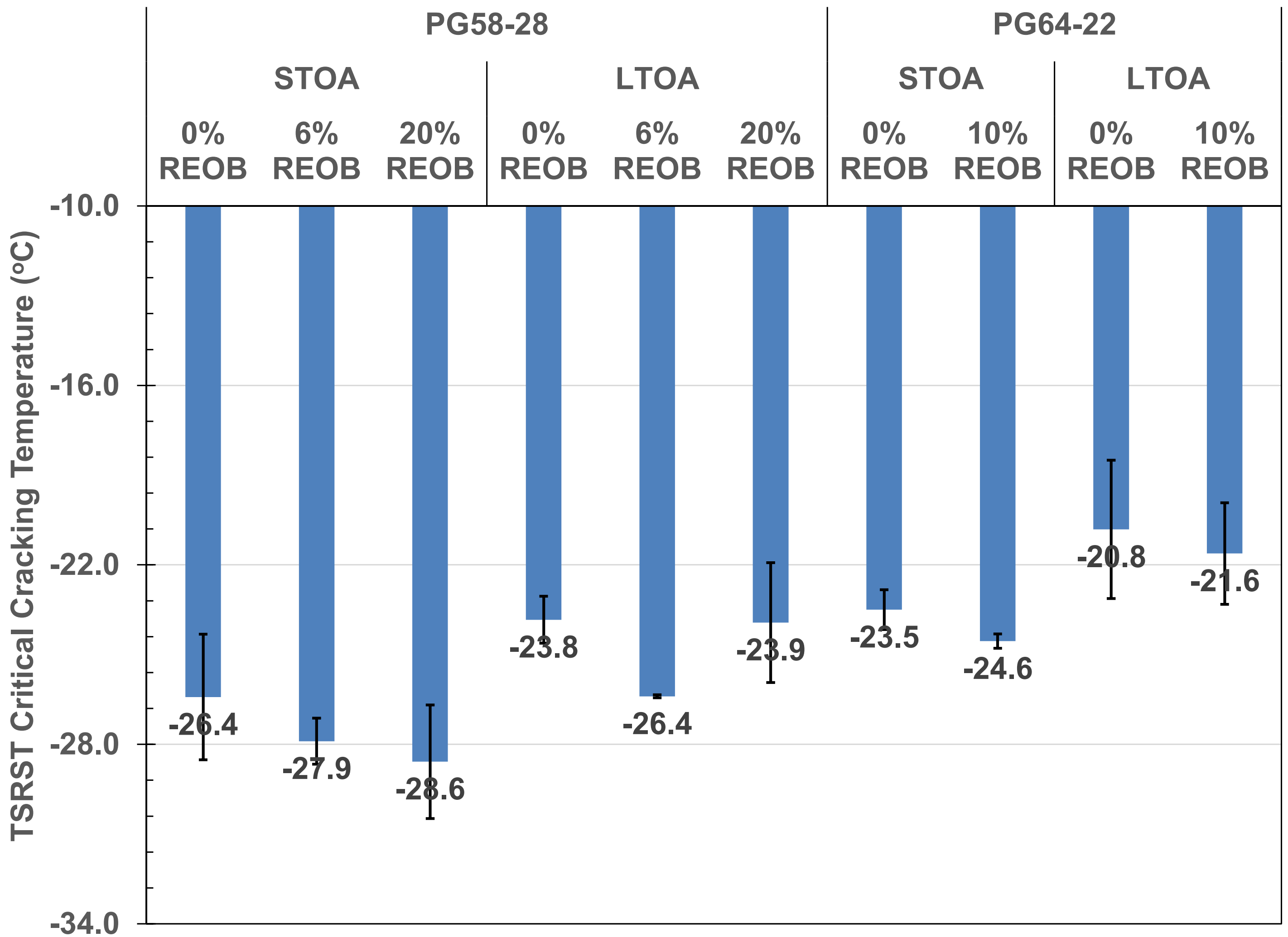
Semi-Circular Bend (25°C) – Source #1



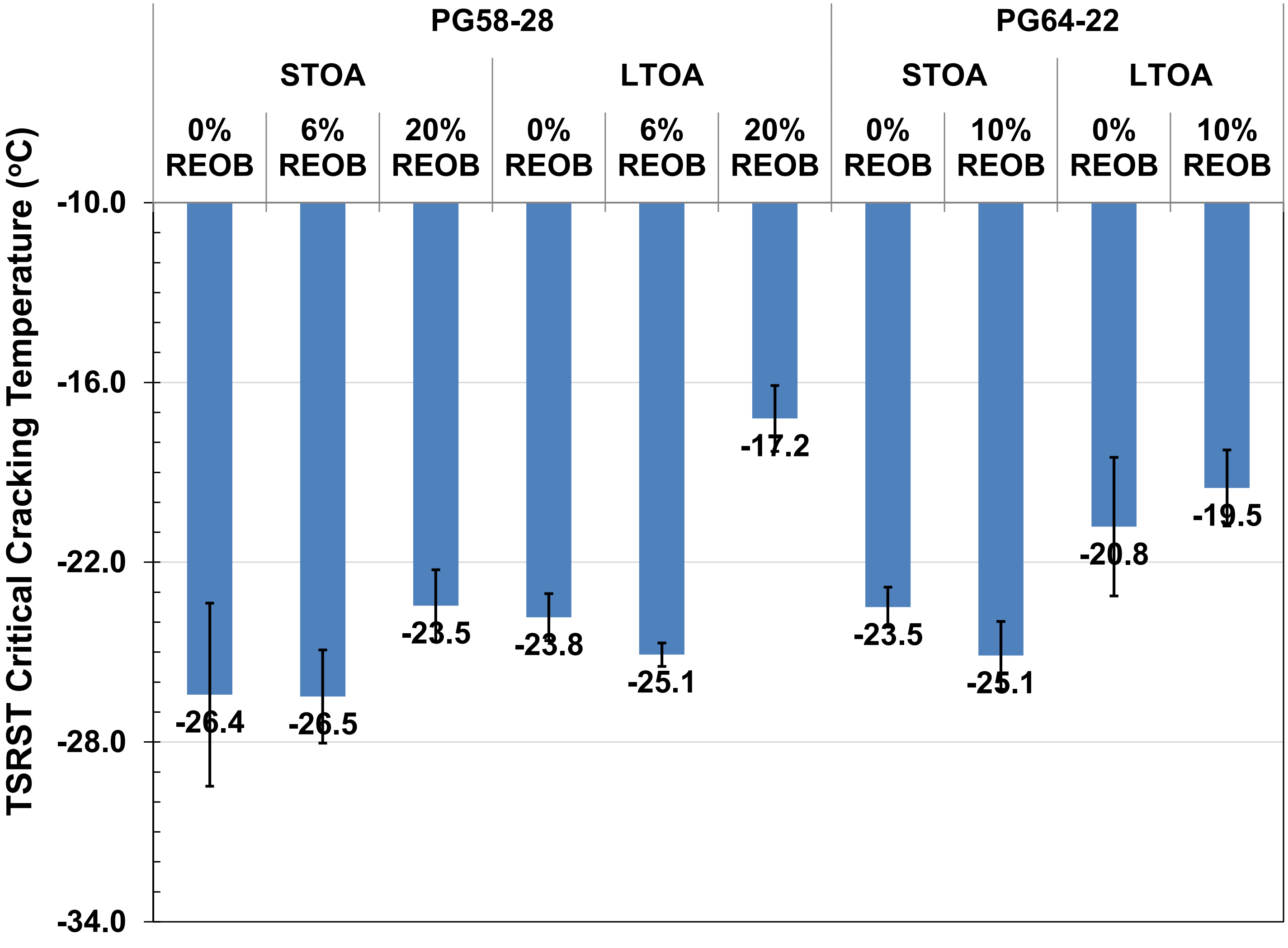
Semi-Circular Bend (25°C) – Source #2



TSRST Low Temp Critical Cracking – Source #1



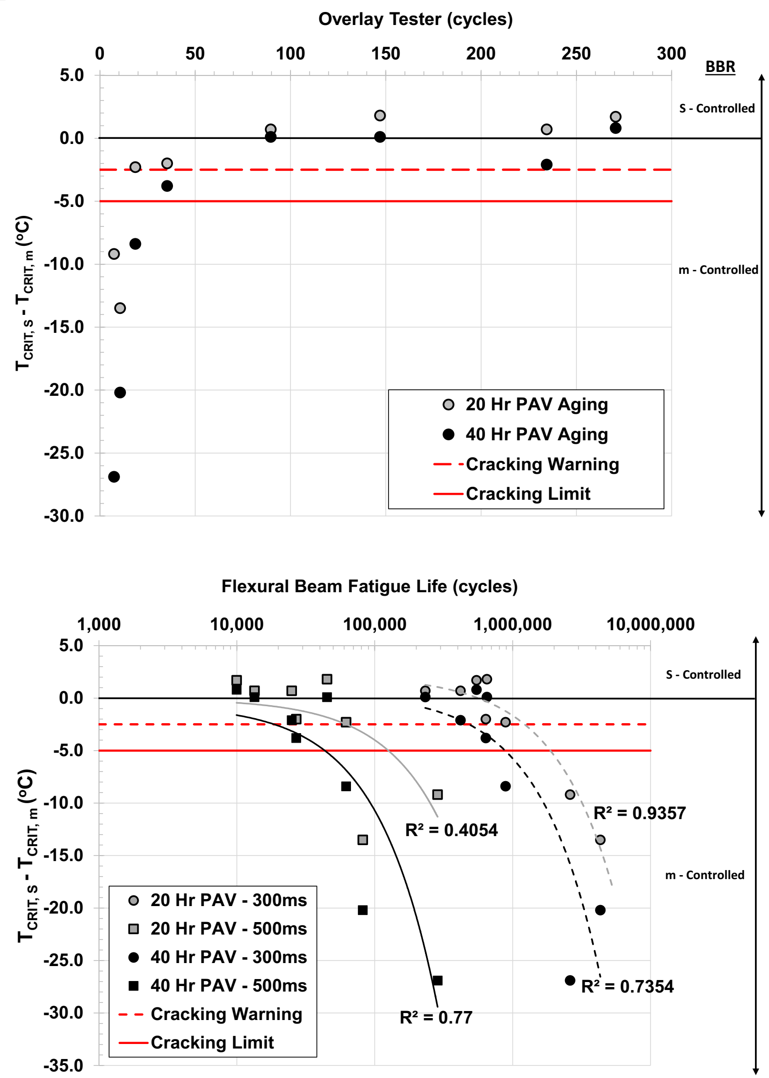
TSRST Low Temp Critical Cracking – Source #2



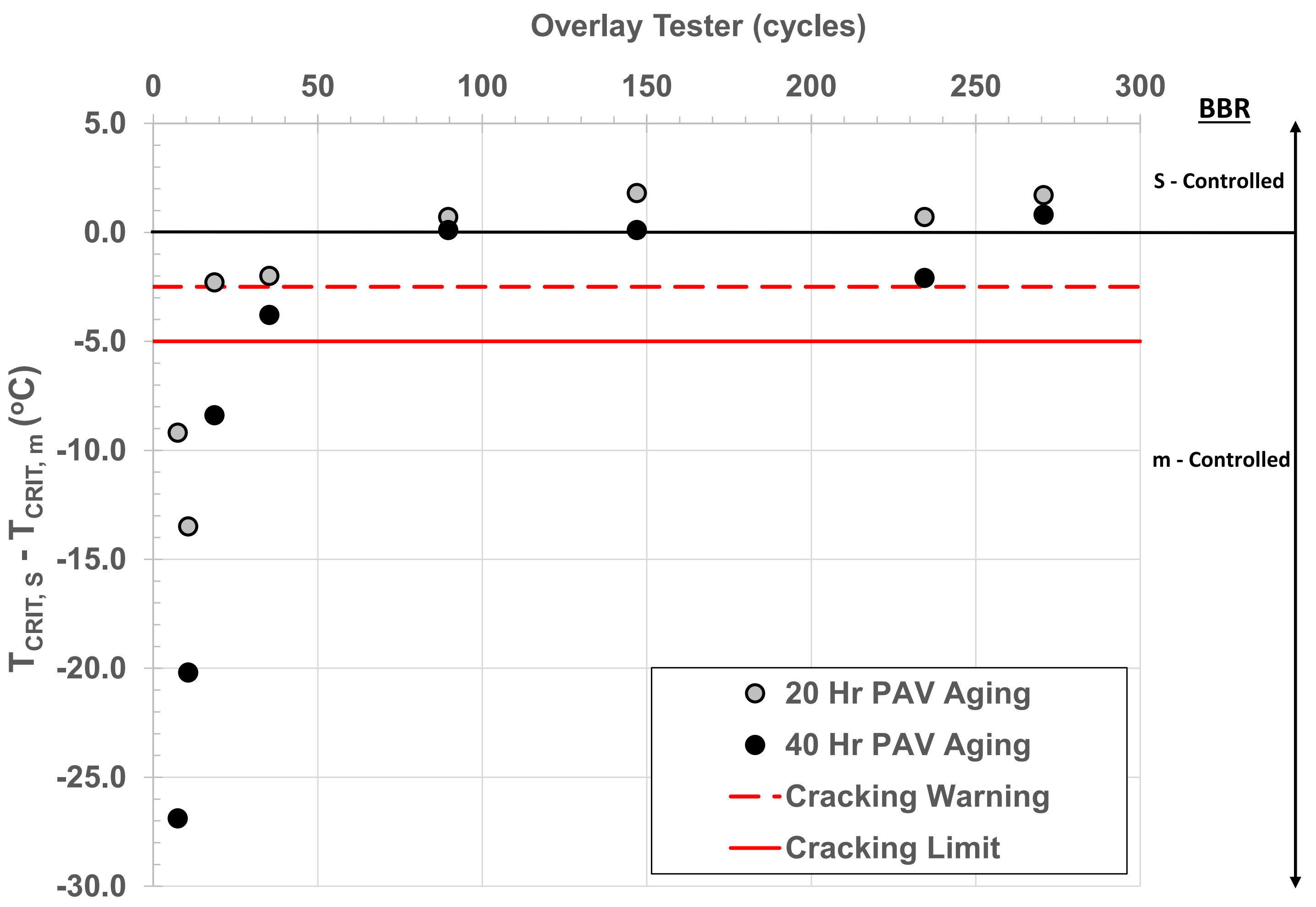
Binder to Mixture Performance Comparisons

Fatigue - Binder to Mixture Comparisons

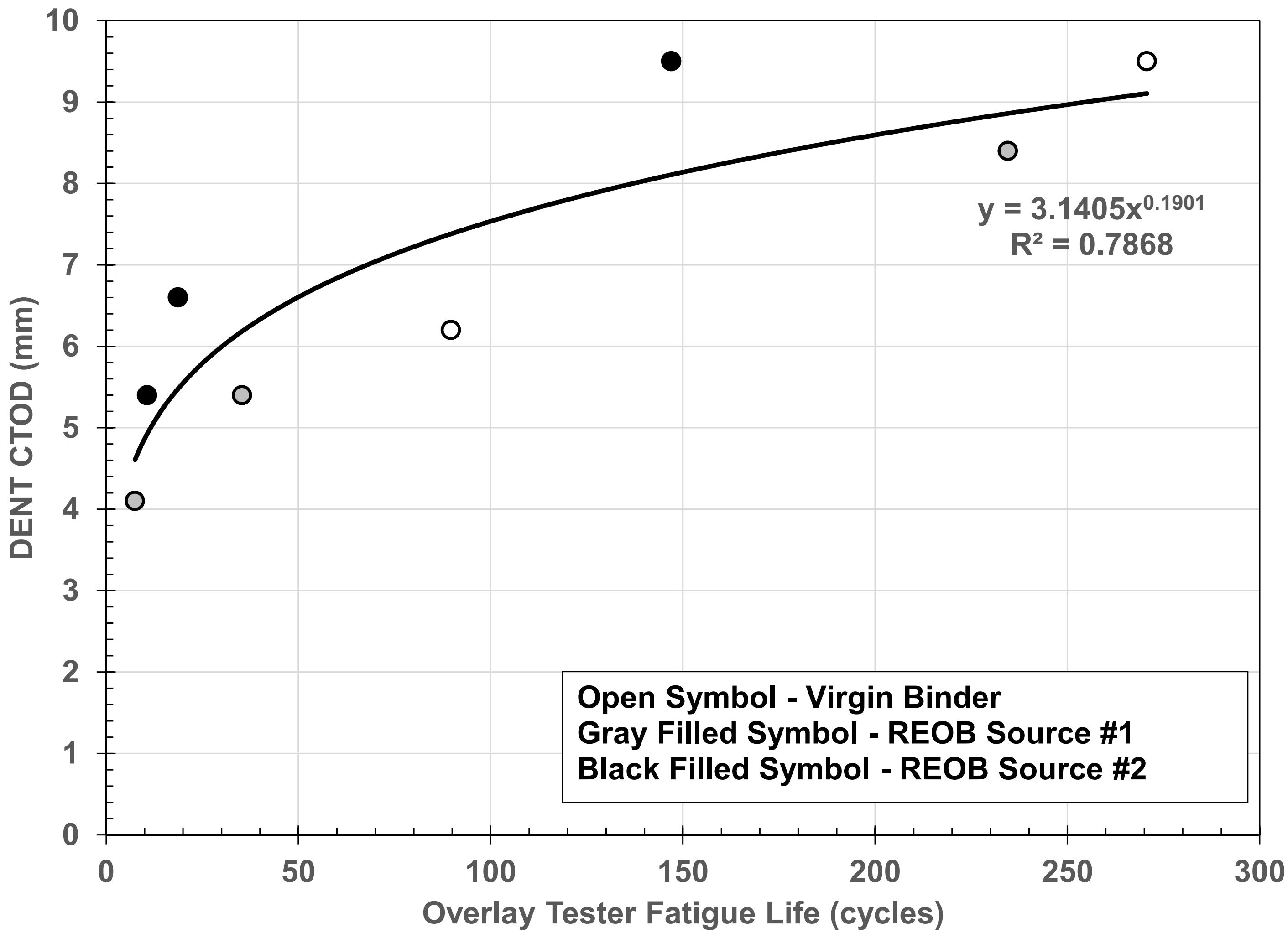
- Comparisons were made between the binder and mixture fatigue parameters.
- Only Overlay Tester showed good correlation
  - Some cases, Beam Fatigue was counter intuitive to what was expected
- Poor correlation between SCB J_C and binder properties



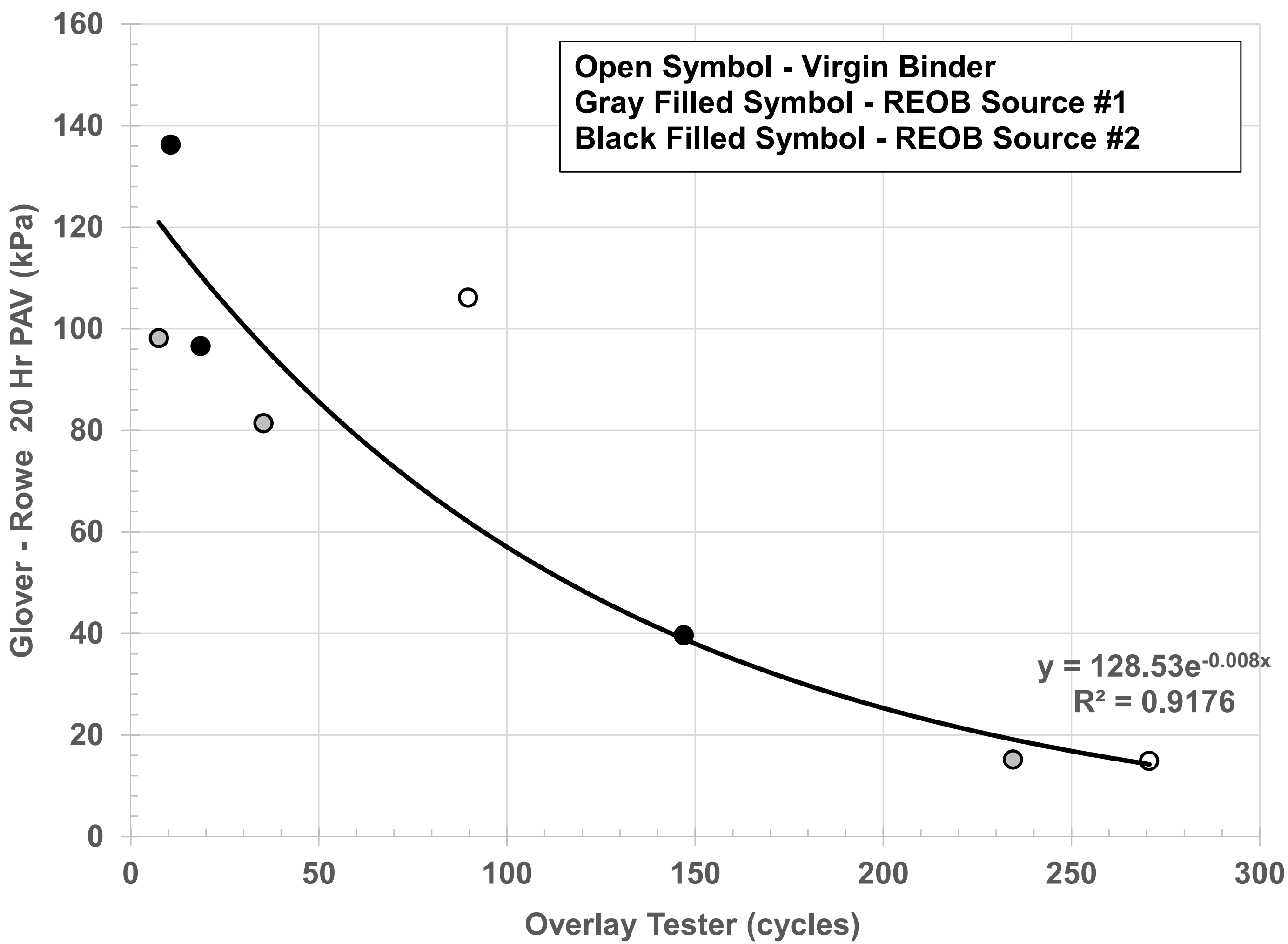
Overlay Tester (LTOA) vs BBR ΔT_{crit} Difference



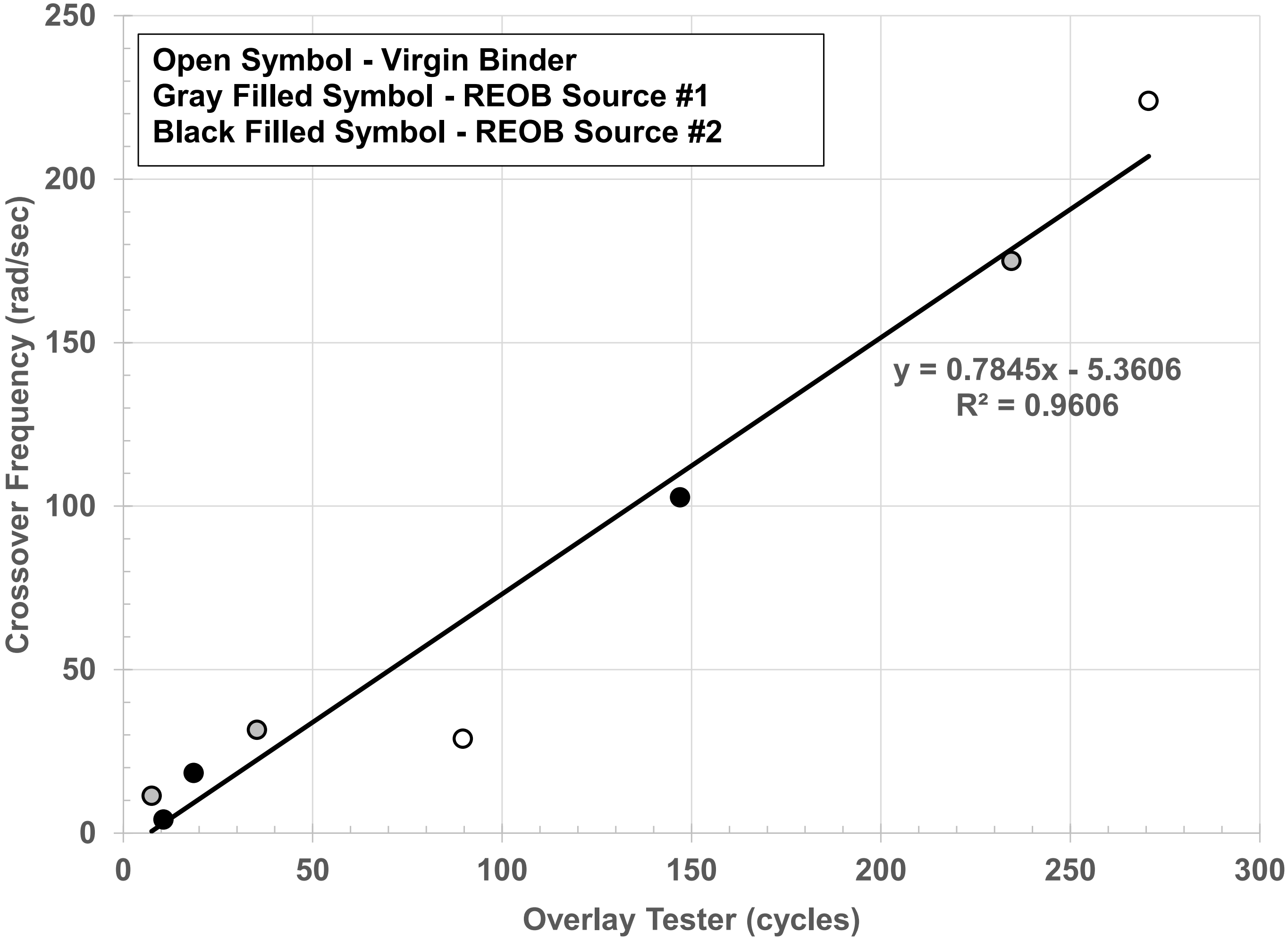
Overlay Tester (LTOA) vs DENT CTOD (20 Hr PAV)



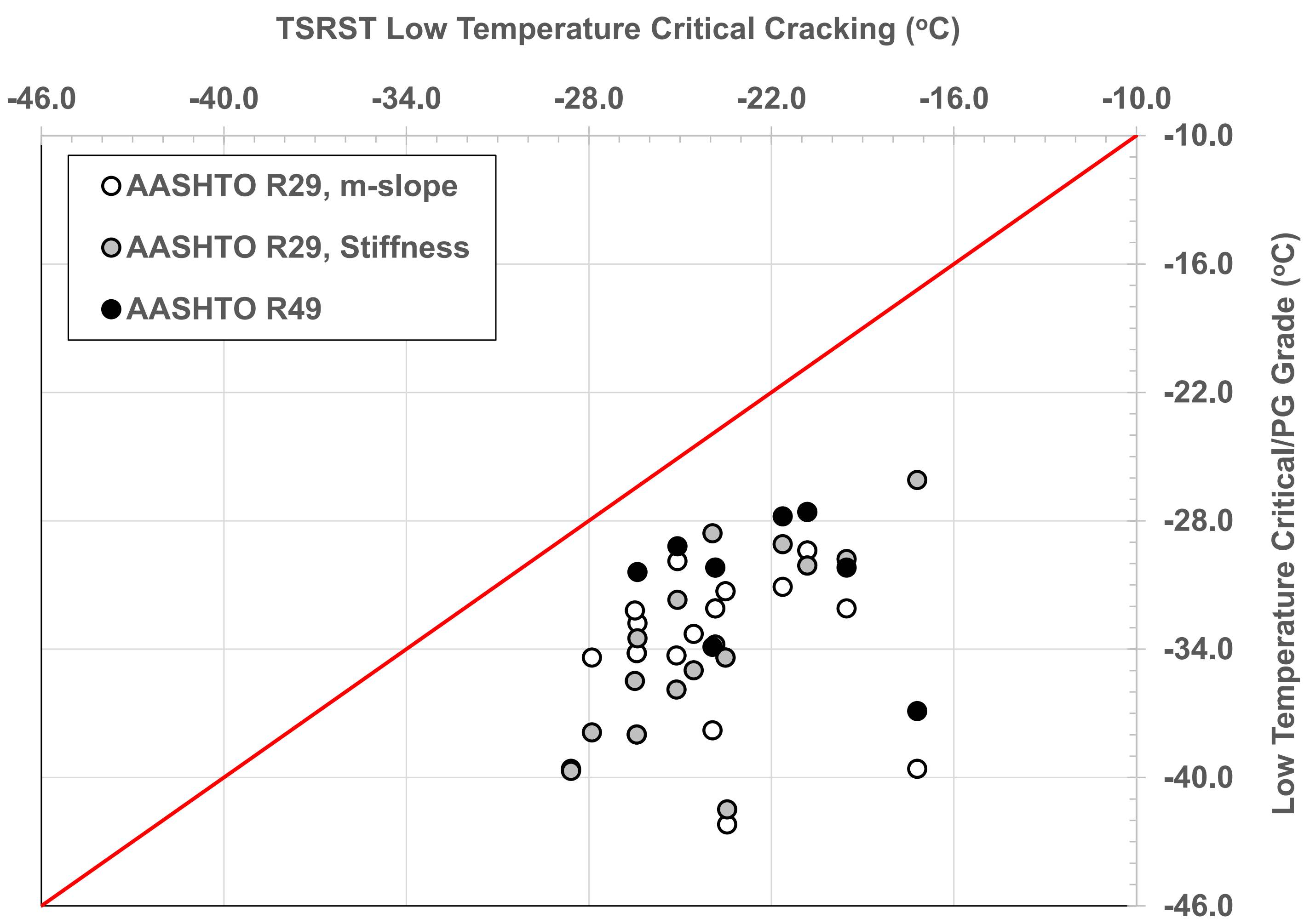
Overlay Tester (LTOA) vs Glover-Rowe Parameter (20 Hr PAV)



Overlay Tester (LTOA) vs Cross-over Frequency (20 Hr PAV)



Low Temperature Critical Cracking – Mixture vs Binder



General Comments on REOB Work

- Degree of aging has a greater impact on REOB modified asphalt performance when compared to Neat binders
- REOB source was found influence the performance of REOB modified asphalt (i.e. – not all REOB created equal)
- REOB dosage rate has a impact on performance, but magnitude not the same for each REOB source
  - Slight differences were found between Neat and 6% REOB binders/mixtures – greater differences found at higher REOB concentrations

General Comments on REOB Work

- Stiffness and aging behavior in E* of REOB and neat binders similar
- Different ranking between fatigue cracking mixture tests
  - Almost complete reverse in ranking between Flexural Beam Fatigue (crack initiation/stiffness-based) and Overlay Tester (crack propagation)
- Low temperature TSRST performance differed based on source
  - Larger differences between REOB and neat binders for Source #2
- Binder "fatigue" tests correlated well with the Overlay Tester and were sensitive to REOB dosage
  - BBR ΔTcrit Difference
  - Cross-over frequency
  - Glover-Rowe
  - DENT CTOD

Thank you for your time!
Questions?

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