Modified Asphalt: A Lifetime Pavement Improvement

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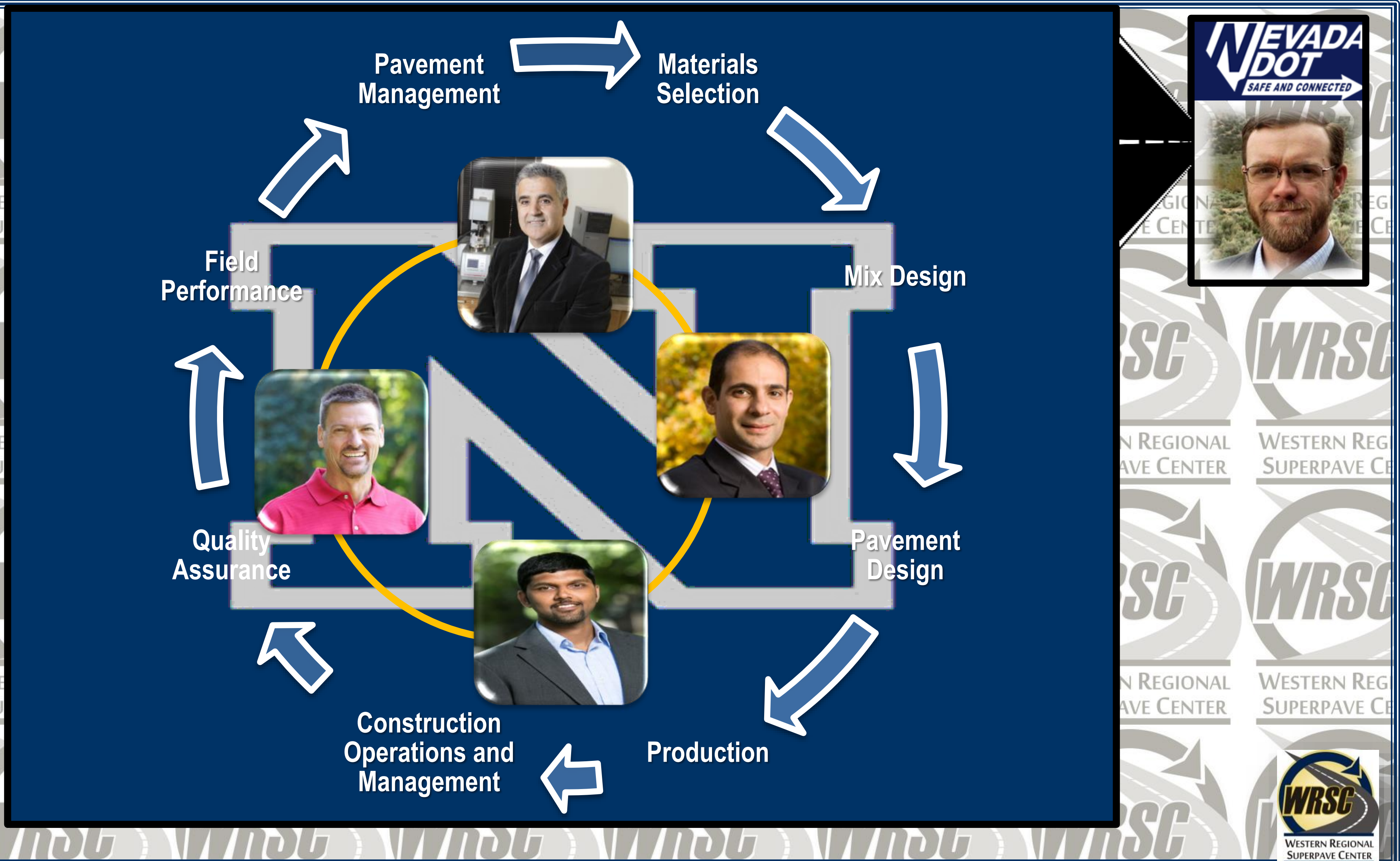
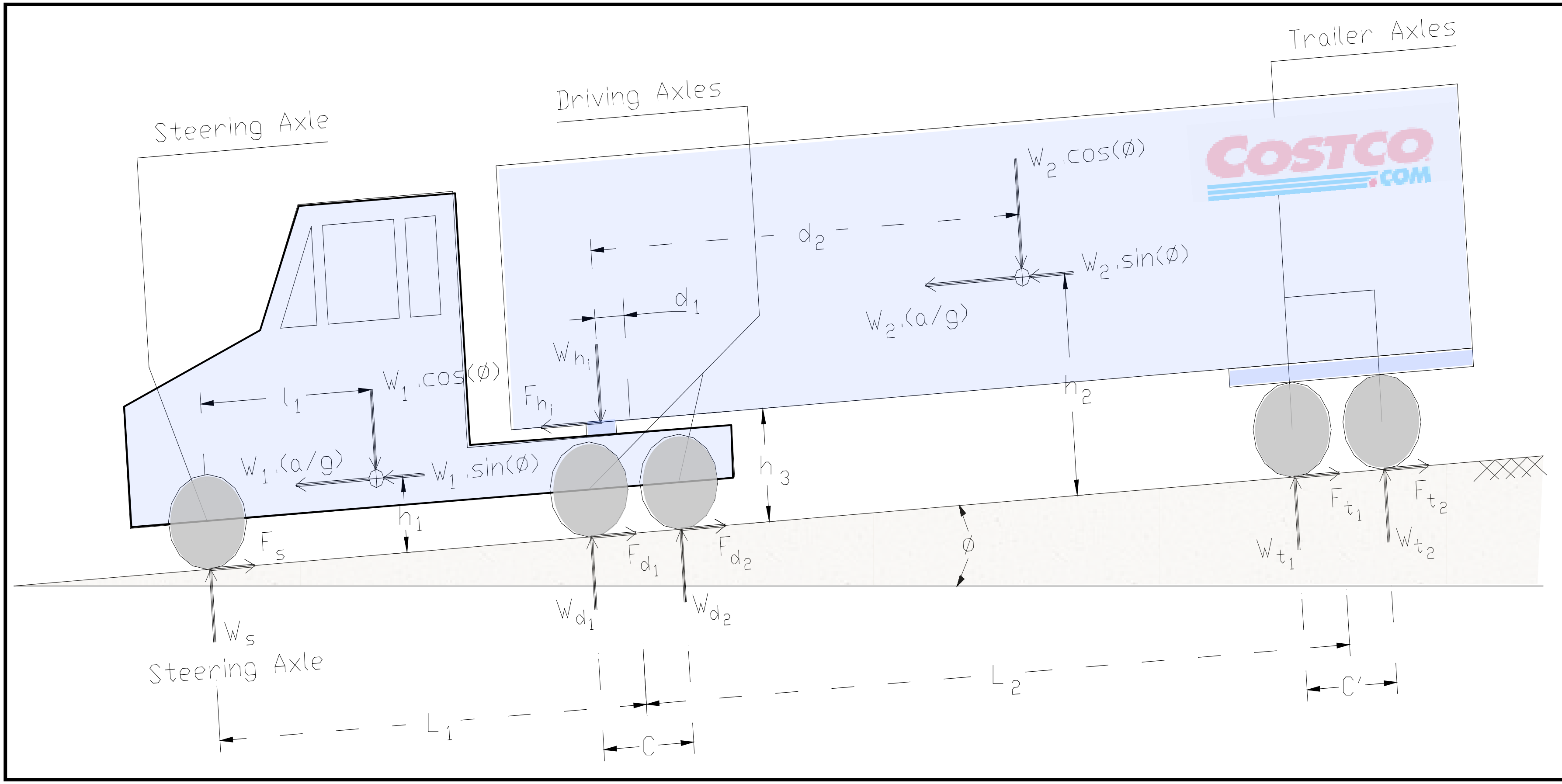
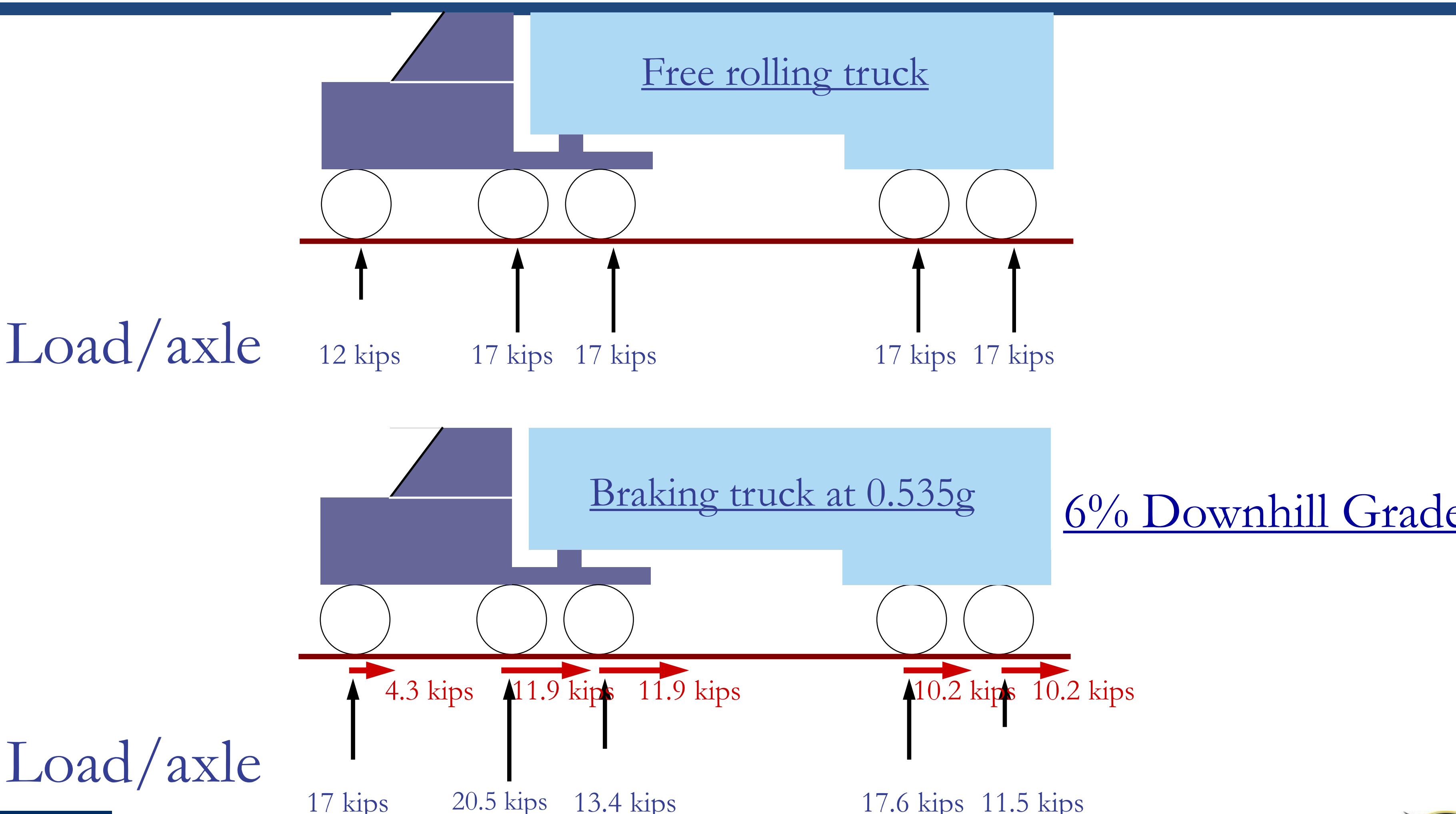
Pavement Engineering & Science at UNR



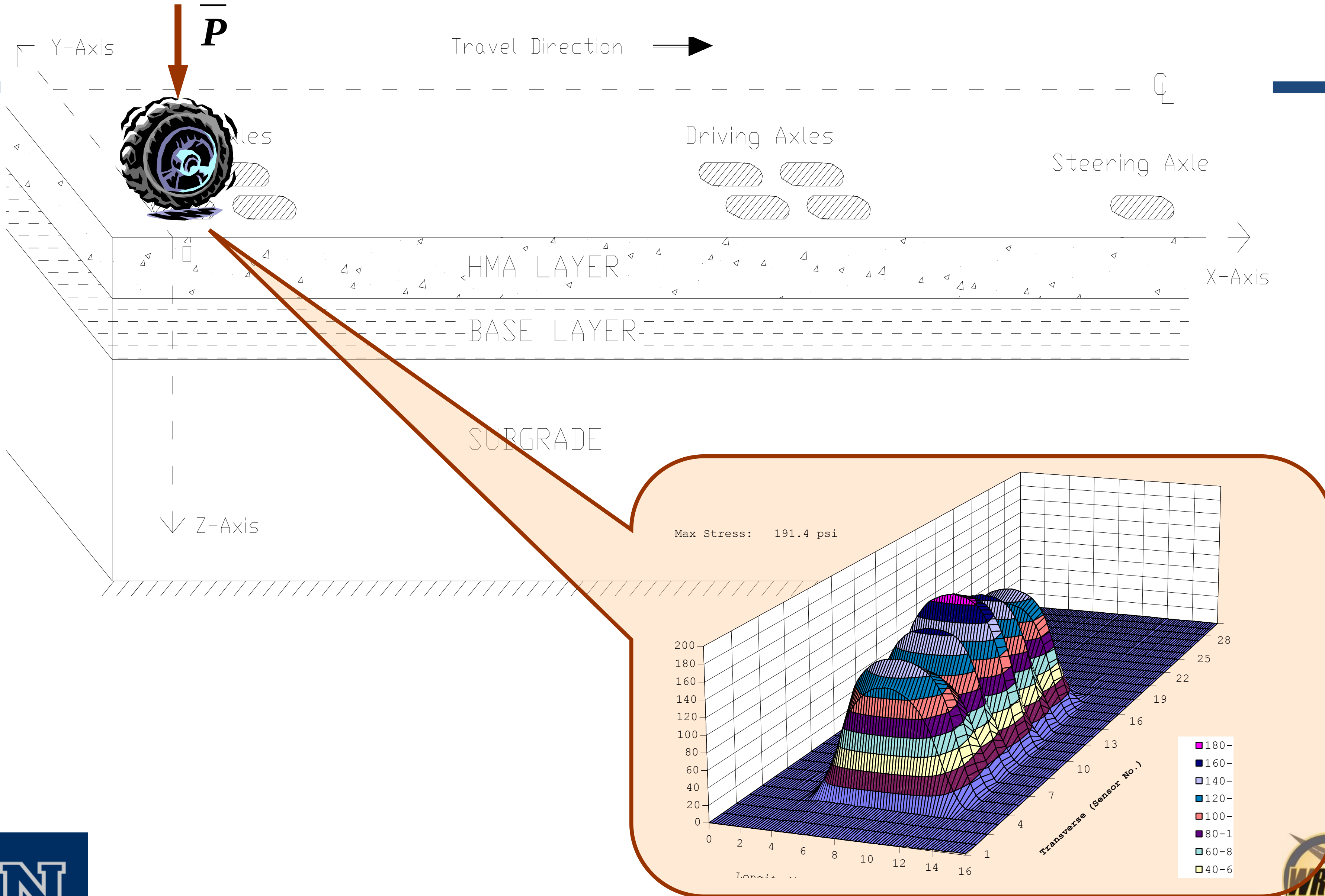
Actual Load Distributions



Load Distribution During Braking



Tire-Pavement Interaction



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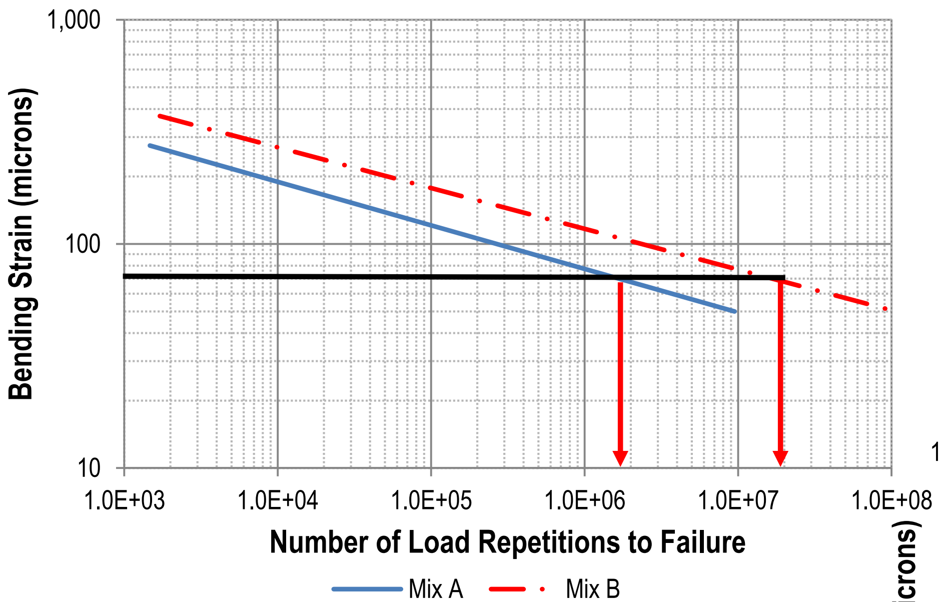
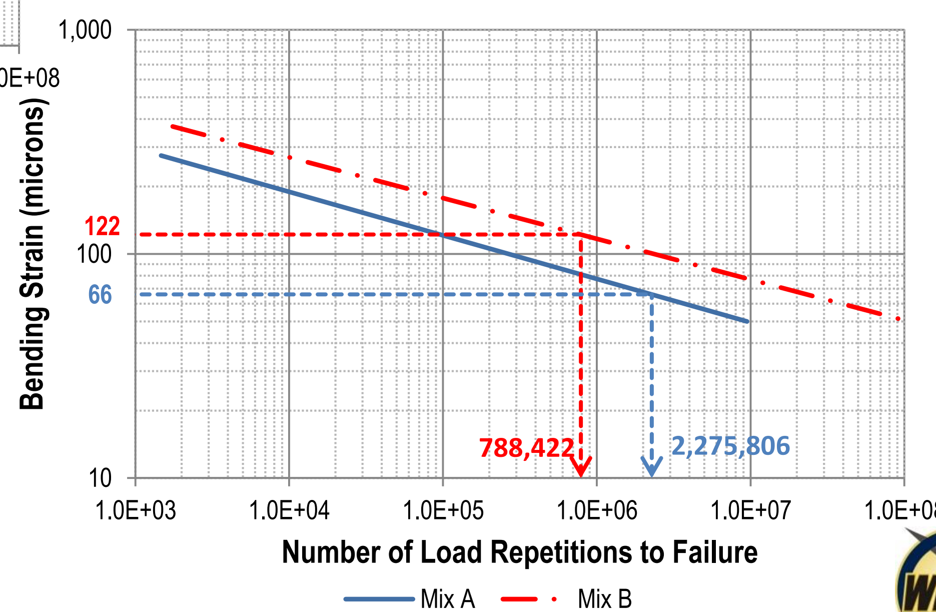
Level of Analysis



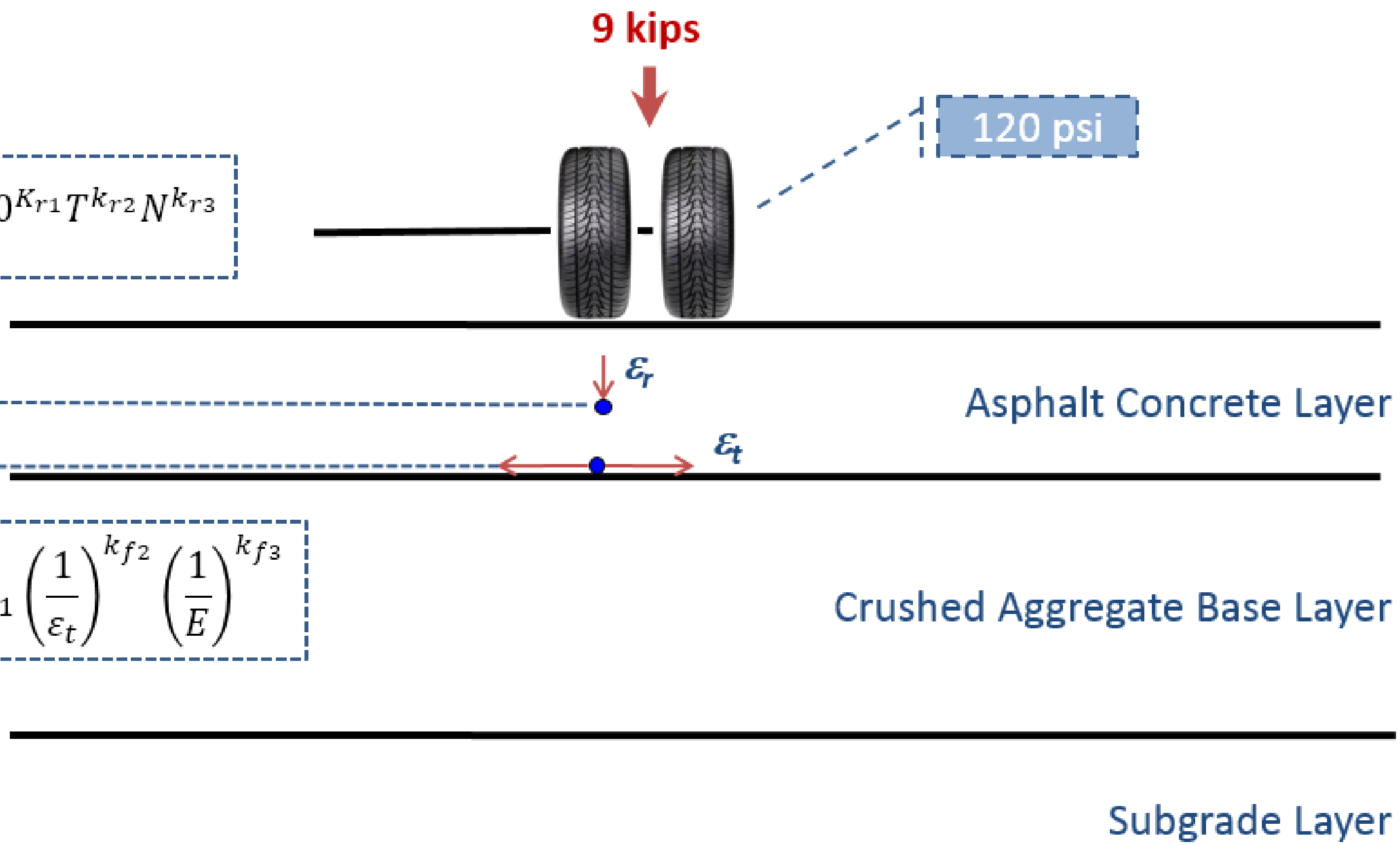
Simple

Mechanistic



Full Mechanistic Analysis

$$\frac{\varepsilon_p}{\varepsilon_r} = 10^{K_{r1}} T^{k_{r2}} N^{k_{r3}}$$



$$N_f = k_{f1} \left(\frac{1}{\varepsilon_t}\right)^{k_{f2}} \left(\frac{1}{E}\right)^{k_{f3}}$$

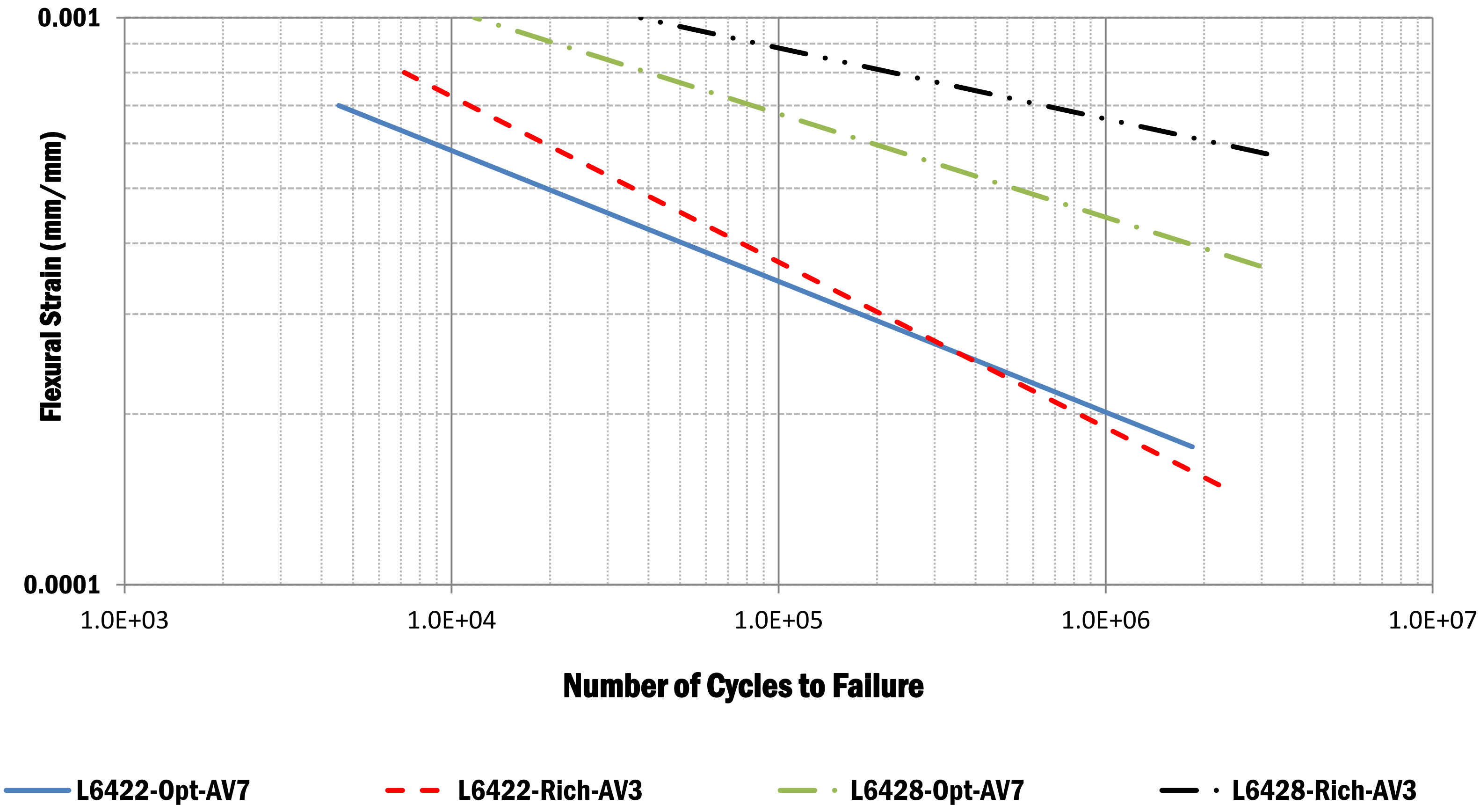
Impact of Polymer-Modification

- Evaluate properties of Neat PG64-22 and PMA PG64-28
  - Optimum
  - Rich: Optimum+0.5%
- Conduct pavement designs
- Compare the LCCA

Properties of Mixtures

Mix ID*	Binder Grade	Binder content (%)	Resilient Modulus at 77°F ksi	Fatigue Model⁺	APA Rut Depth After 8,000 Cycles at 60°C (mm)
L6422-Opt	**PG64-22**	**4.13**	**505**	$N_f = 9.513 \times 10^{-11} \left(\frac{1}{\varepsilon}\right)^{4.335}$	**3.81**
L6422-Rich	**PG64-22**	**4.63**	**610**	$N_f = 1.774 \times 10^{-7} \left(\frac{1}{\varepsilon}\right)^{3.425}$	**4.32**
L6428-Opt	**PG64-28**	**4.31**	**220**	$N_f = 4.146 \times 10^{-13} \left(\frac{1}{\varepsilon}\right)^{5.484}$	**1.52**
L6428-Rich	**PG64-28**	**4.81**	**245**	$N_f = 4.127 \times 10^{-20} \left(\frac{1}{\varepsilon}\right)^{7.986}$	**1.02**

Fatigue Resistance



Impact on Fatigue Life

Pavement structure ID	Top Lift 2 inch	Bottom Lift 4 inch	Tensile strain at the bottom of HMA layer, (micro-strain)	Number of repetitions to fatigue failure, N_f	Increase in fatigue life, N_f
N1Opt	L6422-Opt	L6422-Opt	242	455,380	32%
N1Rich	L6422-Opt	L6422-Rich	220	600,985	
N2Opt	L6428-Opt	L6428-Opt	378	2,436,000	> 1130%
N2Rich	L6428-Opt	L6428-Rich	362	> 30,000,000	
N3Opt	L6428-Opt	L6422-Opt	263	315,680	40%
N3Rich	L6428-Opt	L6422-Rich	240	443,335	
Pavement structure ID	**Top Lift 2 inch**	**Bottom Lift 6 inch**	**Tensile strain at the bottom of HMA layer, (micro-strain)**	**Number of repetitions to fatigue failure, N_f**	**Increase in fatigue life, N_f**
N4Opt	L6422-Opt	L6422-Opt	169	2,156,620	-2%
N4Rich	L6422-Opt	L6422-Rich	152	2,104,780	
N5Opt	L6428-Opt	L6428-Opt	272	14,717,300	> 105%
N5Rich	L6428-Opt	L6428-Rich	260	> 30,000,000	
N6Opt	L6428-Opt	L6422-Opt	183	1,512,040	5%
N6Rich	L6428-Opt	L6422-Rich	166	1,583,325	

Life Cycle Cost Analysis

Pavement Structure	Description	Lift thickness (inch)	Total Cost/mile ($)	Findings
Constant fatigue life for 6.0 – Inch HMA layer				
N1Rich	L6422-Opt	2.0	177,000	Equivalent fatigue life for a saving of $1,987/mile
	L6422-Rich	3.8		
N2Rich	L6428-Opt	2.0	127,650	Equivalent fatigue life for a saving of $75,158/mile
	L6428-Rich	1.6		
N3Rich	L6428-Opt	2.0	178,450	Equivalent fatigue life for a saving of $8,450/mile
	L6422-Rich	3.5		
Constant fatigue life for 8.0 – inch HMA layer				
N4Rich	L6422-Opt	2.0	280,950	Equivalent fatigue life for a cost of $42,350/mile
	L6422-Rich	6.3		
N5Rich	L6428-Opt	2.0	173,700	Equivalent fatigue life for a saving of $96,730/mile
	L6428-Rich	2.8		
N6Rich	L6428-Opt	2.0	251,500	Equivalent fatigue life for a cost of $4,970/mile
	L6422-Rich	6.0		

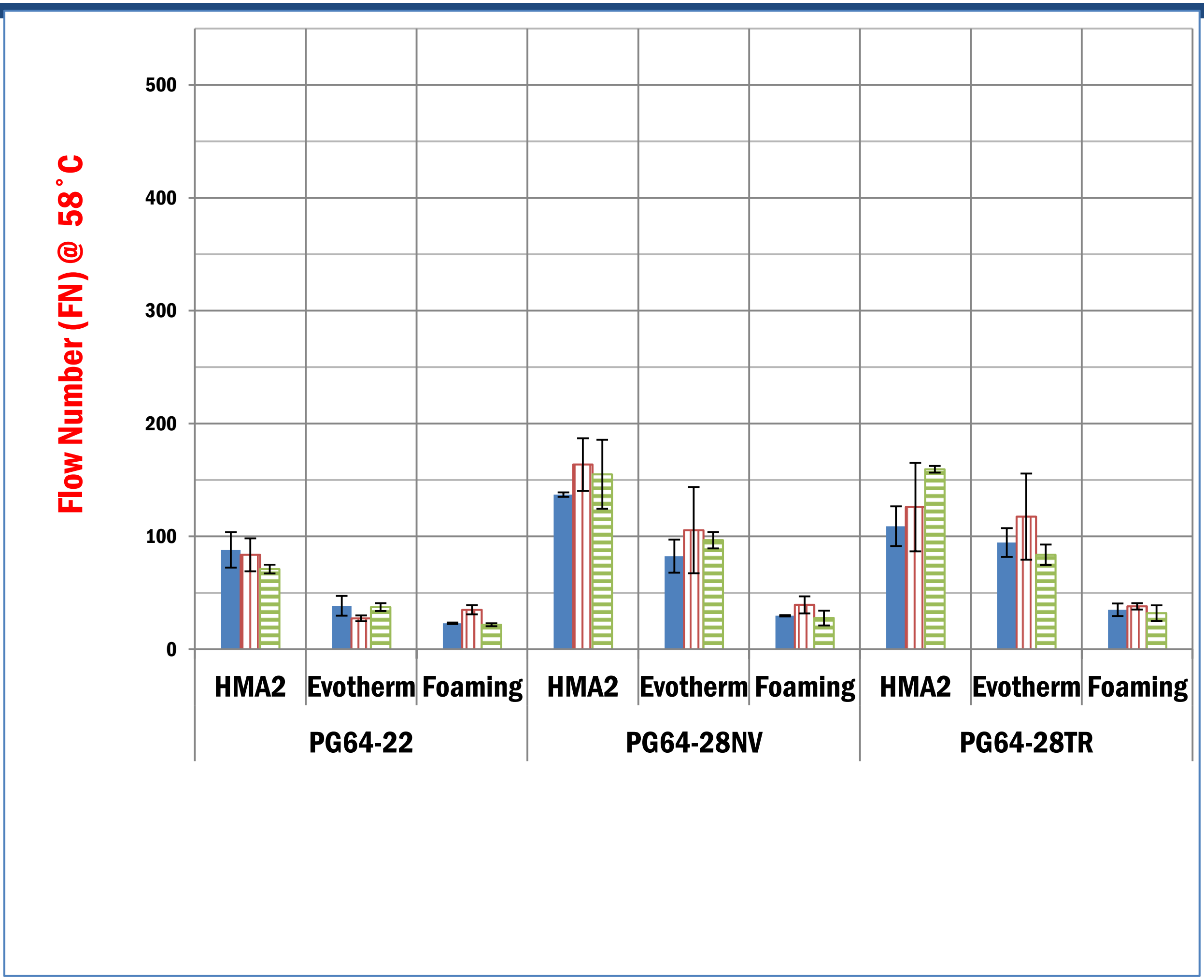
Fatigue Performance - RTC

Pavement Structure	Traffic speed	Tensile strain at the bottom of HMA layer, 4"depth, (microns)	Number of repetitions to fatigue failure, N_f
Structure 1 2.0” PG64-28NV 2.0” PG64-22	Fast	204	540,000
	Slow	285	220,000
Structure 2 2.0” PG64-28NV 2.0” PG64-22 rich	Fast	200	2,200,000
	Slow	285	560,000
Structure 3 2.0” PG64-28NV 2.0” PG64-28NV	Fast	264	will not fail in fatigue
	Slow	407	33,000,000

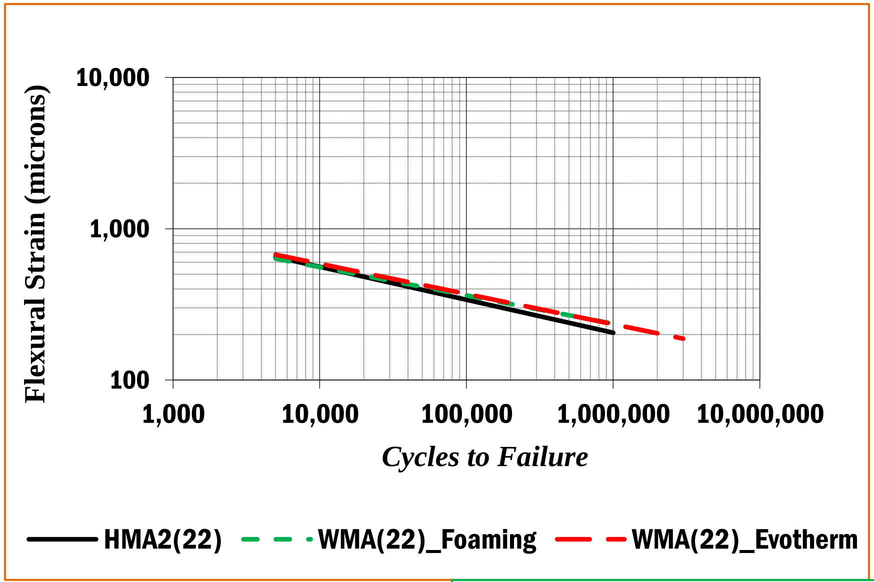
Modification with Polymer and Tire Rubber

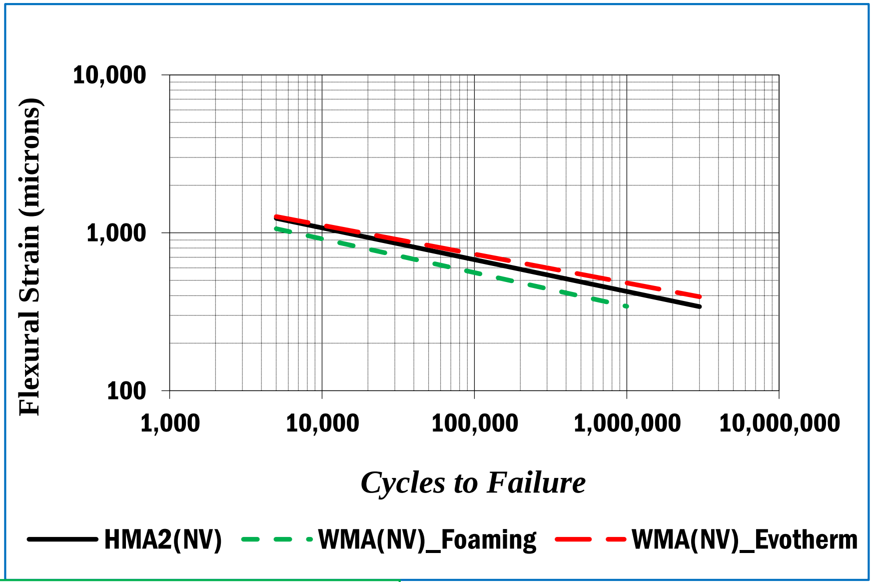
- How the modified binders interact with:
  - Warm Mix Asphalt Additives
  - Anti-strip Additives

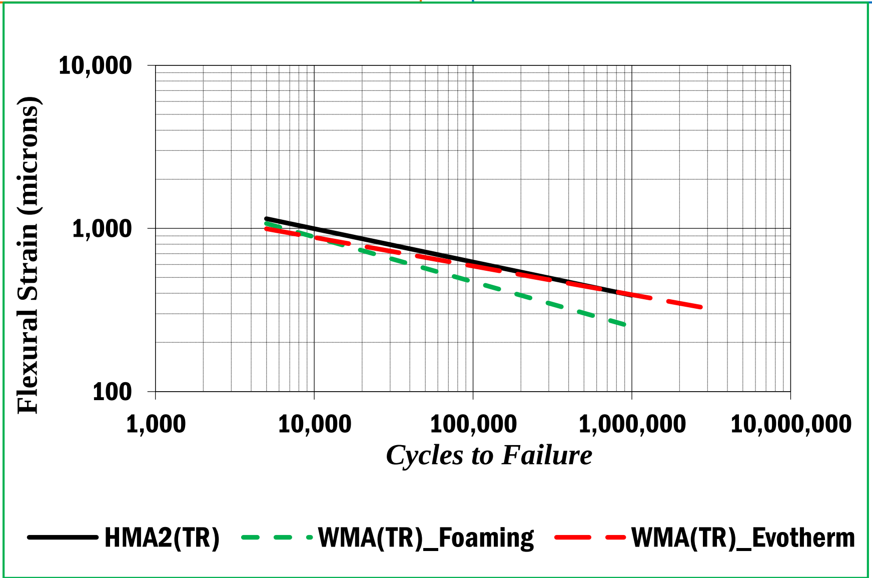
Resistance to Permanent Deformation



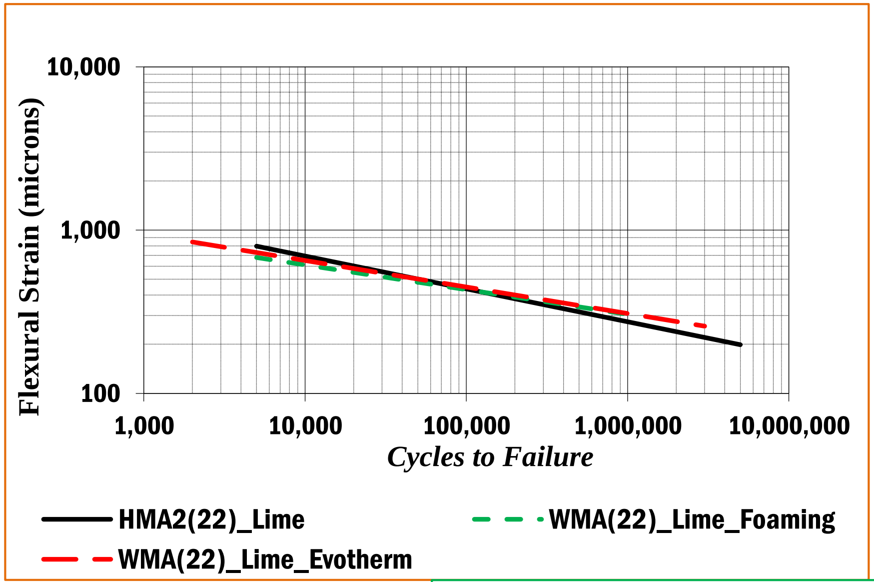
Beam Fatigue Curves
Untreated Mixtures

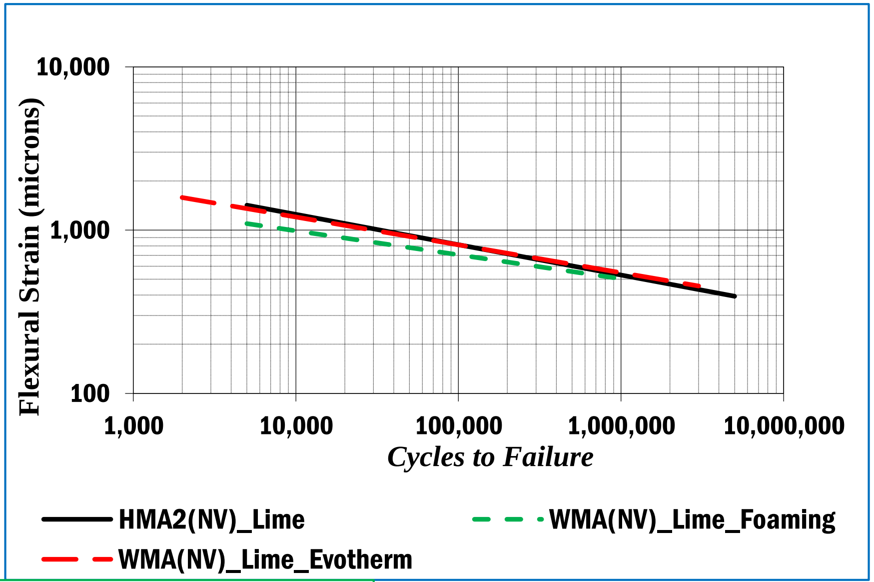


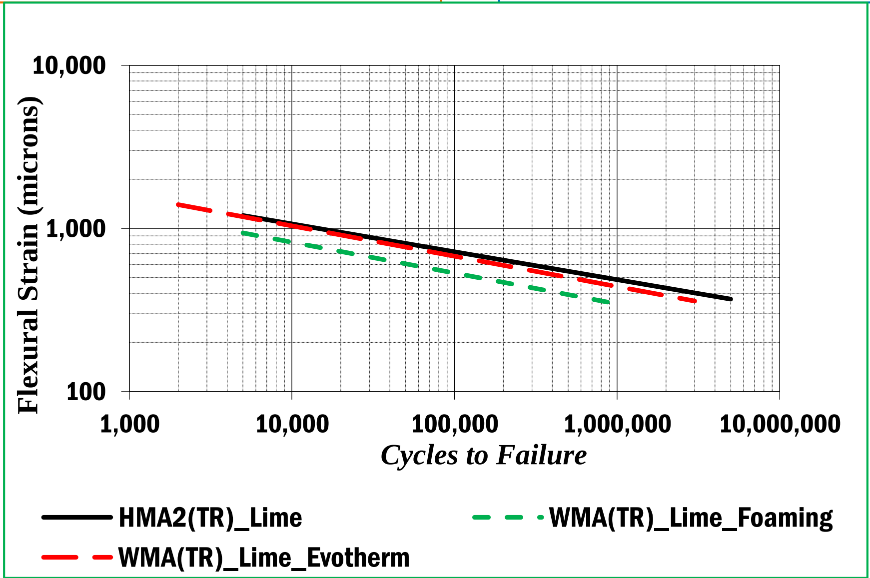




Beam Fatigue Curves
Lime treated Mixtures







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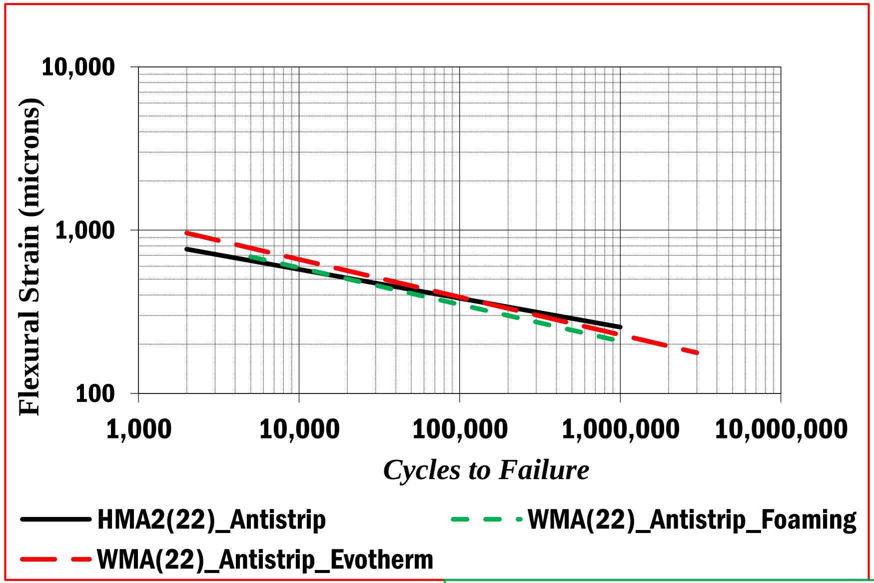
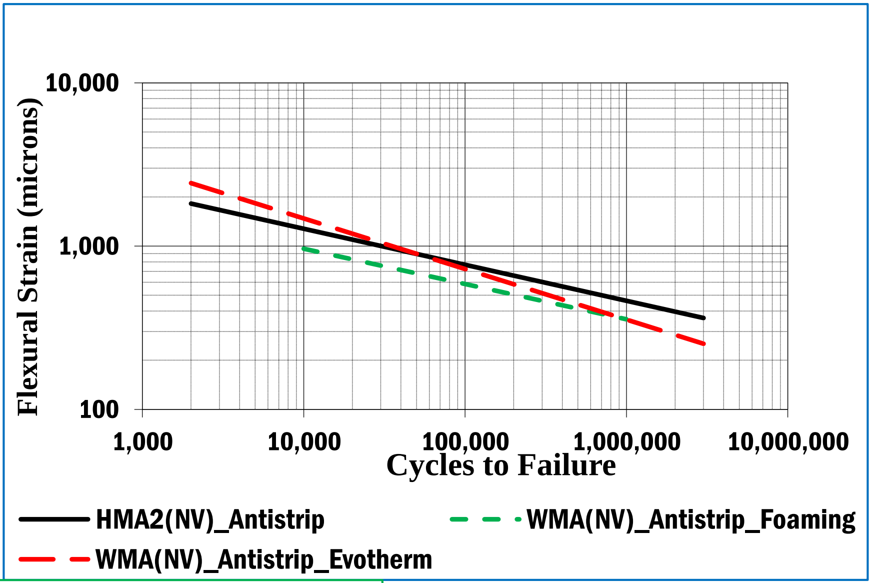
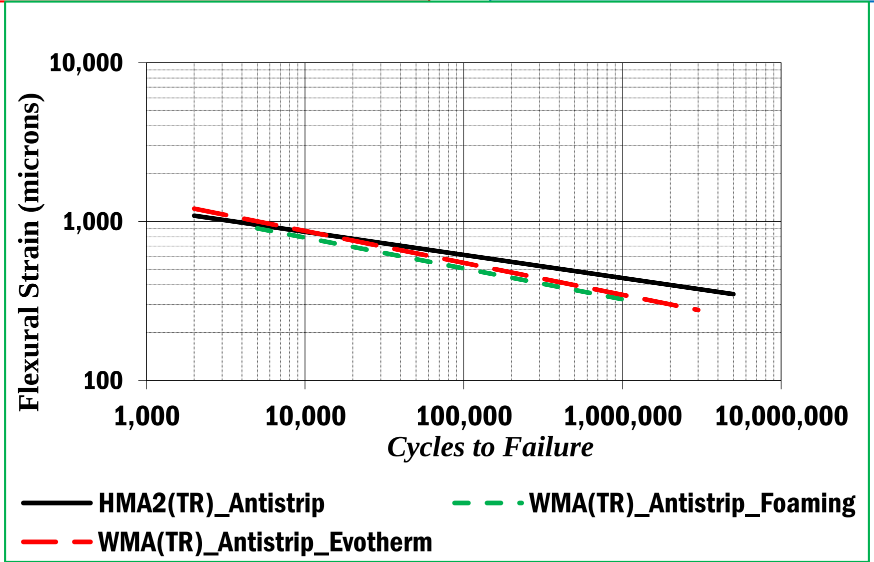
Beam Fatigue Curves

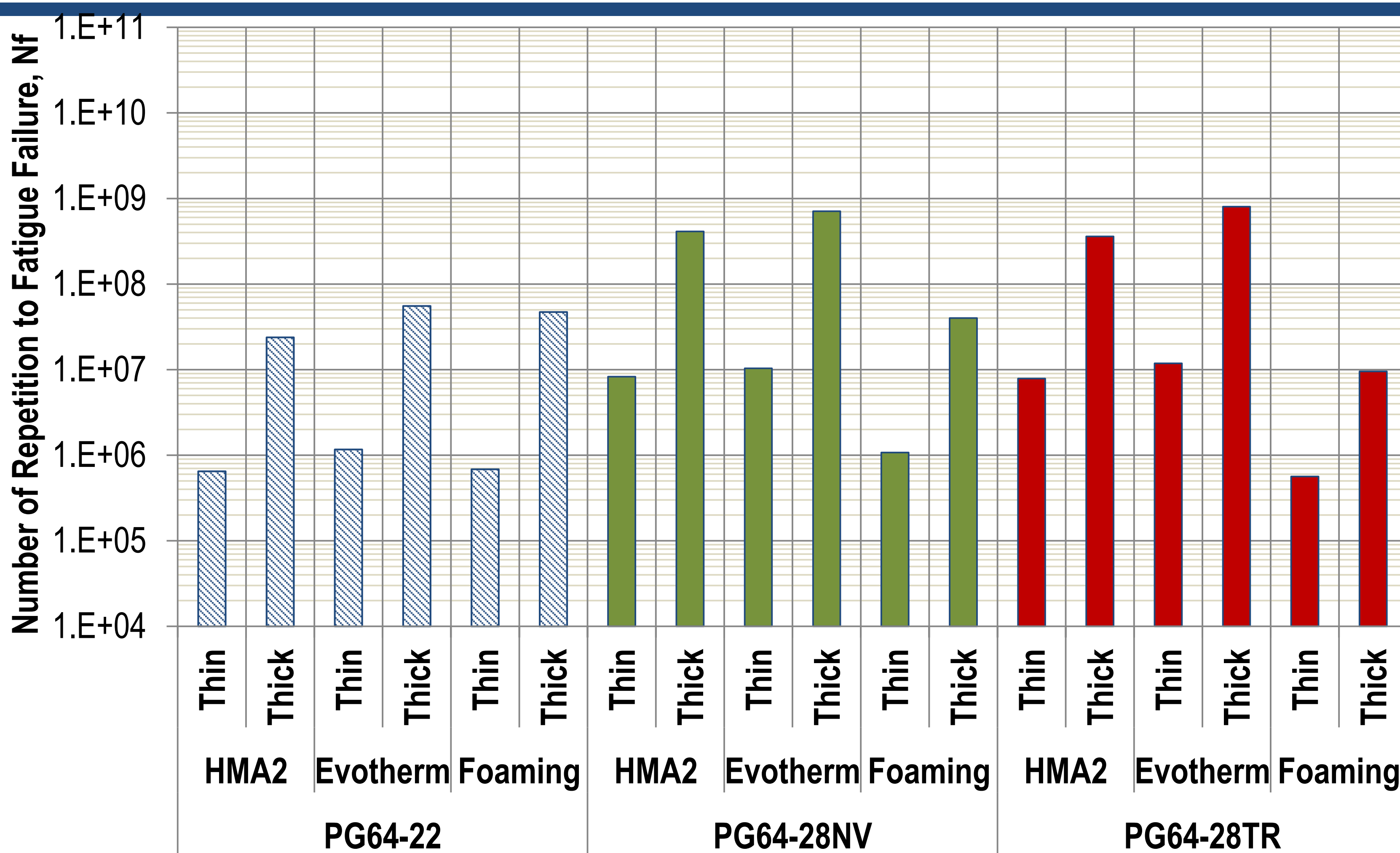
Liquid treated Mixtures



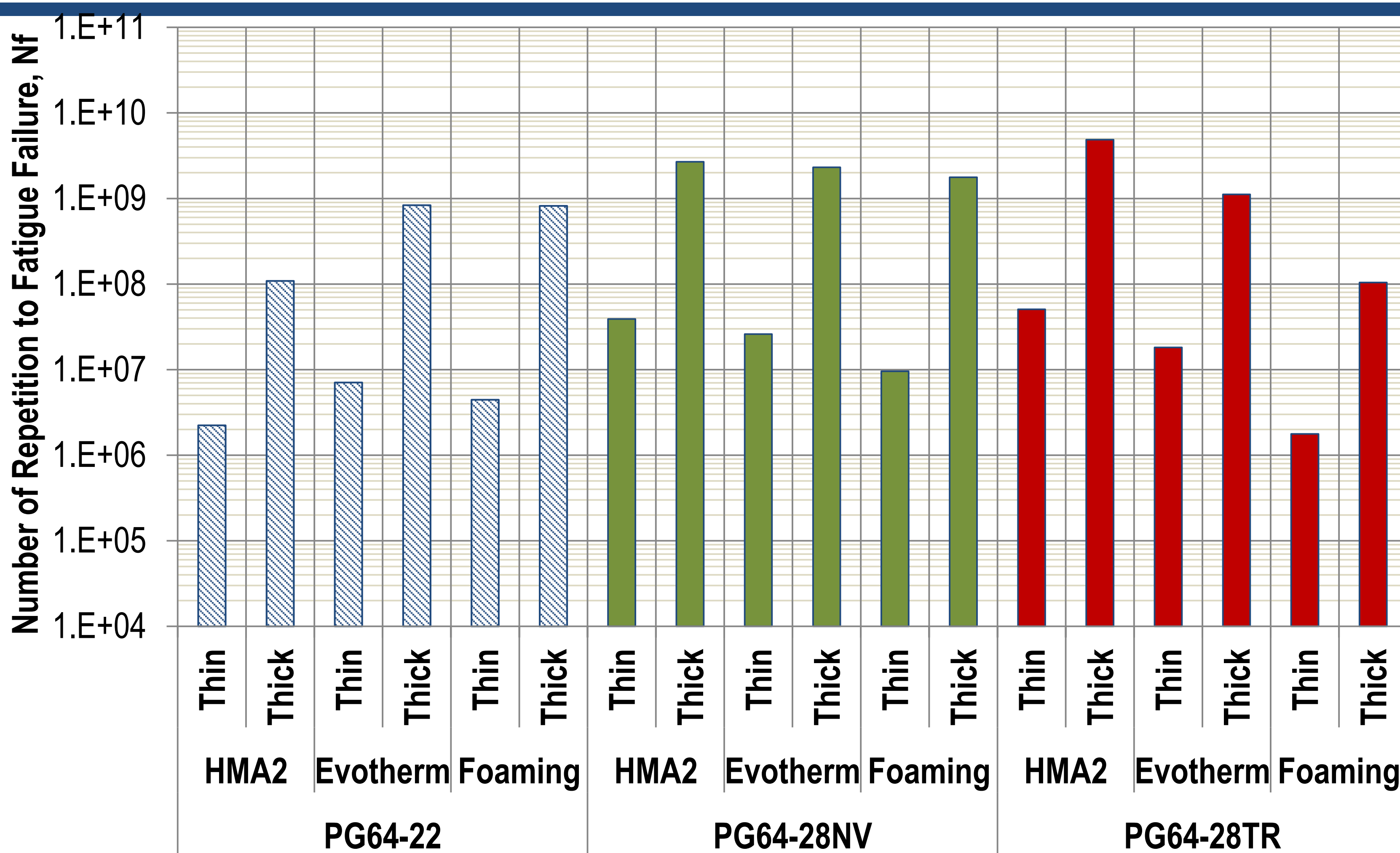




Fatigue Life of Un-treated Mixtures



Fatigue Life of Lime-treated Mixtures



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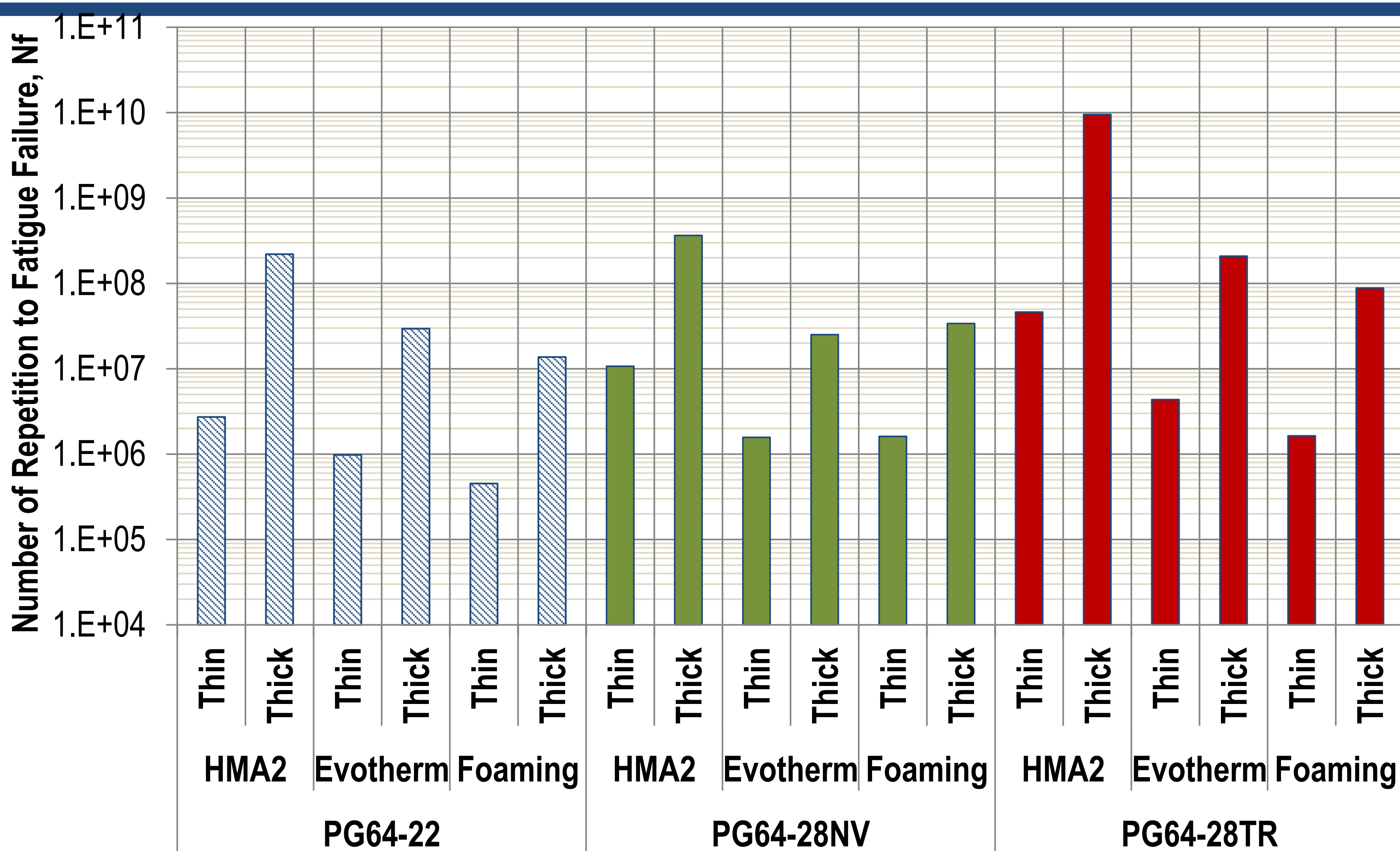
Fatigue Life of Liquid-treated Mixtures



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Conclusions

- Polymer and TR modified mixtures:
  - Both Very effective with lime:
    - Moisture damage
    - Rutting
    - Fatigue
  - With liquid:
    - TR Similar to PM in Moisture Damage and Rutting
    - TR Better than PM in Fatigue

Gilsonite-Modified Binders

Property/Test Conditions	PG76-16 (CA – AZ)			PG64-28 (CA – NV)		
	Control	Gilsonite	Specs	Control	Gilsonite	Specs
FP, (°C)	230+	230+	> 230	230+	230+	> 230
RV, (Pa.s)	1.006	1.092	≤ 3.0 @ 135°C	0.861	0.681	≤ 3.0 @ 135°C
DSR on Original, G*/sinδ, 10rad/sec, (KPa)	1.500	1.370	≥ 1.0 @ 76°C	1.820	1.600	≥ 1.0 @ 64°C
RTFO, mass loss, (%)	0.9	0.1	≤ 1.0	0.5	0.2	≤ 1.0
DSR on RTFO-aged, G*/sinδ, 10rad/sec, (KPa)	4.175	2.890	≥ 2.2 @ 76°C	3.550	4.225	≥ 2.2 @ 64°C
Required by Caltrans DSR on RTFO-aged, delta (δ), 10rad/sec, degrees	65.0	83.3	NA	64.3	77.6	≤ 80° @ 64°C
DSR on PAV-aged, G*sinδ, 10rad/sec, KPa	2620	1150	≤ 5000 @ 34°C	1720	2185	≤ 5000 @ 22°C
BBR on PAV-aged, S, 60sec, MPa	136	62	≤ 300 @ -6°C	133	119	≤ 300 @ -18°C
BBR on PAV-aged, m-value, 60sec	0.345	0.358	≥ 0.300 @ -6°C	0.342	0.300	≥ 0.300 @ -18°C

COMPARISON OF PERFORMNCE LIFE

Pavement	Design Applications	Mixture	Rutting @ 40°C			Fatigue @ 21°C		
			ε_r (micron)	N_r (million)	Rutting Life Ratio	ε_t (micron)	N_f (million)	Fatigue Life Ratio
Thin 100mm-AC 150mm-base	Highways: 60 mph No-Braking	76-16C	138	6.8		160	8.7	
		76-16G	82	>100	>10	131	36.7	4.2
		64-28C	429	0.01		196	44.9	
		64-28G	185	6.2	>10	153	>100	2.2
Thin 100mm-AC 150mm-base	Urban Streets: 10 mph Braking	76-16C	242	0.94		185	3.7	
		76-16G	137	20.4	>10	147	18.0	4.9
		64-28C	1101	No-Design[1]		248	12.2	
		64-28G	350	0.37	>10	181	59.1	4.8
Thick 150mm-AC 300mm-base	Highways: 60 mph No-Braking	76-16C	134	25.4		98	>100	
		76-16G	81	>100	4.0	81	>100	
		64-28C	400	0.05		120	>100	
		64-28G	178	33.6	>10	94	>100	
Thick 150mm-AC 300mm-base	Urban Streets: 10 mph Braking	76-16C	230	3.8		114	66.5	
		76-16G	132	>100	>10	90	>100	1.5
		64-28C	1001	No-Design[1]		156	>100	
		64-28G	330	2.2	>10	112	>100	

Recommendations

- Engineered blend of: Gilsonite + Polymer
  - Increase the binder content to the point of equivalency:
    - E*
    - FN
    - Cost
  - Fatigue and Thermal Cracking will be significantly improved
  - Higher durability

Florida DOT Research on High Polymer Mixes

- Florida DOT follows the AASHTO 1993 methodology for conducting new and rehabilitated flexible pavement designs.
- Structural coefficient for PMA mixes: 0.44

Objective: **Determine the structural layer coefficient for HP mixes to be adopted in new and rehabilitation designs conducted following the AASHTO 1993 methodology.**

Experimental Plan *(1)*

I. Laboratory Evaluation of HP Binders and Mixes

Selection of Materials

Aggregates
- 9.5mm NMAS
- 12.5mm NMAS

Asphalt Binders
-PG76-22 PMA
-HP Binder

Mix Designs (16 Mixes)
-Traffic C for 9.5mm NMAS
-Traffic D & E for 12.5mm NMAS

Engineering Properties
-Dynamic Modulus (E*)

Performance Characteristics
- MEPDG Rutting model
- MEPDG Fatigue model
- Top-down cracking model
- Reflective cracking model

II. Flexible Pavement Modeling & Advanced Mechanistic Analysis under Heavy Moving Loads using 3D-MOVE

Experimental Plan (2)

II. Flexible Pavement Modeling & Advanced Mechanistic Analysis under Heavy Moving Loads using 3D-MOVE

Pavement Structures (24 designs)
- Traffic Levels: C, D, & E
- New designs for PG76-22 PMA
- Overlay design for PG76-22 PMA

Critical Pavement Responses
- Loading conditions: Static, Highway, Slow-braking
- e.g. Vertical strain at middle of AC sub-layers, tensile strain at bottom of AC layer, etc…

Determination of Structural Coefficients for HP AC Mixes

III. Verification: Large-Scale Pavement Testing using PaveBox

IV. Advanced Numerical Modeling of PaveBox using FLAC3D

PMA Control Section

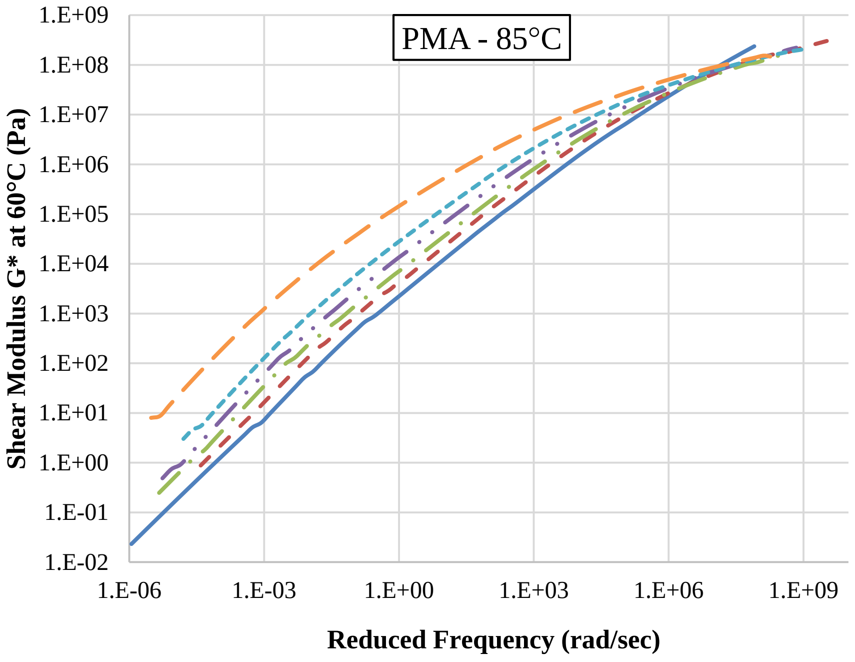
HP Reduced Section

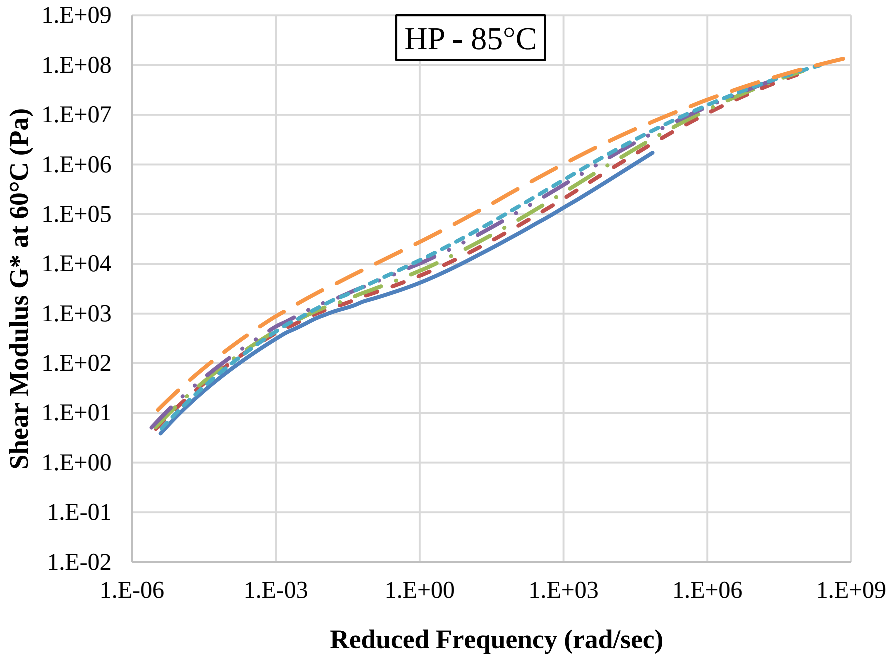
Data Analysis

Final Recommendations

Binder Master Curve

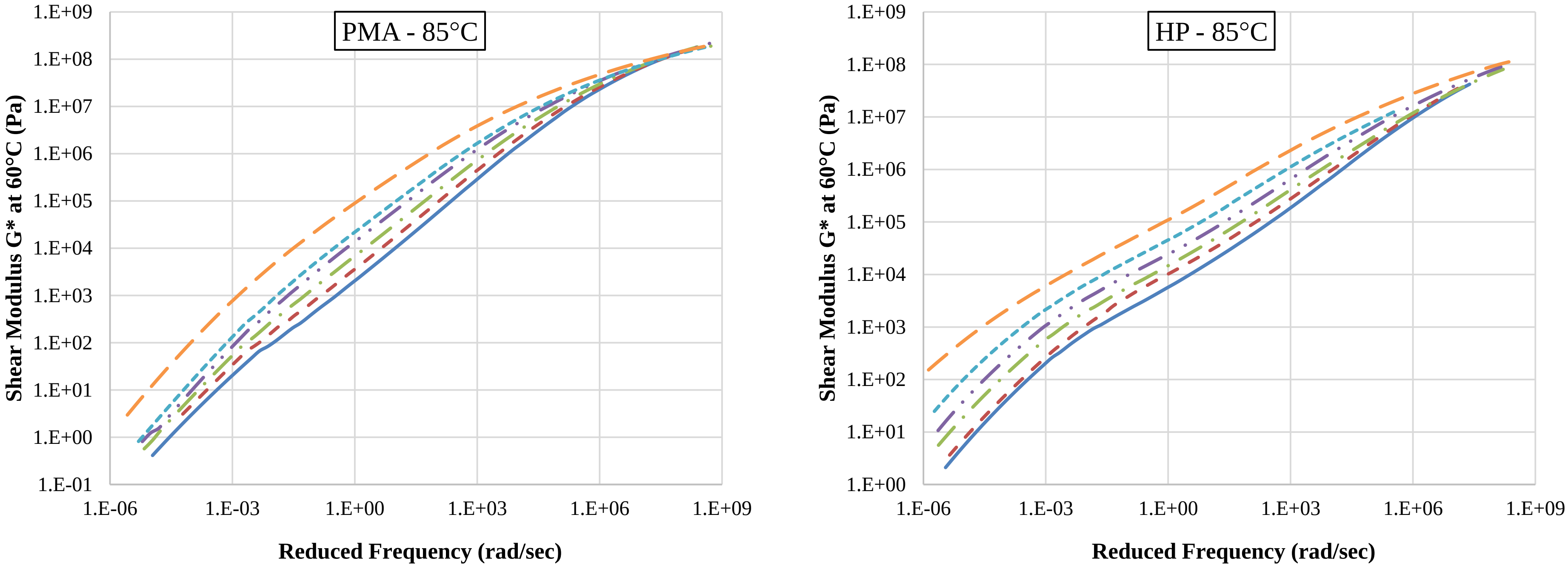
1, 4, 8, 15, 25, and 45 days



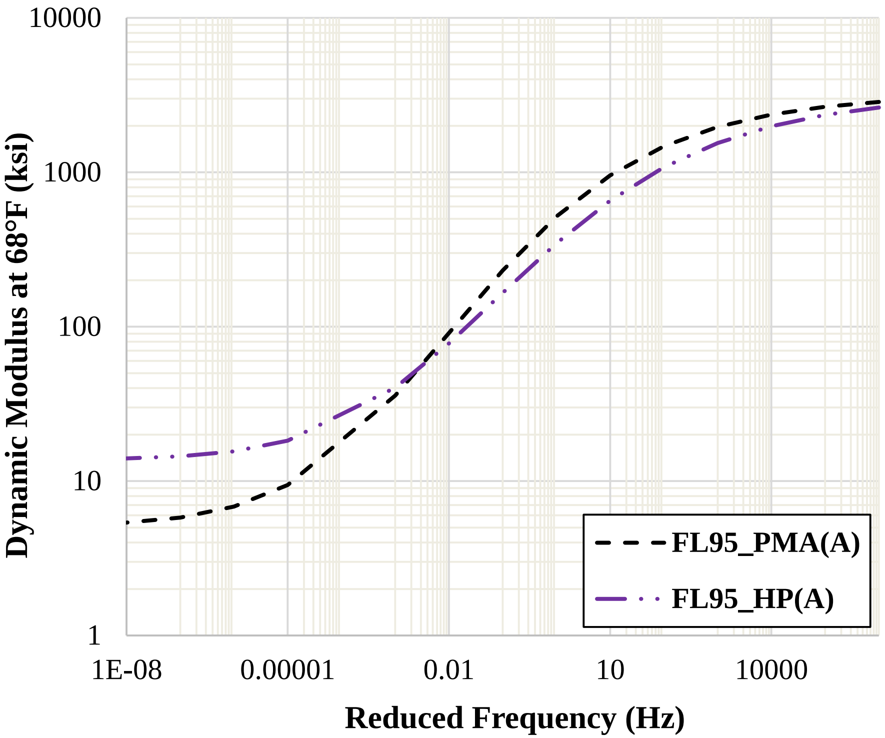


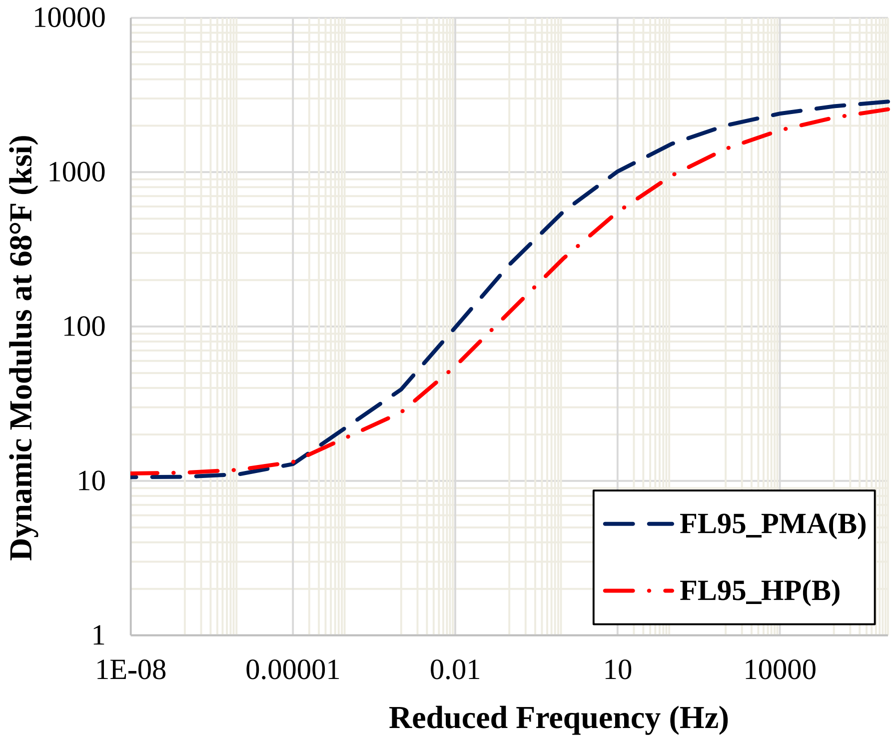
Binder Master Curve

1, 4, 8, 15, 25, and 45 days

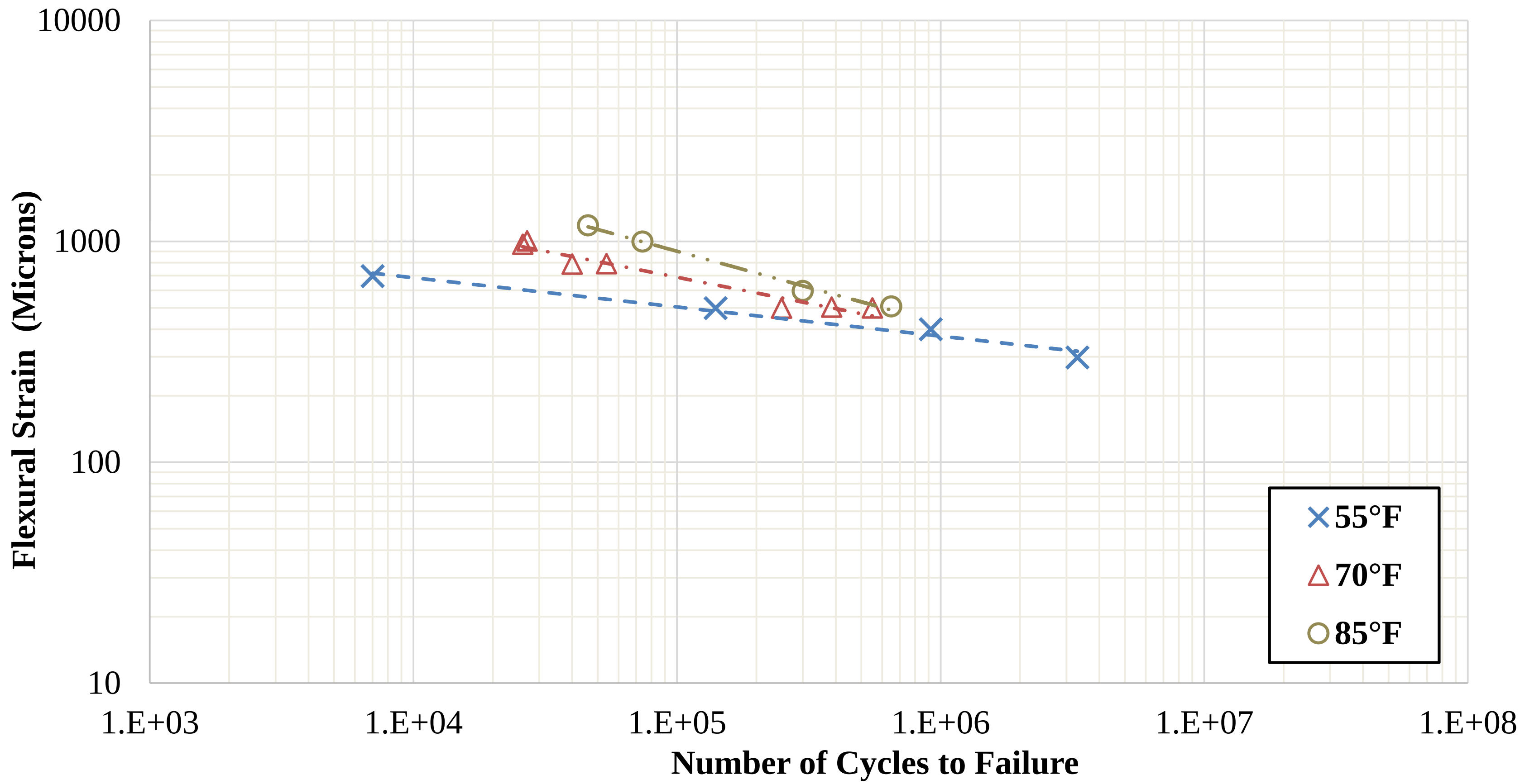


Dynamic Modulus

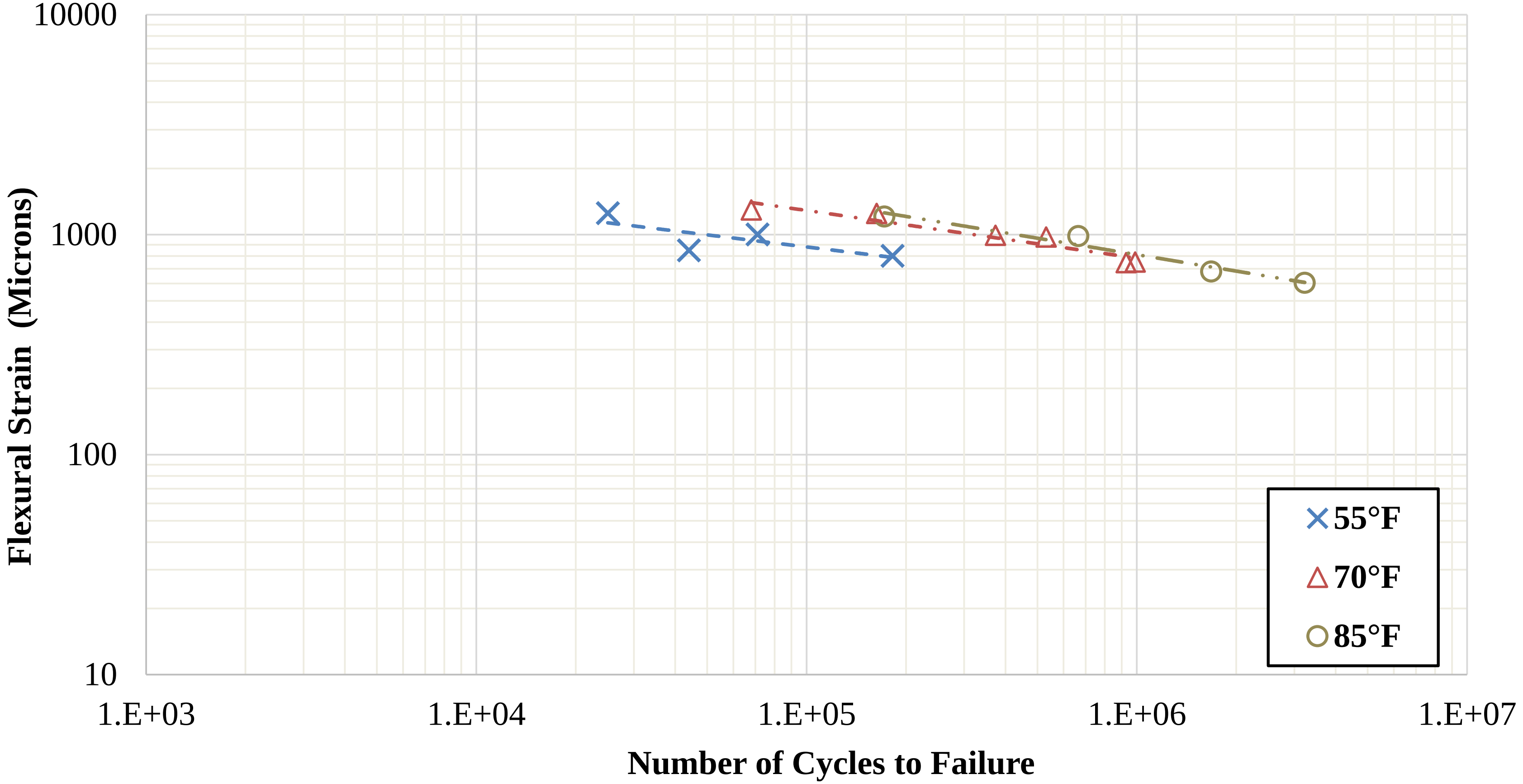




Fatigue Resistance - PMA



Fatigue Resistance HP



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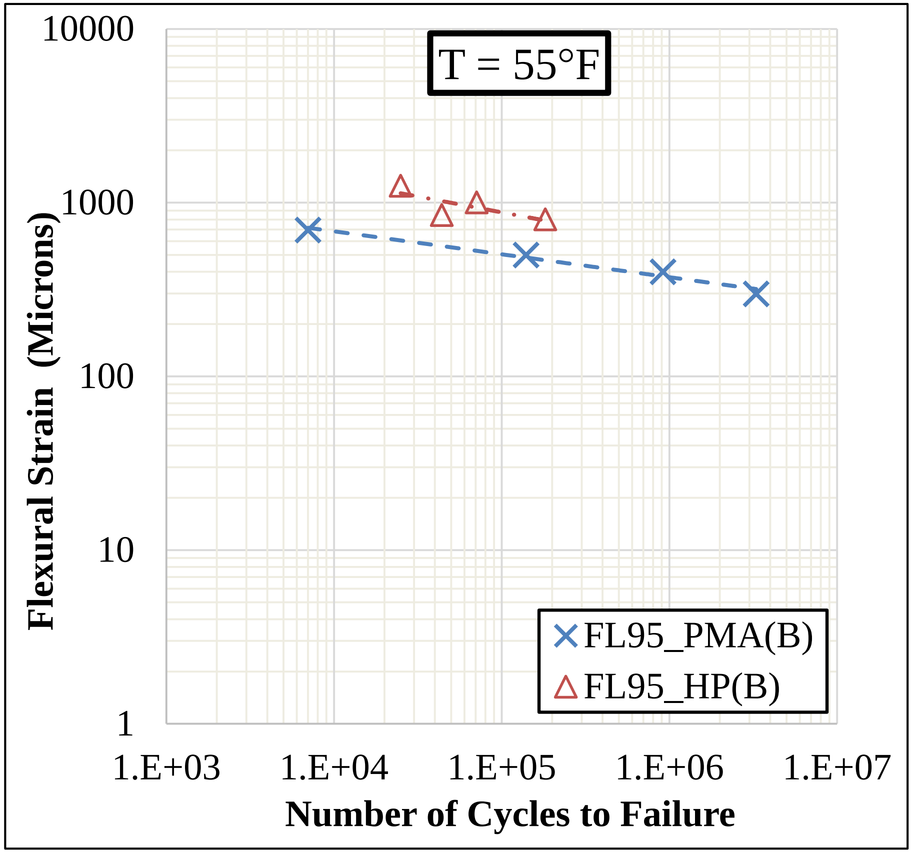
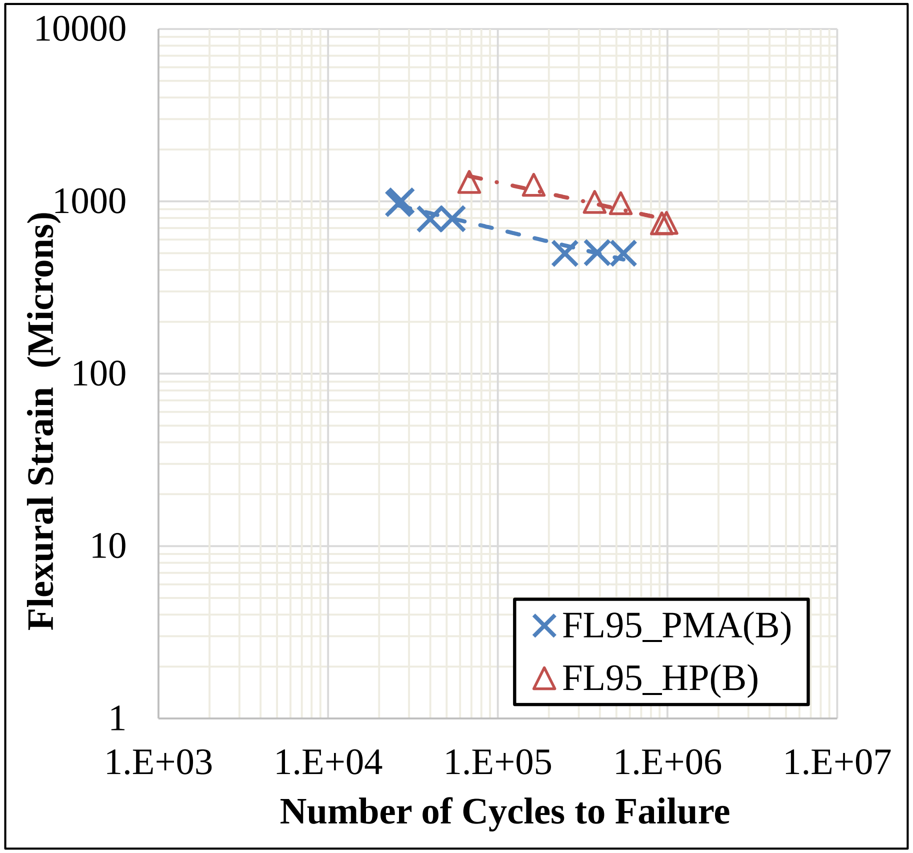
Fatigue Resistance





Thank You!